PREFACE

The Volcano Letter was an informal publication issued at irregular intervals by the Hawaiian Volcano Observatory (HVO) during the years 1925 to 1955. Individual issues contain information on volcanic activity, volcano research, and volcano monitoring in Hawaii. Information on volcanic activity at other locations is also occasionally included.

To increase accessibility of this resource, previously only available in print format, this compilation was scanned from the highest quality Volcano Letter originals in the HVO archives. Optical Character Recognition (OCR) was run on the entire file. In addition, the file size was reduced by making it compatible with only Adobe Reader v. 8 and later. The scanning was done by Jim Kauahikaua and the quality control and posting was done by Katie Mulliken, both current staff at the Hawaiian Volcano Observatory.

Originals of the first three Volcano Letters could not be found so copies plus the Title Page and Index for 1925 have been extracted from an excellent scan of Volcano Letters for 1925 to 1929 available in Books.Google.com

The Volcano Letter was published by HVO through multiple changes in administration, including the Hawaiian Volcano Research Association (1925-1932), the U.S. Geological Survey (1932-1935), the Department of the Interior (1935-1938), and the University of Hawaiʻi (1938-1955). Issues 1–262 were published weekly from January 1, 1925, to January 2, 1930, and consisted of a single page of text. Issues 263–384, also published weekly, from January 9, 1930–May 5, 1932, were generally longer—four-pages—and provided more detail on volcanic activity, including photographs, maps, and plots. Weekly issues 385–387, published May 12–26, 1932, were a single page of text due to budget reductions brought on by the Great Depression. Budget restrictions reduced the publishing frequency to monthly for issues 388–428, covering the period of June 1932 to October 1935; these issues were generally shorter, 1–2 pages, and sometimes featured figures. From November 1935 to July 1938, issues 429–461 remained monthly but increased in length (generally eight pages) and featured figures frequently. Issues 462–530, published over the period of August 1938–December 1955, varied in length from 2–15 pages, but were published quarterly, rather than monthly.

Six of the letters are misnumbered:
Jan. 21, 1926 number is 55 though it should 56
July 29, 1926 number is 82 though it should be 83
Feb. 16, 1928 number is 161 though it should be 164
May 31, 1928 number is 197 though it should be 179
Nov. 29, 1928 number is 204 though it should be 205

For background information on the Hawaiian Volcano Observatory: https://pubs.usgs.gov/gip/135/

The Volcano Letter publications are also available in print:

Fiske, R.S., Simkin, T., and Nielsen, E.A., eds.,1987, The Volcano Letter, No. 1-530. See https://www.si.edu/object/siris_sil_328087

April 2023

THE VOLCANO LETTER

No. 511 | **U. S. Geological Survey** | **January–March, 1951**

PUBLISHED BY THE UNIVERSITY OF HAWAII

BEGINNING OF GEOMAGNETIC OBSERVATIONS AT HAWAIIAN VOLCANO OBSERVATORY

By G. A. MACDONALD

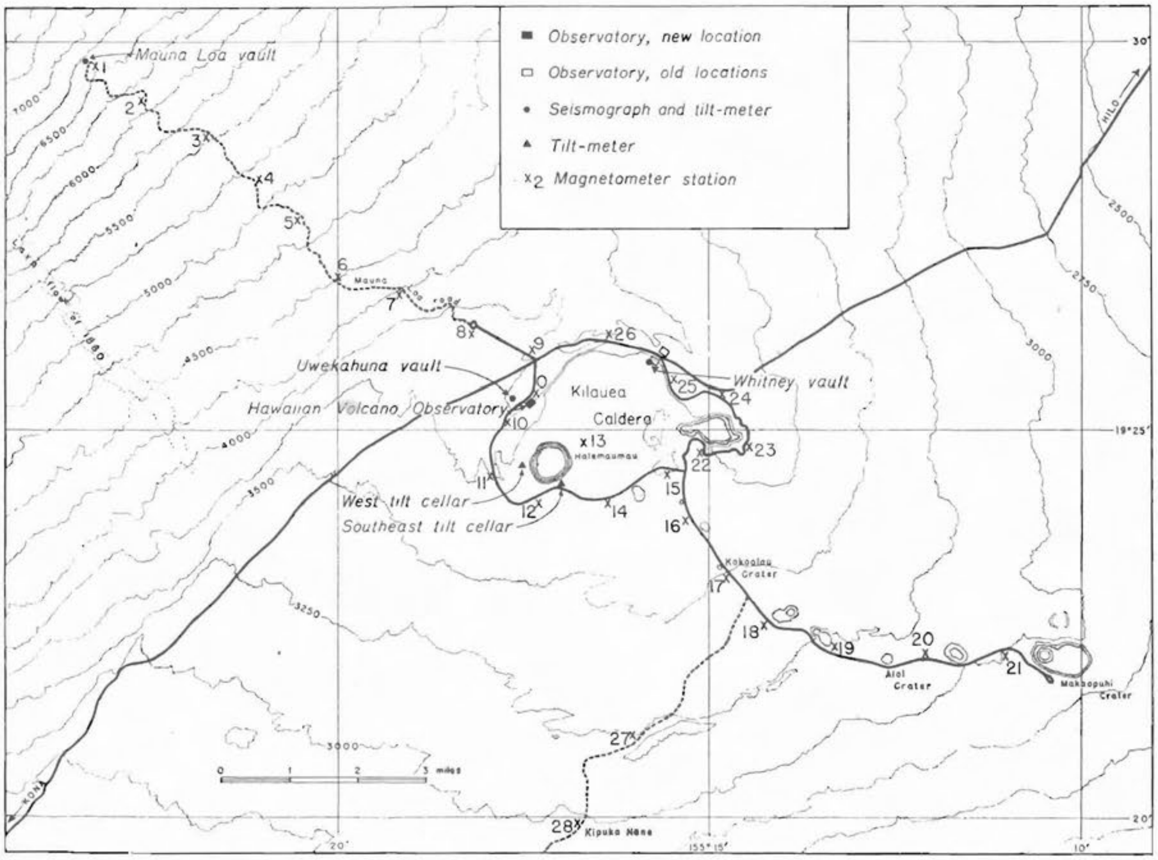

FIGURE 1. Kilauea Caldera and environs, showing locations of Observatory and permanent magnetometer stations.

For the past several years the staff of the Hawaiian Volcano Observatory has wanted to start geomagnetic measurements at Kilauea and Mauna Loa volcanoes. Results obtained by workers on volcanoes in other areas, especially Japan (Kato, 1933–35; Takahasi and Hirano, 1941), have suggested that magnetic measurements in Hawaii might give information on magmatic conditions and movements beneath the surface and, in addition, might supplement other methods in predicting eruptions. Preliminary studies by Omer (1945) suggested some correlation between volcanic conditions on the island of Hawaii and small variations in the magnetic field at Honolulu, nearly 200 miles away.

The opportunity to begin magnetic studies came early in 1950 when two Wolfson vertical magnetometers were made available to the Volcano Observatory by the Geophysics Branch of the U. S. Geological Survey. H. R. Joesting and J. H. Swartz of the Geophysics Branch, accompanied by R. E. Wilcox of the General Geology Branch of the Geological Survey, spent the first 3 weeks of February, 1950, at the Observatory setting up procedures to be followed, calibrating instruments, and instructing Observatory personnel in their use. Joesting and Swartz have kindly read and criticized the manuscript of this paper.

A series of permanent observation stations was established during February and March on Kilauea and on the lower slopes of Mauna Loa. The location of the

Difference in vertical intensity of geomagnetism (in gammas) at other stations, compared to that at station 0.

Station Number	1950 Feb. 17	Mar. 20	Apr. 3–4	May 9–10	June 9	June 12	July 15–16	Aug. 12–13	Sept. 21–22	Oct. 21	Nov. 28–29	Dec. 28	1951 Jan. 20–21	Feb. 24	Mar. 20
1	......	—683	— 744	— 828	—794	—795	— 864	— 823	— 806	—847	—1003	......	— 821	—792	— 858
2	......	— 37	— 54	— 18	......	— 36	— 60	— 84	— 1	— 35	— 228	......	— 87	+ 13	— 46
3	......	—271	— 303	— 301	—329	—304	— 348	......	— 300	—364	— 508	......	— 348	—247	— 524
4	......	—291	— 345	— 326	......	—327	— 400	— 342	— 326	—371	— 551	......	— 368	......	— 486
5	......	+ 77	+ 57	+ 62	+ 83	+112	+ 96	+ 77	+ 131	+ 26	— 85	......	+ 73	+233	— 81
6	......	—117	— 141	— 176	......	—117	— 148	......	— 136	—121	— 336	......	— 139	......	— 308
7	......	— 76	— 107	— 120	—115	— 82	— 110	......	— 79	— 75	— 339	......	......	— 66	......
8	......	—615	— 659	— 765	......	—710	— 762	— 728	— 697	—692	— 976	—756	— 724	—625	—1060
9	......	—714	— 758	— 899	—865	—835	— 901	— 834	— 793	—834	—1098	—869	— 912	—766	—1179
10	—681	......	— 669	— 760	......	......	— 785	— 705	— 676	—676	—1019	—778	......	—629	—1052
11	—171	......	— 204	— 212	......	......	— 244	— 166	— 143	—155	— 497	—177	......	......	+ 290
12	—677	......	— 676	— 745	......	......	— 760	— 696	— 658	—676	—1053	—700	......	......	— 339
13	......	......	— 536	— 604	......	......	— 588	— 559	— 541	—541	— 919	—506	......	—431	......
14	— 35	......	— 69	— 45	......	......	— 31	— 19	— 21	— 26	— 443	— 30	......	+ 62	+ 216
15	+416	......	+ 433	+ 486	......	......	+ 452	+ 456	+ 437	+437	+ 73	+466	......	+621	+ 788
16	......	......	+ 177	+ 198	......	......	+ 178	+ 217	+ 217	+217	+ 209	+168	+ 199	+306	+ 526
17	......	......	— 663	— 740	......	......	— 758	— 684	— 685	—732	— 672	—666	......	—609	— 367
18	......	......	— 418	— 473	......	......	— 466	— 451	— 411	—454	— 791	—441	— 460	—345	— 178
19	......	......	+ 287	+ 353	......	......	+ 326	......	+ 313	+352	+ 16	+332	+ 331	+414	+ 598
20	......	......	— 273	— 304	......	......	— 283	— 258	— 258	—310	— 581	—311	— 280	—180	— 18
21	......	......	+ 257	+ 288	......	......	+ 311	......	+ 319	+294	+ 67	+274	+ 279	+398	+ 552
22	+786	......	+ 784	+ 899	......	......	+ 894	......	+ 845	......	+ 697	+823	+1108	......	+ 889
23	......	......	+1167	+1358	......	......	+1334	+1255	+1219	......	+1168	......	+1284	......	+1278
24	......	......	— 46	— 45	......	......	— 47	— 50	— 7	......	— 186	......	— 8	......	— 123
25	......	......	......	+2547	......	......	......	+2550	+2591	......	+2555	......	+2602	......	+3843
26	......	......	+ 243	+ 288	......	......	+ 291	+ 289	+ 276	......	+ 189	......	+ 342	......	......
27	......	......	......	— 872	......	......	— 910	— 850	— 827	—896	— 895	......	— 924	—937	— 825
28	......	......	......	— 927	......	......	— 921	— 925	— 897	—957	— 958	......	— 976	—994	— 920

stations is shown in Figure 1. The number of stations is not as great as might be desired, but is limited by the amount of time available for the work.

Each station was set at a point where closely spaced set-ups of the magnetometer showed the magnetic field to be reasonably regular over an area of approximately 100 square feet. At each station three concrete hubs were set and small pits drilled in them to receive the ends of the magnetometer tripod legs. The tripod legs are kept at a fixed length when the stations are occupied, and each leg is placed on the same hub in successive readings at each station. The leveling screws also are turned out as nearly as possible to the same distance for each set-up. Thus the position of the instrument, both horizontally and vertically, is as nearly as possible the same for successive readings at a given station.

It is planned to occupy each station approximately once a month, but during some months the Observatory staff has not had time to occupy all of the stations. The stations are so widely distributed that considerable time is needed for travel between them. All the readings of each set are made on one day, or on 2 successive days.

The procedure is as follows. One instrument is set on station 0, near the Volcano Observatory at the western edge of Kilauea Caldera (Fig. 1). After the reading at station 0 is obtained, the instrument is taken to each of the other stations and readings obtained at them. Readings are made with the north end of the balance pointed first east and then west; the average of the two sets of readings is used, thus compensating for any small errors in orientation and leveling of the instrument. Immediately after the first instrument is removed from station 0, the second instrument is set up at that station and it is read at frequent intervals throughout the time the first instrument is in use at the other stations. From the readings at station 0, a curve of diurnal variation is constructed which is used in correcting the readings at the other stations. At the end of the traverse the first instrument is again set on station 0, and, after correcting for diurnal variation, any closing error is distributed linearly throughout the time of operation. The instrument is recalibrated for sensitivity in the laboratory following each series of readings. The corrected scale readings are then converted into gammas, and the strength of the magnetic attraction at each station is recorded in terms of difference in gammas from that at station 0.

In some respects the program is not ideal, but it represents the best which the limited available time and small size of the Observatory staff allow at present. If results appear to justify it, it is hoped that the program can be expanded and improved in the future. The data obtained thus far are shown in the accompanying table.

Joesting and Swartz again visited the Volcano Observatory in June, 1950, during the eruption of Mauna Loa for the purpose of checking on the progress of the investigation and the operation of the instruments. Of the measurements listed in the table, those for June 12 were made by them. The others were made by members of the Observatory staff, principally C. K. Wentworth and the writer, aided during March and April by J. B. Orr of the National Park Service. On March 8 and 9, 1951, F. C. Farnham of the Geophysics Branch made measurements with an absolute magnetometer at station 0 close to the Volcano Observatory and at a newly established station close to the seismograph station at St. Joseph's School in Hilo.

It is too soon to attempt much interpretation of the results. It is believed possible that the rise of hot magma underground may cause a detectable change in the vertical component of the magnetic field at the surface. It will be noted in the accompanying table that several of the stations (1 to 9) which lie on the line between the Observatory and the Mauna Loa seismograph showed a decrease in magnetism as related to station 0. Mauna Loa erupted on June 1, and there is some possibility that the decrease in magnetism at these stations on Mauna Loa may have been in some way related to the then-impending eruption. However, the distance of the closest station from either the eruptive axis of the volcano (beneath the summit caldera) or the locality on the southwest rift where the eruption took place is so great (13 and 20 miles, respectively) that the apparent correlation is regarded with little confidence.

Early in July, soon after the end of the Mauna Loa eruption, a line of three stations was established running southeastward for 1.5 miles from a point on the recently active rift. It is planned to make readings at these stations at intervals of about 6 months during the next few years to determine whether any definite discernible effect results from cooling of the magma in the rift.

Variations at the stations on Kilauea have thus far been rather irregular. It appears that during the past year volcanism at Kilauea may have been at its lowest ebb in the historical period, and hence that the time of commencement of the magnetic program may have been exceptionally favorable in respect to detection of any changes which may accompany the return of surficial volcanic activity.

REFERENCES

KATO, Y. SEISMIC AND VOLCANIC ACTIVITIES AND CHANGES IN THE EARTH'S MAGNETIC FIELD. Japanese Jour. Astron. and Geophys. 10: 249–262, 1933; 12: 1–26, 1934; 12: 237–243, 1935.

OMER, G. ON MAGNETIC STUDIES. Volcano Letter 487, pp. 1–4, 1945.

TAKAHASI, R., and HIRANO, K. CHANGES IN THE VERTICAL INTENSITY OF GEOMAGNETISM THAT ACCOMPANIED THE ERUPTION [OF MIYAKE-SIMA IN 1940]. Tokyo Imp. Univ., Earthquake Res. Inst. Bul. 19: 373–380, 1941.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY–MARCH, 1951

VOLCANOLOGY

January

The year 1951 commenced with both Mauna Loa and Kilauea volcanoes quiescent. During the month of January, 18 earthquakes were recorded at the Whitney vault on the northeastern rim of Kilauea Caldera; 8 of these were recorded also on the seismograph on the lower east slope of Mauna Loa. This was the smallest number of earthquakes recorded during any month since October, 1947.

At the Whitney vault ground surface tilting was in the main southward, following the usual seasonal pattern for this time of year. From January 7 to 17, however, there was a sharp northward tilting of approximately 2 seconds of arc. Most cracks in the vicinity of Kilauea Caldera opened or closed very little. Cracks near the southeastern edge of Halemaumau continued to open.

Conspicuous steam clouds rose from Halemaumau on January 22, after heavy rains.

February

Mauna Loa and Kilauea continued quiet during February. The seismograph at the northeastern rim of Kilauea Caldera recorded 25 earthquakes during the month; 16 of these were recorded also on the Mauna Loa seismograph. An earthquake felt in the vicinity of Kapapala at 10:55 A.M. on February 14 originated at a depth of about 7 miles on or near the Kaoiki fault zone near Ainapo on the southeastern flank of Mauna Loa. At 7:26 on the morning of February 16 a somewhat stronger earthquake was felt from Naalehu to Hilo. It had its origin about 15 miles below a point on the northeast rift zone of Mauna Loa near Puu Ulaula. Most of the small earthquakes during the month originated at Kilauea.

Tilting of the ground at the northeast rim of Kilauea Caldera continued southward, as is normal for this season of the year. There was almost no accumulation of east–west tilt during the month. However, because there is normally a westward tilting at this time of the year, the absence of tilting may indicate a small increase of volcanic pressure beneath Mauna Loa.

The vents of the 1950 eruption of Mauna Loa were visited on February 9 and 10. Steam was issuing from the fissures from 10,200 to 11,500 feet altitude, and large amounts of sulfurous fume were being liberated in the vicinity of 10,000 feet. The source cracks were still warm, but no heat could be detected in most of the thin flows near the vents. The thick flows near the highway in Kona are still hot beneath the surface. Fume was visible on the southwest rift from the Volcano Observatory on the afternoon of February 16.

During heavy rains in late February, spectacular steam clouds rose from Halemaumau, giving evidence that the vent of Kilauea Volcano is still very hot only a short distance below the surface.

March

The period of quiet at Hawaiian volcanoes which began in late December continued through March. The seismograph at the northeast rim of Kilauea Caldera recorded 27 earthquakes during the month, 2 more than were recorded during February. Only 14 of these were recorded at the Mauna Loa station. A quake which was felt in the Volcano district and Hilo on the evening of March 14 originated at a depth of about 7 miles on the east rift zone of Kilauea, 5 miles east–northeast of Makaopuhi Crater. At 6:41 A.M. on March 20 another earthquake was felt by a few persons in the Puueo district of Hilo. This quake had its origin about 6 miles below the eastern slope of Mauna Loa, 3 miles east of Kulani Cone. From March 15 to 19 several small earthquakes originated on the western slope of Mauna Loa near Kealakekua, possibly on the fault which runs out to sea at the northern edge of Kealakekua Bay.

Tilting of the ground surface at the northeastern rim of Kilauea Caldera continued southward through March. Southward tilting is normal during this part of the year. However, from March 7 to 17 the tilting was distinctly more rapid than normal, indicating a slight decrease of volcanic pressure beneath Kilauea Caldera. This, like the short spell of northerly tilting in January, indicates fluctuation of pressure, demonstrating that the lava column beneath Kilauea Caldera is still mobile. Slight westward tilting also occurred during the month, as is usual at this season.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning		Whitney Vault (Northeast rim)		Uwekahuna Vault (West rim)	
		Amount	Direction	Amount	Direction
December	31	0.9″	S 45° W	0.4″	S 56° W
January	7	0.8″	N 38° E	0.7″	S 26° W
	14	0.7″	N	1.5″	N 70° W
	21	2.0″	S 35° E	2.4″	N 15° W
	28	0.6″	S 37° W	0.2″	N 27° E
February	4	1.2″	S 45° W	1.2″	S 70° E
	11	1.5″	N 38° E	1.5″	S 58° W
	18	1.5″	S 35° E	2.3″	N 78° E, S 52° W
	25	1.6″	S 42° W	2.4″	N 78° E
March	4	2.1″	S 26° W	1.5″	E
	11	4.1″	S 5° W	0.7″	S 15° E
	18	1.2″	S 16° W	0.5″	S 79° E
	25	0.6″	W	0.4″	N 63° E

TILTING OF THE GROUND

At the Whitney Laboratory of Seismology, situated at the site of the original Volcano Observatory building on the northeastern rim of Kilauea Caldera, ground tilting was in the southward direction, normal for this season of the year, except for a brief period of fairly strong northward tilting from January 7 to 17 and another less marked period of northward tilting from February 10 to 21. There was a slight eastward tilting in January and almost no accumulation of east–west tilt in February. However, since the normal seasonal tilting is westward in February, both the January and February records indicate a small increase in volcanic pressure beneath Mauna Loa. Normal westward tilting continued through the month of March. Records of tilting at the Uwekahuna vault are not yet long enough to determine the normal pattern of seasonal tilting at that locality.

CRACK MEASUREMENTS

The only crack which showed much change in width during the 3-month period preceding March 31 is the one which crosses the tourists' observation platform at the southeastern edge of Halemaumau. That crack opened 1.1 centimeters at the northern end, the amount of opening decreasing southward to zero at a point between measuring stations 8 and 9, south of the observation platform. Crack 37, on the floor of Kilauea Caldera about a quarter of a mile southeast of Halemaumau, opened 1 millimeter; crack 101-A, near Chain of Craters Road about 0.2 mile northwest of Devil's Throat, closed about the same amount.

TEMPERATURE MEASUREMENTS

The temperature of the steam well at the Sulphur Bank measured 204.5° F. on December 31 and January 30, and 205° F. on March 1 and March 31.

SEISMOLOGY

Earthquake Data, January–March, 1951

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

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Dec. 31	5	1	0	1	0	0	3.75	0
Jan. 7	0	0	0	0	0	0	0.0	0
Jan. 14	4	0	0	0	0	0	1.0	0
Jan. 21	5	1	0	0	0	0	1.75	0
Jan. 28	2	0	0	0	0	0	0.5	0
Feb. 4	3	0	0	0	0	0	0.75	0
Feb. 11	6	1	0	2	0	0	6.0	2
Feb. 18	1	6	0	0	0	0	3.25	1
Feb. 25	2	3	0	0	0	0	2.0	0
Mar. 4	4	5	0	0	0	0	3.5	1
Mar. 11	3	4	1	1	0	0	5.75	0
Mar. 18	5	1	1	0	0	0	2.75	0
Mar. 25	1	0	0	0	0	0	0.25	0

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

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The arrival times are given to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich. 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 at the northeast rim of Kilauea Caldera. 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.

1. Jan. 3, 03:39, very feeble.
2. Jan. 6, 04:58, slight. Southwest rift of Mauna Loa at about 8,000 feet altitude.
3. Jan. 26, 06:40, very feeble.
4. Feb. 14, 10:55, slight (moderate, Mauna Loa), felt at Kapapala. Kaoiki fault near Ainapo, about 7 miles deep.
5. Feb. 16, 07:26, slight (moderate, Mauna Loa), felt from Hilo to Naalehu. Northeast rift of Mauna Loa near Puu Ulaula, about 15 miles deep.
6. Feb. 16, 18:58, very feeble.
7. Feb. 20, 20:01, very feeble.
8. Feb. 20, 20:47, very feeble.
9. Feb. 20, 21:47, very feeble.
10. Feb. 21, 21:26, very feeble.
11. Feb. 23, 03:41, very feeble.
12. Feb. 24, 17:39, very feeble.
13. Feb. 26, 01:28, very feeble (feeble, Kona).
14. Feb. 26, 09:21, very feeble.
15. Feb. 28, 14:13, very feeble.
16. Mar. 5, 03:53, very feeble.
17. Mar. 5, 03:56, very feeble.
18. Mar. 5, 09:33, very feeble.
19. Mar. 5, 16:44, very feeble. Northeast rift of Mauna Loa.
20. Mar. 8, 16:30, very feeble. Nearly under Hilo, about 25 miles deep.
21. Mar. 14, 03:47, very feeble. Hilina fault, southeast of Kilauea Caldera.
22. Mar. 14, 03:48, feeble. East rift of Kilauea.
23. Mar. 14, 20:50, slight, felt in Hilo and Volcano areas. East rift of Kilauea 3 miles east–northeast of Napau Crater, about 7 miles deep.
24. Mar. 15, 04:38, very feeble (feeble, Mauna Loa). West slope of Mauna Loa near Kealakekua.
25. Mar. 15, 11:34, very feeble.
26. Mar. 15, 16:43, very feeble (slight, Kona). West slope of Mauna Loa near Kealakekua.
27. Mar. 20, 06:42, feeble, felt in Puueo. East slope of Mauna Loa 3 miles east of Kulani Cone, about 6 miles deep.
28. Mar. 24, 06:28, no record at Kilauea (very feeble, Kona). West slope of Mauna Loa.
29. Mar. 24, 22:33, very feeble.

TELESEISMS

Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey.

Jan. 13, 12:20, slight. About 150 miles east of Alaska Peninsula.
Jan. 17, 11:17, slight. Southeastern New Guinea.
Feb. 19, 12:38, moderate. About 500 miles west of Easter Island.
Mar. 10, 12:06, slight. Fiji Islands region.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

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

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

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

THE VOLCANO LETTER

No. 512 **U. S. Geological Survey** **April–June, 1951**

PUBLISHED BY THE UNIVERSITY OF HAWAII

THE KILAUEA EARTHQUAKE OF APRIL 22, 1951, AND ITS AFTERSHOCKS

By GORDON A. MACDONALD

At 2:52 Hawaiian time, on the afternoon of April 22, the southern part of the island of Hawaii experienced the strongest earthquake in this area since 1929, and possibly since 1908. The epicenter of the quake lay just east of Kilauea Caldera. The intensity of V, on the modified Mercalli scale, was essentially uniform for 30 miles northeast and southwest of the epicenter, to Hilo and Naalehu, respectively. This uniformity of intensity over such a broad area indicates that the origin of the earthquake was at a considerable depth, probably 25 to 30 miles. It was impossible to determine either the epicenter or the depth of origin instrumentally, because all the seismographs of the local net were dismantled by the beginning of the preliminary waves. The operator of the Hilo seismograph station, Brother Bernard T. Pleimann of St. Joseph's School, reached the dismantled instrument and reassembled it in time to record the coda of the earthquake. Shaking continued on the Hilo instrument for 16 minutes.

The preliminary determination of epicenter, issued by the U. S. Coast and Geodetic Survey on April 24, gives the time at the origin as 00:52:21 on April 23, Greenwich time, and the magnitude on the Gutenberg-Richter scale as 6.5 as determined at Pasadena and 6.0 at Berkeley.

The earthquake was felt generally over the island of Hawaii and by many persons on the islands of Maui and Oahu. Damage resulting from the quake was slight. On the southern part of the island of Hawaii many small objects were overturned, and some dishes were broken. Many, but not all, pendulum clocks were stopped. A water pipe was broken at the Volcano Observatory, and a plate glass window at Glenwood was cracked. Water slopped over the rims of some tanks. Small earth slips occurred in road cuts between Kilauea Caldera and Hilo, and north of Hilo along the Hamakua Coast. Several rock slides occurred on the walls of Kilauea Caldera and a very large number on the unstable walls of Halemaumau crater. All the latter were small. No large blocks of the crater rim were displaced, although many cracks near the rim were widened appreciably. The crack which crosses the tourist area at the southeast rim of the crater opened 6 mm. at the time of the earthquake and 3 mm. more during the period of aftershocks. Small slides continued in Halemaumau for about a week after the big earthquake. Small rock avalanches occurred on the walls of Alae and Makaopuhi craters, on the east rift zone of Kilauea, and Superintendent F. R. Oberhansley of Hawaii National Park reported rock falls at the cliffs of Hilina Pali and Puu Kapukapu, on the southern shore of the island. Minor cracking of the highway occurred at the northeast rim of Kilauea Caldera, ¼ mile southeast of the Whitney Laboratory (Fig. 1), apparently caused by settling of a thin fill under the pavement when the block at the edge of the caldera moved forward slightly. Cracking in the soil also was observed at several places north and east of Kilauea Caldera, apparently caused by lurching of the soil. No surface faulting was observed.

The Bosch-Omori seismograph at the Whitney Laboratory on the northeast rim of Kilauea Caldera (Fig. 1) and the vertical seismograph at Uwekahuna were dismantled. The vertical seismograph was back in operation at 15:20, but resumption of recording on the Bosch-Omori seismograph was delayed until 16:45 by electric power failure caused by the earthquake. The wire suspensions on the heavy mass of one component of the Hawaiian-type seismograph at the Mauna Loa station were broken, and the mass, weighing approximately 225 pounds, was deposited on the floor of the vault, 3 feet from its proper position. At the Uwekahuna vault, the wire suspensions on both components of a semiportable tiltmeter were broken and the horizontal pendulums, each weighing 35 pounds, dropped onto the pier. The breaking of the wire suspensions, which have considerable strength under normal conditions of lateral swing of the pendulums, suggests a vertical dancing of the pendulums. This, together with the dismantling of the vertical seismograph, which is seldom dismantled even by strong earthquakes, appears to indicate a high angle of emergence of the earthquake vibrations, consonant with a deep origin nearly beneath Kilauea Caldera.

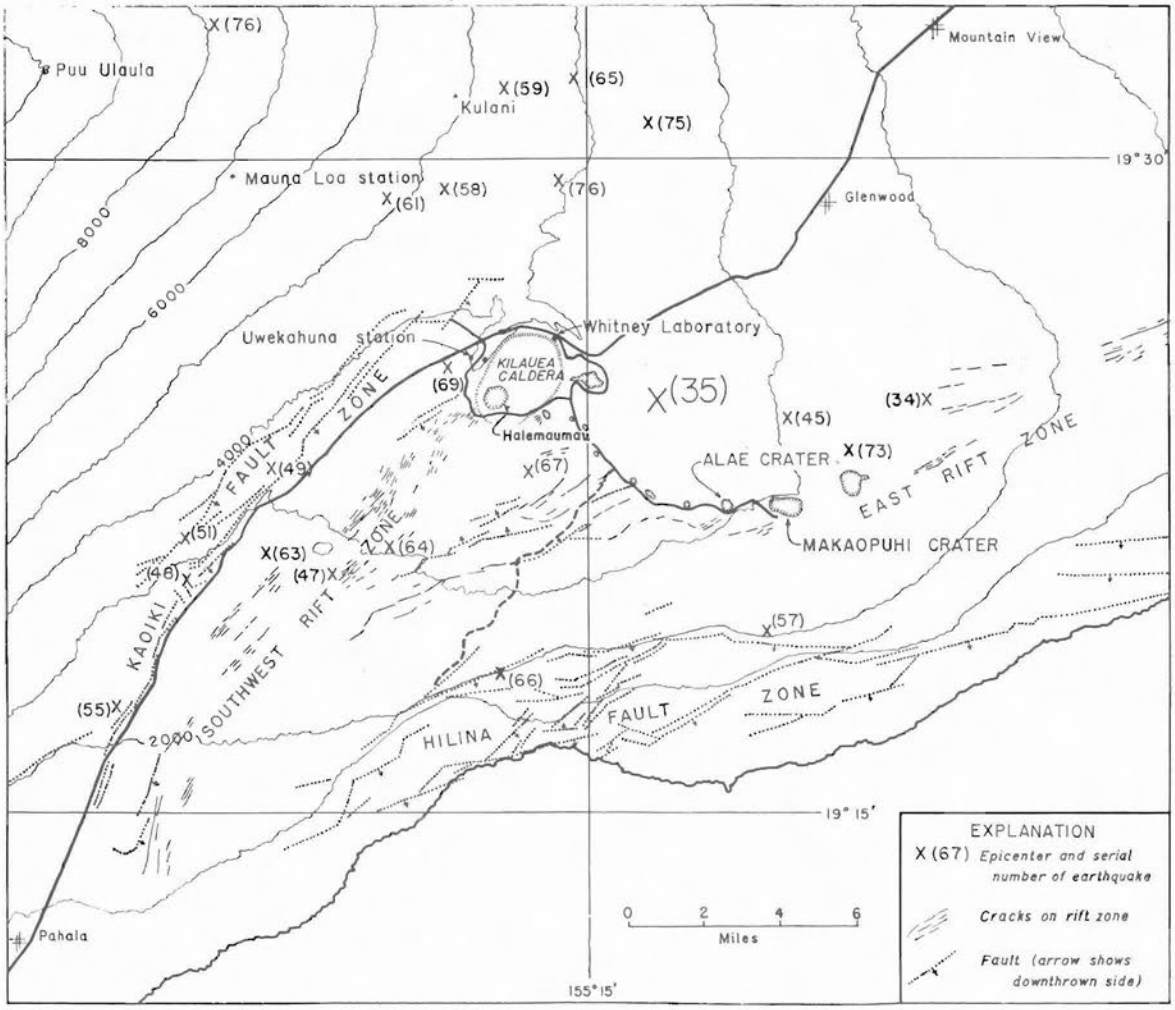

FIGURE 1. Map of Kilauea Caldera and vicinity, showing the epicenters of the large earthquake of April 22 and its aftershocks in relation to fault zones and the rift zones of Kilauea volcano. The epicenter of earthquake 35 was estimated on non-instrumental grounds and its location is only approximate.

Damage to the seismographs and tiltmeters made it impossible to determine with certainty the direction of tilt during the earthquake, but it probably was southeastward at the Whitney station and eastward at Uwekahuna. The direction of first motion of the earthquake was south and east at the Whitney station, and down at the vertical seismograph at Uwekahuna. It is believed that the earthquake accompanied a marked subsidence at Kilauea, probably caused by a decrease of volcanic pressure at depth. Subsidence is suggested by the direction of first motion, the probable direction of tilt, and the observed generalization that the strongest local earthquakes generally, if not always, accompany subsidence rather than tumescence. It is interesting that the subsidence was immediately followed by the beginning of rapid northward tilting of the ground at the Whitney station, apparently indicating restoration of the pressure. This rapid northward tilting continued until June 8 (see section on Volcanology, page 4).

At 04:53:53 H.S.T. on April 22, the major earthquake was preceded by a moderate earthquake which originated at a depth of about 21 miles on the east rift zone of Kilauea volcano, 10 miles east of the caldera (Fig. 1, location 34).

During the 7 days following the major shock, 108 earthquakes were recorded on the Volcano Observatory seismographs. Of these, 71 occurred on April 22 and 23. More than half were tremors, too small to permit identification of separate phases in the record. Figure 2 is a graph of daily seismicity from April 20 to 30, derived by assigning a numerical value to each earthquake, depending on its intensity, and totaling these values for each day. The scale of seismicity in use at the Hawaiian Volcano Observatory is an arbitrary one, based on the amplitude of the record produced by the earthquake on the seismographs. It has previously been described by A. E. Jones.[1] The grades of earthquake intensity and numerical values assigned to them are listed in the accompanying table.

As indicated in the table, earthquakes of seismicity value 1 to 4 correspond approximately to the same numerical grades in the Rossi-Forel and modified Mercalli scales of earthquake intensity. However, because the Volcano Observatory scale is based on instrumental effects, the correspondence to the other intensity scales and the descriptions of non-instrumental effects in the table are not always exact.

All earthquakes producing a double amplitude of os-

[1] JONES, A. E., CHART OF KILAUEA SEISMICITY. Volcano Letter 371: 1–3. 1932.

cillation of more than 60 mm. on the Bosch-Omori seismograph are classified as strong, and receive the same seismicity rating. Thus the big earthquake of April 22 received the same seismicity value as the much smaller "strong" earthquakes which took place on April 23 and 26. If allowance were made for this, the seismicity on April 22 would be somewhat increased. The high seismicity on April 22 and 23 results principally from the large number of very small aftershocks (tremors and very feeble earthquakes) on those days.

Most of the aftershocks were too small to be located, phase arrivals not being recognizable on the seismograms, or recognizable only on the record of one station. Only 19 could be located with reasonable certainty. The epicenters of these are shown in Figure 1, in which the number accompanying the cross indicating the epicenter is the serial number of the earthquake for the current year. The date, time, and intensity of the earthquake are given following its serial number in the table in the section on Seismology, pages 4 and 5. All the located aftershocks were of comparatively shallow origin. The deepest was that at 03:57 on April 26 (Serial No. 73), at a depth of about 11 miles on the east rift zone of Kilauea. Most of the others originated at depths of 3 to 8 miles.

In general, the aftershocks fall into two groups, one distributed along the rift zones of Kilauea volcano, and the other associated with the Kaoiki fault zone along the southeast slope of Mauna Loa and the prolongation of the Kaoiki zone northeastward beyond any recognized surface fault offsets. It is of interest to note that the northeastward continuation of the Kaoiki fault was suggested years ago by H. O. Wood,[2] who also found an apparent clustering of earthquakes along this line. The Kaoiki fault zone lies at, or close to, the surface contact between Kilauea and Mauna Loa volcanoes. The earthquake activity along this zone possibly resulted from relative downward movement of Kilauea along the Kaoiki faults in response to decrease of volcanic pressure beneath Kilauea.

[2] Wood, H. O. A CONSIDERATION OF RECENT EARTHQUAKES LOCAL TO HAWAII, AND OF THE SEISMOLOGICAL PROBLEM THEY INDICATE. Hawaiian Volcano Obs. Bul. 3(5): 56–57. 1915.

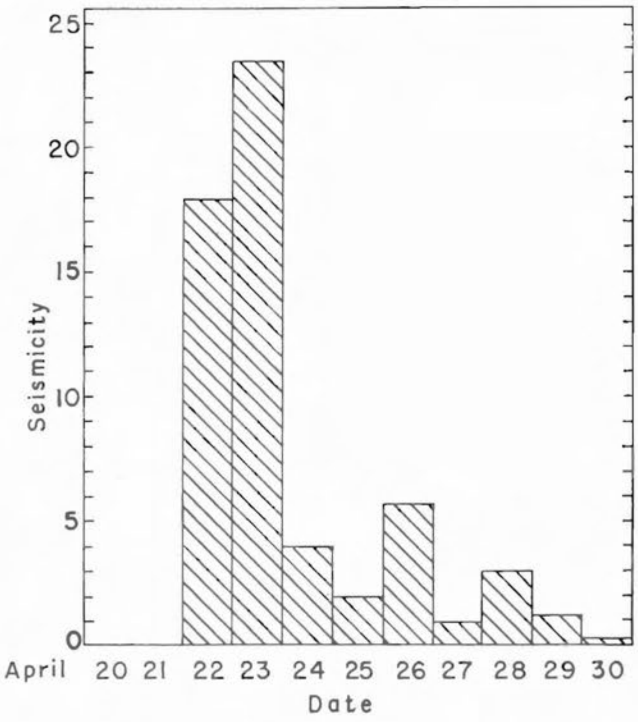

Figure 2. Graph showing seismicity at the Whitney Laboratory, at the northeast rim of Kilauea Caldera, during late April, 1951.

Many of the small aftershocks, which could not be definitely located, appear almost certainly to have originated beneath Kilauea Caldera or along one of the rift zones in the immediate vicinity of the caldera. Two of the quakes originated along the Hilina fault zone near the southern coast of Kilauea.

Comparison of Earthquake Intensity Scales

Hawaiian Volcano Observatory Scale			Description of Non-Instrumental Effects	Approximate Grade in Rossi-Forel and Modified Mercalli Scales
Designation	Double amplitude of motion on Bosch-Omori seismograph*	Seismicity value		
	mm.			
Tremor	< ½	¼	Not felt.	
Very feeble	½–4	½	Not felt or only very rarely felt by very few persons in especially favorable positions, usually lying down.	
Feeble	4–11	1	Not felt or felt only by a few persons in favorable positions.	I
Slight	11–25	2	Felt by many persons at rest. Hanging objects may swing.	II
Moderate	25–60	3	Felt generally, by persons in or out of doors. Hanging objects swing.	III
Strong	> 60	4	Felt by everyone or nearly everyone. Objects swing. Dishes, doors, and windows rattle. Minor damage may result.	IV–V

* Static magnification of Bosch-Omori seismograph is approximately 115.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL–JUNE, 1951

VOLCANOLOGY

April

The volcanic quiescence of the first quarter of the year continued into April. It was shattered on April 22 by the heavy earthquake and swarm of aftershocks described on previous pages. Seismographs of the Hawaiian Volcano Observatory recorded 132 earthquakes during the month of April. Of these, 108 were aftershocks of the big earthquake of April 22. The Kilauea origin of most of the shakes is shown by the fact that 125 of them were recorded on the instruments at the rim of Kilauea Caldera and only 89 of them at the Mauna Loa station.

The distinct uneasiness of Kilauea volcano was further shown by the commencement, on June 24, of fairly rapid tumescence of the volcano, expressed by northward tilting at the Whitney Laboratory at a rate considerably in excess of the normal rate for that time of year. It should be noted also that the reversal from southward to northward tilting came nearly a month earlier than usual.

May

The rapid northward tilting of the ground at the northern rim of Kilauea Caldera, which commenced in April, continued throughout May. By the end of the month a total of 6 seconds of arc of northerly tilting had accumulated. This rate is approximately twice as great as the normal rate of northward tilting at this season of the year, and indicates a continued increase of volcanic pressure beneath Kilauea. Some cracks on the floor of the caldera and along the Chain of Craters road opened slightly during the month, possibly in response to tumescence of the mountain.

Volcano Observatory seismographs recorded 41 earthquakes during May. Of these, 36 were recorded at the Whitney Laboratory and 20 at the Mauna Loa station. A feeble earthquake, felt by a few persons in the Volcano district just after noon on May 17, originated under Kilauea volcano, about 6 miles south of the crater.

June

The marked northward tilting of the ground at the northern edge of Kilauea Caldera continued into early June. After June 8, however, the rate of northward tilting decreased to about normal for this season of the year. During late May, the rate of eastward tilting was approximately normal for that season. However, on June 3, it became appreciably greater than normal and continued above normal for the remainder of the month, indicating an increase of volcanic pressure beneath the summit area of Mauna Loa.

During June, 42 earthquakes were recorded on the seismographs. Of these, 28 were recorded at the Whitney Laboratory and 29 at the Mauna Loa station. Slight earthquakes were felt by some persons from the Volcano district to Hilo at 10:49 P.M. on June 7 and 8:32 A.M. on June 11. Both originated on the east rift zone of Kilauea volcano, the first near Pauahi crater, and the second 6 miles southwest of Pahoa. A series of small earthquakes (mostly tremors) on June 18 and 19, recorded only on the Mauna Loa seismograph, indicate some movement on the northeast rift zone of Mauna Loa.

The northern end of the crack which crosses the observation area at the southeast rim of Halemaumau crater opened another 3 mm. during June. Other cracks in the vicinity also opened slightly.

The temperature of the steam at the Sulphur Bank well remained at 205° F. from March 31 to July 2.

TELESEISMS

Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey.

April 30, 05:35, slight. Celebes region.
May 19, 04:59, slight.
May 19, 06:45, slight.
June 16, 23:54, slight. Three hundred miles off the Oregon coast.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning	Whitney Vault (Northeast rim) Amount	Direction	Uwekahuna Vault* (West rim) Amount	Direction
April 1	0.5″	N 45° W	0.9″	S 74° W
8	0.8″	S 63° E	0.3″	N 45° W
15	1.3″	S 85° W	0.2″	S 72° W
22	1.4″	N 22° E	1.4″	S 62° W
29	0.4″	N 27° W	0.6″	N 74° W
May 6	1.0″	N 7° W	1.1″	N 81° W
13	1.2″	N 17° E	......	....
20	1.1″	N 18° E	2.8″	S 9° E
27	1.9″	N 15° E	0.4″	S 19° E
June 3	1.0″	N 60° E	1.4″	S 17° E
10	1.6″	S 86° E	2.1″	N 3° W
17	0.4″	N 56° E	1.4″	N 17° W
24	1.4″	N 52° E	0.6″	N 53° W

* Record previous to May 13 from a small, semiportable tiltmeter. During early May, a pair of heavy, horizontal pendulums was installed, and the record after May 20 is from this new instrument. The record for the week starting May 13 is considered unreliable because of improper operation of the east-west pendulum.

SEISMOLOGY

Earthquake Data, April–June, 1951

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

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
April 1	3	1	0	0	0	0	1.25	0
8	7	1	1	0	0	0	3.25	0
15	3	1	0	0	0	0	1.25	0
22	67	26	3	4	1	3	55.75	0
29	11	1	0	0	0	0	3.25	1
May 6	0	2	2	0	0	0	3.0	0
13	8	4	1	0	0	0	5.0	1
20	5	3	0	0	0	0	2.75	0
27	1	2	0	0	0	0	1.25	0
June 3	3	0	0	1	0	0	2.75	0
10	4	2	0	1	0	0	4.0	1
17	9	2	1	0	0	0	4.25	0
24	4	1	0	0	0	0	1.5	0

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

The data for the following local disturbances were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The arrival times are given to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich 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 at the northeast rim of Kilauea Caldera. 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.

30. Apr. 4, 10:43, very feeble.
31. Apr. 13, 01:19, very feeble, felt at Waimea. About 8 miles southwest of Waimea, shallow.
32. Apr. 13, 14:53, feeble. East flank of Kilauea.
33. Apr. 15, 13:36, very feeble.
34. Apr. 22, 04:54, moderate, felt at Kapapala and from Volcano district to Hilo. East rift of Kilauea 7 miles S 15° E of Glenwood, 21 miles deep.
35. Apr. 22, 14:52, very strong, felt all over Hawaii Island and on Maui and Oahu. East rift of Kilauea near the caldera, 25 to 30 miles deep.
36. Apr. 22, 15:25, very feeble.
37. Apr. 22, 15:27, very feeble.
38. Apr. 22, 15:41, very feeble.
39. Apr. 22, 15:49, very feeble.

40. Apr. 22, 15 : 50, very feeble.
41. Apr. 22, 15 : 51, very feeble.
42. Apr. 22, 16 : 08, very feeble.
43. Apr. 22, 16 : 14, very feeble.
44. Apr. 22, 16 : 49, very feeble.
45. Apr. 22, 17 : 19, feeble. East rift of Kilauea 7 miles east of the caldera, about 8 miles deep.
46. Apr. 22, 17 : 30, very feeble.
47. Apr. 22, 18 : 46, very feeble. Southwest rift of Kilauea near Mauna Iki, about 5 miles deep.
48. Apr. 22, 20 : 30, tremor (very feeble, Mauna Loa).
49. Apr. 22, 21 : 11, tremor (very feeble, Mauna Loa).
50. Apr. 22, 23 : 30, very feeble.
51. Apr. 22, 23 : 40, very feeble. Kaoiki fault near Ainapo.
52. Apr. 23, 00 : 17, very feeble.
53. Apr. 23, 02 : 46, very feeble.
54. Apr. 23, 03 : 04, very feeble. Kaoiki fault near Kapapala.
55. Apr. 23, 03 : 27, very feeble.
56. Apr. 23, 04 : 37, very feeble.
57. Apr. 23, 04 : 40, slight. East rift of Kilauea 2 miles south of Makaopuhi, 4 miles deep.
58. Apr. 23, 04 : 41, slight. Three miles north of Kilauea Caldera, about 5 miles deep.
59. Apr. 23, 04 : 44, feeble. Near Kulani cone, about 7 miles deep.
60. Apr. 23, 05 : 24, very feeble.
61. Apr. 23, 05 : 48, slight. Five miles northwest of Kilauea Caldera, about 6 miles deep.
62. Apr. 23, 06 : 13, very feeble.
63. Apr. 23, 06 : 36, strong, felt in Volcano district. Southwest rift of Kilauea 2 miles southwest of Mauna Iki, 5 miles deep.
64. Apr. 23, 21 : 53, very feeble. Southwest rift of Kilauea near Puu Koae, about 5 miles deep.
65. Apr. 23, 22 : 16, very feeble. Two miles southwest of Kulani cone, about 5 miles deep.
66. Apr. 23, 22 : 18, very feeble.
67. Apr. 24, 01 : 14, very feeble.
68. Apr. 24, 01 : 29, very feeble.
69. Apr. 24, 11 : 30, very feeble. Near Bird Park, about 11 miles deep.
70. Apr. 25, 11 : 41, very feeble.
71. Apr. 25, 22 : 38, very feeble.
72. Apr. 26, 00 : 57, tremor (very feeble, Mauna Loa).
73. Apr. 26, 03 : 58, strong, felt in Volcano district. East rift of Kilauea near Makaopuhi, about 12 miles deep.
74. Apr. 26, 05 : 51, feeble. Waimea plain about 6 miles east of Waimea.
75. Apr. 28, 07 : 38, slight. Four miles east of Kulani cone, shallow.
76. Apr. 29, 16 : 19, very feeble. About 3 miles southeast of Kulani cone.
77. May 6, 08 : 53, very feeble, felt by one person in Volcano district, and some in Pahala and Naalehu. Kaoiki fault zone, 3 miles southwest of Pahala.
78. May 7, 12 : 36, very feeble.
79. May 8, 00 : 38, feeble.
80. May 10, 15 : 24, feeble. East rift of Kilauea near Puu Huluhulu, shallow.
81. May 13, 00 : 24, very feeble.
82. May 14, 18 : 41, very feeble. Southwest rift of Kilauea near Mauna Iki, shallow.
83. May 15, 22 : 10, very feeble.
84. May 17, 12 : 12, feeble.
85 May 18, 03 : 00, very feeble.
86. May 20, 13 : 34, very feeble.
87. May 20, 16 : 16, very feeble.
88. May 25, 03 : 10, very feeble.
89. May 30, 21 : 59, very feeble.
90. May 31, 09 : 13, very feeble.
91. June 3, 04 : 45, tremor (very feeble, Mauna Loa).
92. June 4, 14 : 36, no record at Whitney vault (very feeble, Kona).
93. June 7, 22 : 50, slight, felt in Volcano district and by a few in Hilo. East rift of Kilauea near Pauahi crater, shallow.
94. June 11, 08 : 33, slight, felt generally from Hilo to Volcano district. East rift of Kilauea 6 miles west of Pahoa, about 7 miles deep.
95. June 11, 19 : 23, tremor (very feeble, Mauna Loa).
96. June 12, 12 : 12, tremor (very feeble, Mauna Loa).
97. June 14, 11 : 12, very feeble.
98. June 15, 13 : 19, very feeble. Probably beneath Kilauea Caldera.
99. June 17, 12 : 01, very feeble (slight, Mauna Loa). Nine miles west of Mokuaweoweo, about 16 miles deep.
100. June 19, 05 : 15, feeble.
101. June 22, 08 : 11, tremor (very feeble, Mauna Loa).
102. June 23, 01 : 14, very feeble.
103. June 27, 07 : 27, very feeble.
104. June 27, 11 : 49, tremor (very feeble, Mauna Loa).

VOLCANO NOTES AND NEWS

This new feature of the VOLCANO LETTER is intended to furnish the reader with notices of recent volcanic activity all over the world, notices of recent publications of special importance to the field of volcanology, and brief statements of what other workers in volcanology are doing. No attempt will be made to be exhaustive in the treatment of any of these. Available space necessitates brevity. Accounts of volcanic activity will be credited to the person submitting them, or to the source from which they are drawn. Persons everywhere are urged to send in brief accounts of volcanic activity or statements of research programs in which they, or fellow workers, are involved. Communications should be addressed to the Director, Hawaiian Volcano Observatory, Hawaii National Park P. O., Hawaii.

ERUPTION OF OSHIMA VOLCANO

Prof. Hisashi Kuno of Tokyo University writes that the Oshima volcano became active on July 16, 1950. Oshima occupies an island of the Idzu group, about 60 miles south of Tokyo. The volcano had been dormant since 1940. The 1950 activity built a new cinder cone on the rim of the old crater of Mihara-yama, a large cone in the caldera of Oshima volcano. The new cinder cone reached a height of 100 meters above its base. Lava issued from the base of the new cone and filled the bottom of the old Mihara crater. On September 13, several tongues of lava overflowed the rim of Mihara crater and reached the floor of the caldera. The temperature of the lava was 1200°C. in a lava fountain, 1090° at the origin of one of the flows which spilled out of the crater, and about 900° at a point where the flow had nearly ceased moving. The viscosity of the lava was 3×10^5 c.g.s. at a point where the temperature was about 1000°. The eruption ended abruptly on September 23. The erupted lava is augite-hypersthene basalt, closely similar to that of the 1778 eruption.

The total amount of erupted material, including cinder, was estimated by S. Marauchi [*Natural Science and Museum* 17 (4): 19. 1950] as 48,000,000 tons.

ERUPTION OF SANTIAGO VOLCANO

Santiago volcano, in southwest Nicaragua, resumed solfataric activity early in 1946, after 19 years of dormancy. The fumes, containing sulfur dioxide and sulfuric acid, have been causing great damage to near-by coffee plantations. An investigation of the activity and of the accompanying crop damage was made in April, 1951, by Ray E. Wilcox of the U. S. Geological Survey. Plans are going forward in cooperation with the U. S. Department of Agriculture for alleviation of injury to the coffee plantations by the volcanic fumes.

PERSONNEL CHANGES AT HAWAIIAN VOLCANO OBSERVATORY

Ruy H. Finch, Director of the Hawaiian Volcano Observatory since 1940, retired late in February and was succeeded by Gordon A. Macdonald. Mr. Finch first came to the Observatory in 1919, at a time when it was operated by the United States Weather Bureau. From 1919 to 1926, he served as assistant to Dr. T. A. Jaggar. When the Observatory was taken over by the Geological Survey in 1924, Finch transferred to the Survey. He was temporarily in charge of the Observatory, during the absence of Dr. Jaggar, throughout most of the great steam explosions of Kilauea volcano in 1924. We owe the excellent record of that eruption largely to his personal observations and to his organization of volunteer observers to keep a 24-hour watch on the volcano. In 1926, the Survey sent Finch to establish the volcano observatory at Mount Lassen, in northern California. From 1926 to 1935, he operated the Lassen Observatory and studied other volcanoes in the Cascade Range. In 1931 and 1932, he was the leader of expeditions to study Akutan and Shishaldin volcanoes in the Aleutian Islands. Finch left the Lassen Observatory in 1935, when it was taken over by the National Park Service, and became an apple grower near Watsonville, California. In 1940, Dr. Jaggar retired as Director of the Hawaiian Volcano Observatory, and Ruy Finch was recalled as his successor. Through the war years, the work of the Observatory was greatly curtailed by reductions in staff and other restrictions. In spite of these and other difficulties, Finch managed to keep the operations going on a basis sufficient to insure the all-important continuity of records. His prediction of the 1942 eruption of Mauna Loa was an outstanding success.

Ruy Finch's retirement culminates a lifetime of service and important contributions to the science of volcanology. Following his retirement, Finch returned with his family to Watsonville, where he is again an orchardist. His long experience and intimate knowledge of Hawaiian volcanoes, as well as his pleasant personality and keen wit, will be greatly missed by the Observatory staff. Even in retirement, Ruy's great interest in volcanoes is certain to continue, and we have every reason to expect further contributions by him to the science of volcanology.

Early in May the staff of the Hawaiian Volcano Observatory was augmented by the appointment of Dr. C. K. Wentworth as full-time geologist. From 1935 until his retirement in early May, 1951, Wentworth served as geologist for the Honolulu Board of Water Supply. Since 1949, he has held a part-time appointment at the Volcano Observatory. During the next few months his principal scientific activity is expected to lie in the Observatory's geomagnetic program, in field studies of volcanic features, and in instrumentation.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director

Chester K. Wentworth, Geologist

John C. Forbes, Laboratory Mechanic

LaVieve G. Forbes, Secretary, part-time

University of Hawaii:

T. A. Jaggar, Geophysicist

Seismograph Station Operators:
Hilo Station:

Brother B. T. Pleimann, St. Joseph's School

Kealakekua Station:

Howard M. Tatsuno, Konawaena School

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

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

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

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

THE VOLCANO LETTER

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PUBLISHED BY THE UNIVERSITY OF HAWAII

THE KONA EARTHQUAKE OF AUGUST 21, 1951

By GORDON A. MACDONALD and CHESTER K. WENTWORTH

INTRODUCTION

The earthquake which shook the island of Hawaii early on August 21 probably was the strongest since 1868, when a series of violent earthquakes did great damage in Kau. A special study of the quake has been made by the staff of the Hawaiian Volcano Observatory, and a detailed report will be published elsewhere. Lack of space limits us to a summary here.

A great many persons have aided us in the investigation. It is impossible to mention individually all who have given us information. Special mention should be made of Howard M. Tatsuno and Sister Mary Thecla, seismograph operators at Kealakekua and Hilo, respectively; Miss Nancy R. Wallace, Mrs. Alfred E. Hansen, and Allan P. Johnston, who reported on many of the aftershocks; Homer A. Hayes, who furnished information on damage and on other subjects; Mark Sutherland, John Iwane, and Masuoka Nagai, who supplied information on damage, especially to tanks; Commander C. A. George and Roland White, of the U. S. Coast and Geodetic Survey, who supplied copies of the seismograms of the major quake at Barbers' Point, Oahu, and of the tide gauge records from Honolulu and Hilo harbors. Dr. T. A. Jaggar has read and approved the manuscript. To these and all other persons who aided the investigation, we extend our sincere thanks.

NARRATIVE

At 57 minutes past midnight on August 21, residents of the island of Hawaii were awakened by a violent earthquake. The violence was greatest in central Kona, from Kealakekua to Hookena (Fig. 1). In the vicinity of Napoopoo the initial movement appears to have been largely up and down, with some swaying in an east–west direction, changing as the quake continued to what appeared to observers to be a somewhat circular motion. Noise was intense as doors and windows rattled, dishes and furniture crashed to the floor, water tanks collapsed, and rocks rolled from banks and stone walls. Landslides rushed down the famous burial cliff, Pali

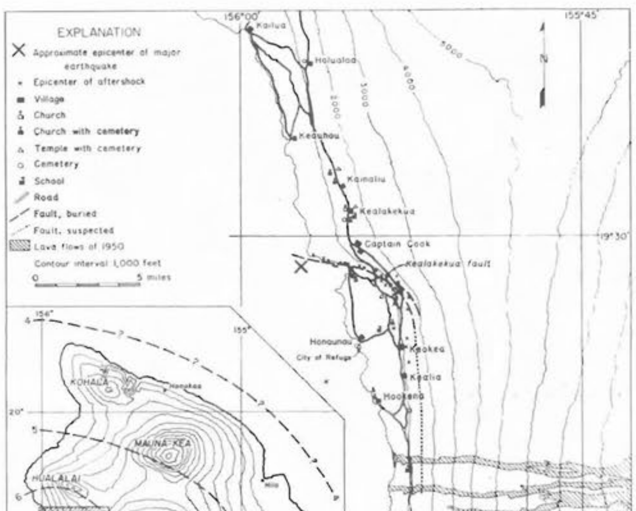

FIGURE 1. Map of the central Kona district showing the location of places mentioned in the text, the approximate locations of the epicenters of the major earthquake of August 21, 1951, and the aftershocks for which reasonably good locations were obtained. The inset map of the island of Hawaii shows the location of the area (shaded) covered by the other map and the approximate position of the isoseismal lines for the major earthquake.

Kapu o Keoua, at Kealakekua Bay. Within moments several houses, churches, and a school building were destroyed or badly damaged, many other houses slightly damaged, about 200 water tanks destroyed or damaged, many miles of stone wall thrown down, roads partly blocked by rock slides, road pavements and shoulders badly cracked, headstones in cemeteries shifted or overturned, and telephone and electric power lines broken. Fortunately, only two small fires broke out, and only two persons received minor injuries.

The ocean was observed withdrawing from shore at Napoopoo, and most of the inhabitants of the village were quickly evacuated to higher ground in fear of a large tsunami, or "tidal wave." A small tsunami actually did occur, but it was too small to do any damage. At Napoopoo the water surface fell about 4 feet, then rose again about 2 feet above its normal level. At Milolii the water level dropped about 3 feet, then rose 3 or 4 feet above its normal position, floating a canoe off the beach. The tide gauges at Honolulu and Hilo showed a distinct disturbance of the water in the harbors.

The earthquake was felt fairly strongly by persons on the most distant parts of the island of Hawaii and weakly by many persons on the island of Maui, and even in Honolulu, more than 180 miles from its origin. Damage extended for more than 50 miles along the highway, from Holualoa to Honuapo (Fig. 1). It was greatest in the 12-mile interval from Kealakekua to Hookena; but as far away as Naalehu, 37 miles from the epicenter of the earthquake, dishes, groceries, and bottles were thrown from shelves, stone walls collapsed, and some damage was done to structures. At Kilauea Caldera, 45 miles from the epicenter, a few objects were overturned, pavement was cracked, and numerous landslides were started on the walls of Halemaumau crater and the main caldera.

The intensity of the earthquake on the modified Mercalli scale of 1931, based on damage and other effects of the quake, was about 7 in the area near the epicenter, decreasing to 4 at the most distant parts of the island, and 2 at Honolulu. The approximate distribution of the intensity is shown by the isoseismal lines on the insert in Figure 1.

DAMAGE BY THE EARTHQUAKE

Many buildings in the Kona area were in some degree damaged by the earthquake. Most structural damage was minor, however. Some houses shifted as much as 3 or 4 inches on their foundations, and many were so twisted that it was difficult or impossible to open or close doors and windows. In nearly all houses dishes and other objects were thrown to the floor, and in stores from Holualoa to Pahala canned goods and bottles were thrown from shelves.

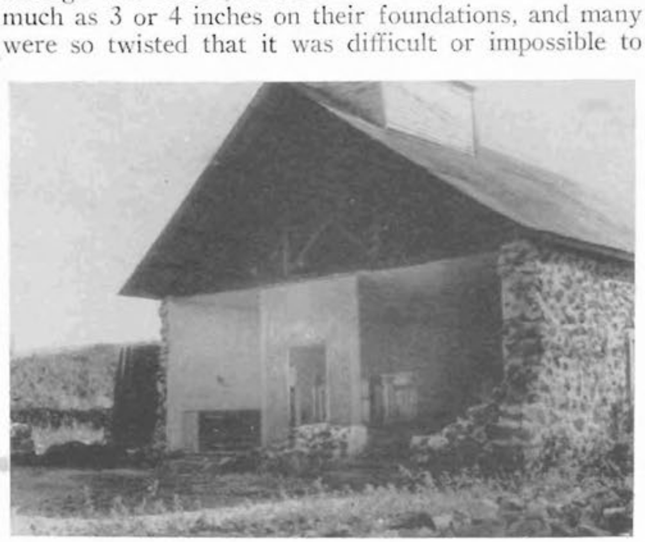

FIGURE 2. Church at Hookena Beach, the front (western) wall destroyed by the earthquake of August 21, 1951. The walls are of lava rock and coral-lime mortar. The debris of the fallen wall has been cleared away.

FIGURE 3. Honaunau School. Note the badly deformed window casings, resulting from the earthquake. In the foreground are the fragments of a large water tank.

As a class, masonry structures suffered the most damage. At Hookena the western wall of the Mission church, constructed of stone and coral-lime mortar, was thrown to the ground (Fig. 2). The upper parts of both the eastern and western walls of the Catholic church, half a mile north of Hookena, were thrown down. These walls, however, were very weakly constructed. The walls of St. Paul's Church, near Kainaliu, were badly cracked, and there was minor cracking of the lintels and interior plaster of Kahikolu Church at Napoopoo. The tower of Central Kona Church at Kealakekua separated slightly from the main building, and its plaster was cracked.

Only a few frame structures were badly damaged. At Hookena the underpinning of two old houses gave way and the houses dropped to the ground. Near Kealia two other houses were similarly damaged. At Kaimalino, 0.8 mile south of Kealia, a shop building slumped downslope when high posts supporting it at the back gave way. A service station at Keokea was damaged in the same manner. All these instances of damage to frame buildings can be traced to the failure of underpinning which was unsound because of age, poor material, or inadequate bracing. The most striking example of all was the Honaunau School, where failure of the underpinning allowed the building to collapse partly and slump to the ground, deforming it so badly that it is considered a total loss (Fig. 3). The failure there appears to have resulted from very inadequate bracing in an east–west direction, approximately parallel to the direction of sway during the earthquake.

As in big earthquakes elsewhere, a large proportion of the damage to buildings resulted from inferior or inappropriate materials, or poor construction. Unreinforced stone or brick masonry structures are especially subject to damage by strong earthquakes, though even in them the use of good mortar and adequate bracing of the structure greatly reduces the risk of damage. In frame structures footings should be firm, materials

FIGURE 4. Stone wall partly destroyed at the City of Refuge, Honaunau. The wall is approximately 10 feet high. The damaged portion is part of that rebuilt in recent years.

sound, and cross bracing, particularly of the underpinning, should be adequate in all directions. The best insurance against earthquake damage is good construction.

The most serious damage was that to water tanks. Kona's water supply comes from rain caught on roofs and stored in tub-type wooden tanks. Of a total of more than 1,000 such tanks in the heavily shaken area, about 200 were destroyed or badly damaged. The loss of water supply seriously endangered the health and comfort of the community. Tank damage extended from Keauhou to Milolii, but was most severe from Captain Cook to Hookena. Tanks showed all degrees of failure, from the development of slight leaks to complete collapse (Fig. 3).

A more detailed report on the damage to tanks will appear in the next Volcano Letter. In summary, it may be said here that the commonest features contributing to tank failure appear to have been poor footings and inadequate cross bracing of the underpinning.

Loose stone walls were greatly damaged by the earthquake. Although the principal damage occurred in the area from Keauhou to 3 miles south of Hookena, isolated instances of wall damage were observed all the way from Naalehu to Honokahau, 5 miles north of Holualoa. It is estimated that a total of many miles of wall will have to be rebuilt.

As with other types of structures, well-built walls proved surprisingly resistant to earthquake. In the construction of many of the older walls, occasional slabs of rock were laid largely or entirely through the wall, to help bind the wall together. These walls showed much less damage than those in which the loose rocks were stacked up with few or no binding slabs. It is interesting to note that the remaining portions of the well-built ancient walls of the City of Refuge, at Honaunau, were undamaged, whereas the recently reconstructed portions of the walls partly collapsed (Fig. 4).

Damage in cemeteries included the shifting, rotation, or overturning of headstones (Fig. 5) and the breaking of some grave caps. In cemeteries from Kealakekua to Honaunau most of the overturned headstones fell westward, though in a few cemeteries nearly as many fell eastward. This resulted partly from lesser stability of the stones in that direction because of the north–south orientation of the longer dimension of their bases and the general westward slope of the terrain, and partly from the east–west direction of shaking.

Damage to roads included cracking of pavement, cracking and slumping of shoulders, and caving of road banks, partly obstructing the roads. Cracking and slumping of the pavement and shoulders took place only on fills (Fig. 6). Some settling and cracking of the pavement appears to have been caused merely by compaction of the underlying fill during the jostling by the earthquake. At other places fills across small gullies were unstable because the batter (departure from vertical) of the edges of the fill were too steep, causing the downslope face of the fill to cave away. At many places the western shoulder moved slightly seaward, away from the pavement, producing cracks along the edge of the pavement or a few inches beyond the edge of the pavement and parallel to it.

A few bank cavings and pavement cracks were found as far away as Kilauea Caldera, 45 miles from the epicenter. However, most road damage is concentrated in the area near the epicenter. The distribution of damage caused by caving of banks, cracking of pavement, and collapse of stone walls along the main highway is shown graphically in Figure 7.

INSTRUMENTAL DATA

The time of occurrence of the earthquake is given by the U. S. Coast and Geodetic Survey's notice of Preliminary Determination of Epicenter at 00:56:57 H.S.T. The preliminary waves started recording on the Bosch-Omori seismograph in the Whitney Laboratory at the northeast rim of Kilauea Caldera at 00:57:09.5. The duration of the preliminary waves at the Whitney Laboratory was 9.5 seconds, corresponding with a distance of origin of approximately 47 miles. The Bosch-Omori seismograph was dismantled shortly after the arrival of the secondary waves. All other seismographs on the island of Hawaii were dismantled by the preliminary waves.

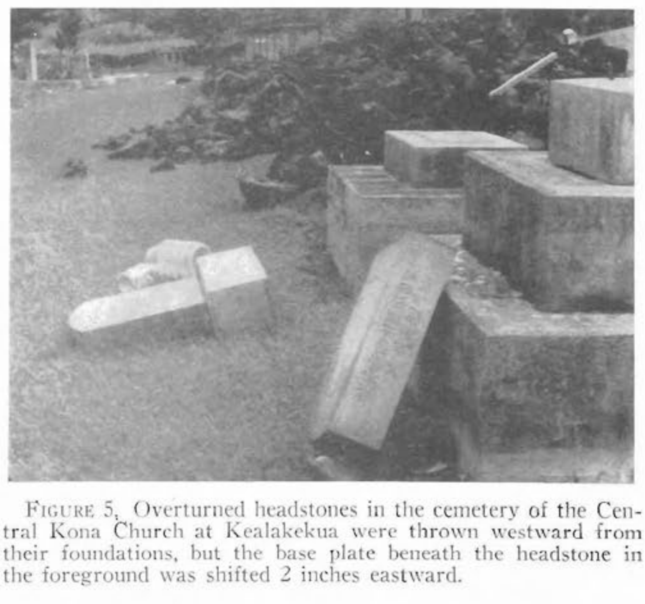

FIGURE 5. Overturned headstones in the cemetery of the Central Kona Church at Kealakekua were thrown westward from their foundations, but the base plate beneath the headstone in the foreground was shifted 2 inches eastward.

The direction of the first movement of the ground at Kilauea Caldera was east–southeast and up, that at the Mauna Loa and Kona stations was east–northeast. At the Kona station the suspensions of the east–west component of the seismograph were broken, and the weight dropped on the floor 2 feet west of the pier. Thus the only usable instrumental data we have on the location of the origin of the earthquake are a distance of approximately 47 miles from the Whitney Laboratory, and rough bearings of west–northwest from Kilauea Caldera and west–southwest from the Mauna Loa and Kona stations. These, together with the distribution of damage, are sufficient to demonstrate that the origin lay offshore west of the general Napoopoo–Honaunau area.

AFTERSHOCKS

The major earthquake was followed by a very large number of aftershocks, ranging in size from tiny tremors barely detectable by the seismographs to strong, generally felt earthquakes of an intensity as great as 4 near their epicenters. Mrs. H. Masuhara, at Keei, counted 109 felt earthquakes between 00:57 and 09:00 o'clock on August 21. The repair of damages to the Kona seismograph was not completed until 15:15 o'clock on August 23, so the total number of aftershocks during the first 2 days is not known. During the first 24 hours after it was restored to operation the Kona seismograph recorded 90 earthquakes. By midnight on August 31 it had recorded 494 quakes and by September 30 nearly a thousand. Most of the larger of these aftershocks produced good records at four or more of the five seismograph stations and could be located with fair certainty. Epicenters of 36 of these aftershocks are shown in Figure 1.

ORIGIN OF THE EARTHQUAKE

The northeastern edge of Kealakekua Bay is a scarp formed by a fault along which the lower slope of Mauna Loa has been moving downward in relation to the rest

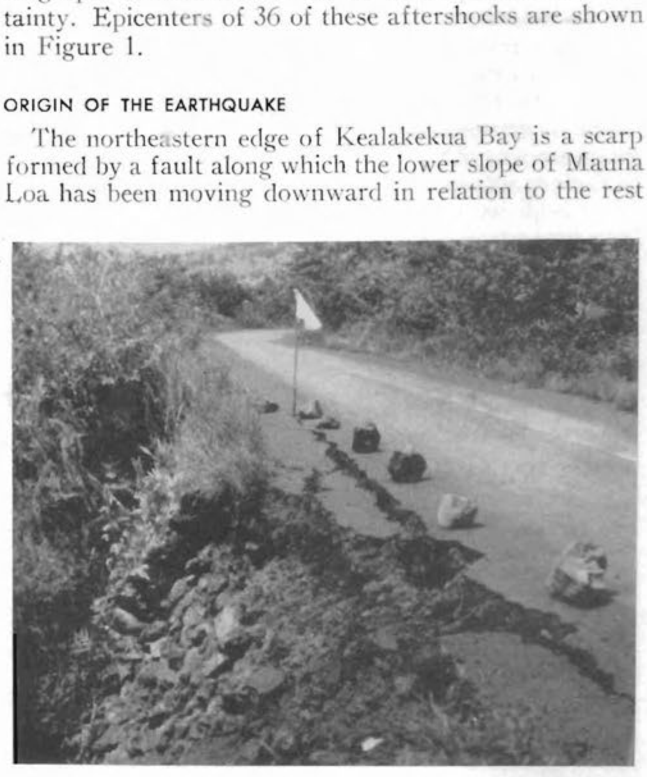

FIGURE 6. Cracking of pavement and slumping of fill at the western edge of the highway near Hookena.

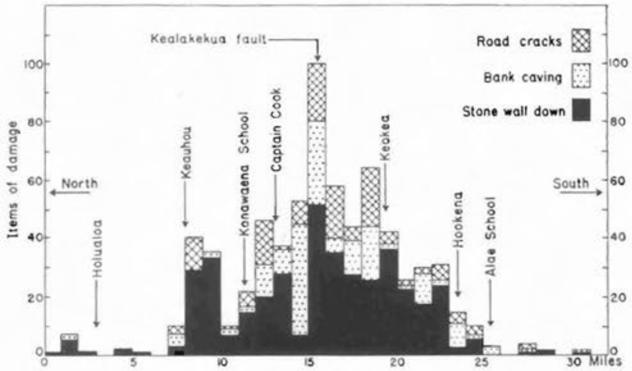

FIGURE 7. Diagram showing the frequency distribution of three of the principal types of earthquake damage along the main highway. The arrows indicate the position on the highway of villages and other features. Note the centering of damage close to Kealakekua Fault.

of the mountain. This fault has been named the Kealakekua Fault.* The total displacement on the Kealakekua Fault is not known, but it is at least 500 feet. Most of the fault scarp has been mantled with later lava flows from Mauna Loa. West–northwestward the fault disappears under the ocean (Fig. 1). Southeastward the scarp runs inland and bends southward. Beyond upper Keei the fault scarp loses its definite identity, but for several miles farther south the abnormally steep western slope of Mauna Loa is suspected, at least in part, to be a reflection of this fault scarp, deeply buried.

Most of the epicenters of the located aftershocks (Fig. 1) lie close to the known portion of the Kealakekua Fault. A few lie close to the suspected southward continuation of the fault. In view of the origin of the great majority of the aftershocks on the Kealakekua Fault, it is highly probable that the major earthquake also was caused by movement on this fault. This is confirmed by the distribution of damage caused by the earthquake. In Figure 6 the peak of the bell-shaped distribution curve corresponds closely with the location of the Kealakekua Fault. Taking into consideration the distance of origin of the earthquake from Kilauea Caldera, the probable epicenter has been placed approximately 3 miles west–northwest of Napoopoo, at north latitude 19° 29′, west longitude 155° 58′. This location is also consistent with the prevalent directions of overturning and rotation of headstones in cemeteries.

In a sense, of course, all earthquakes originating on the island of Hawaii are volcanic. The movements on the Kealakekua Fault which gave rise to the earthquakes of August and September may be related in some way to either an increase of pressure under Mauna Loa and resulting rise of the central part of the volcano, or a readjustment resulting from the great outpouring of lava in June, 1950. Any such relationship is, however, purely conjectural. There is as yet no direct evidence that the earthquakes were related to any specific eruptive episode, past or future.

* STEARNS, HAROLD T., and GORDON A. MACDONALD. GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF HAWAII. Terr. of Hawaii, Dept. of Public Lands, Div. of Hydrog., Bul. 9: 37. 1946.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY–SEPTEMBER, 1951

VOLCANOLOGY

July

Seismically, Hawaiian volcanoes were quiet during the month of July. Only 29 earthquakes were recorded on the Volcano Observatory's seismographs. One of these, a tremor recorded at 11:28 A.M. on July 28 on the seismograph operated by Howard Tatsuno at Konawaena School, was not recorded at any other station. Seventeen earthquakes were recorded at the Whitney Laboratory beneath the Volcano House, and 15 at the Mauna Loa station. A feeble earthquake at 4:07 A.M. on July 1 originated on the southwest rift of Mauna Loa beneath a point near Sulphur Cone. Another at 11:20 P.M. on July 5 originated beneath Kilauea Caldera probably within 3 miles of the surface.

Northward tilting of the ground surface at the northeastern edge of Kilauea Caldera continued throughout the month and amounted to nearly 4 seconds of arc. This rate of tilting is more than twice the average for this season of the year and indicates a continued distinct increase of volcanic pressure beneath Kilauea. Tilting in an east–west direction has shown minor oscillation during the month but no appreciable net change.

Most of the cracks on the floor of Kilauea Caldera opened or closed very little during July. However, the crack which crosses the observation area at the southeast rim of Halemaumau crater opened another 3 millimeters, making a total opening of 46.5 millimeters, or nearly 2 inches, during the past year.

On July 25 small amounts of sulphurous fume were issuing at the 1940 cinder cone in Mokuaweoweo, and a little steam was issuing near the north edge of the 1940 cone and at places on and near the 1949 cone.

August

The outstanding event of the month was the big earthquake of August 21 in Kona. This earthquake and its aftershocks have been discussed on preceding pages. During the remainder of August 21, following the major earthquake at 00:57 A.M., the seismographs at the Volcano Observatory recorded 135 earthquakes. During the month a total of 264 earthquakes was recorded at Kilauea, and 268 at the Mauna Loa station. Of these, 235 occurred after the major earthquake of August 21. The Kona seismograph recorded 494 earthquakes between the time it was repaired and restored to service at 3:15 P.M. on August 23, and midnight on August 31.

The strongest of the earlier aftershocks took place at 1:29, 4:00, 8:03, 9:57, 10:12, 18:32, and 22:48 on August 21; at 6:38 and 17:15 on August 22; and at 16:08 on August 31. Many others were felt in central Kona.

At 17:48 on August 28 a small earthquake originated beneath the east slope of Mauna Loa near Mountain View, and at 18:04 on the same day a smaller one originated just east of Kilauea Caldera. Beginning at 6:02 on the morning of August 23 the seismograph at the Whitney Laboratory of Seismology recorded 21 minutes of continuous tremor, indicating subterranean movement of magma. However, there were no other indications of volcanic unrest during the month.

Northward and eastward tilting of the ground at the Whitney Laboratory were at a rate approximately normal for that season of the year.

On August 14, Chief Ranger E. K. Field and Ranger Elroy Bohlin, of Hawaii National Park, flew over Mokuaweoweo and reported the 1940 cinder cone to be fuming mildly.

September

Earthquake activity continued abundant during September. Most of the activity centered in the Kona area. The Kona seismograph recorded 471 earthquakes during the month, bringing the total number of earthquakes since the big quake early on August 21 to 965. Most of the Kona earthquakes were too small and shallow-seated to be recorded on the seismographs at Kilauea Caldera, 42 miles away. During September the seismograph at the Whitney Laboratory recorded 110 earthquakes, and the Mauna Loa seismograph recorded 106.

Most of the Kona earthquakes originated along the fault which runs out to sea at Napoopoo, forming the great cliff at the north side of Kealakekua Bay. Several earthquakes originated beneath points along the southwest rift zone of Mauna Loa, between 9,000 feet altitude and the summit. A few had their origins beneath the crater and rift zones of Kilauea, and a small shake felt in Hilo at 11:48 P.M. on September 24 had its focus on the northeast rift of Mauna Loa. From September 23 to 26 several earthquakes originated beneath Hualalai volcano. One of these, at 7:01 P.M. September 23, was strong enough to dismantle the Kona seismograph. On September 16, about 20 earthquakes originated along the Kaoiki fault, which forms the line of cliffs northwest of the highway between Bird Park and Pahala. The one at 1:43 A.M. was felt strongly at Kapapala and less strongly at Naalehu and Pahala. Rocks were shaken down from road cuts on the Mauna Loa truck trail. Rock slides were started in Halemaumau and continued at intervals for several days.

The north end of the crack across the observation platform at the southeast rim of Halemaumau opened a quarter inch during the month. Other cracks on the floor of Kilauea Caldera showed little change in width.

Northeastward tilting continued throughout the month at the Whitney Laboratory. The direction and rate of tilting were normal for that season of the year.

The temperature of the steam at the well at Sulphur Bank, near the Volcano House, remained at 205° F. from July 2 until September 30. On September 9, temperature measurements were made on the Ohia Lodge (1950) lava flow in south Kona, near the highway. Temperatures of hot cracks, from 12 to 18 inches below the surface, ranged from 120° C. to about 400° C.

SEISMOLOGY

Earthquake Data, July–September, 1951

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

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
July 1	0	1	1	0	0	0	1.5	0
8	2	0	0	0	0	0	0.5	0
15	9	2	0	0	0	0	3.25	0
22	2	0	0	0	0	0	0.5	0
29	3	2	0	0	0	0	1.75	0
Aug. 5	4	1	1	0	0	0	1.5	0
12	2	0	0	0	0	0	0.5	0
19	128	54	10	7	3	7	120.0	0
26	31	20	1	0	0	0	18.75	1
Sept. 2	12	9	0	0	0	0	7.5	0
9	10	9	1	0	1	0	11.0	0
16	24	17	0	0	0	1	18.5	0
23	8	7	0	1	0	0	7.5	1
30	18	7	1	0	0	0	9.0	0

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

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning	Whitney Vault (Northeast rim)		Uwekahuna Vault (West rim)	
	Amount	Direction	Amount	Direction
July 1	0.7″	N 9° W	0.2″	N 45° E
8	0.8″	N 16° E	1.1″	S 9° E
15	2.2″	N 6° E	3.9″	S
22	1.1″	N 26° W	2.7″	N 24° E
29	0.8″	N 18° E	1.9″	S 45° E
August 5	0.6″	N 36° E	4.2″	N 32° W
12	0.9″	N 67° E	2.4″	S 4° W
19	1.3″	N 26° W	5.0″	S 9° W
26	0.9″	N 40° E	1.8″	S 5° W
September 2	0.3″	N 27° E	2.6″	N 7° E
9	0.3″	S 34° E	0.8″	S 68° W
16	0.6″	N 67° E	5.0″	S
23	1.7″	N 10° E	2.3″	S 16° W
30	0.7″	N 10° E	2.0″	S 20° E

The data for the following local disturbances were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The arrival times are given to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich 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 at the northeast rim of Kilauea Caldera. 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.

105. July 1, 04:07, very feeble. Southwest rift of Mauna Loa near Sulphur Cone.
106. July 5, 23:20, feeble. Beneath Kilauea Caldera, shallow.
107. July 17, 09:52, very feeble.
108. July 19, 19:12, very feeble.
109. Aug. 2, 19:24, very feeble.
110. Aug. 3, 01:40, very feeble.
111. Aug. 6, 23:07, very feeble.
112. Aug. 10, 04:31, feeble. East rift of Kilauea near Napau Crater.
113. Aug. 21, 00:57, strong, intensity 7, much damage in Kona. About 3 miles west-northwest of Napoopoo, probably on Kealakekua Fault.
114. Aug. 21, 01:29, strong. Felt strongly in Kona. Origin near No. 113.
115-135. Aug. 21, very feeble and feeble earthquakes, with origin in Kona.
136. Aug. 21, 03:50, slight. Kona. Felt from Kona to Volcano district.
137. Aug. 21, 04:00, moderate. Kona. Felt from Kona to Volcano district.
138-148. Aug. 21, feeble and very feeble earthquakes, with origin in Kona.
149. Aug. 21, 06:03, slight. Kona.
150-154. Aug. 21, very feeble. Kona.
155. Aug. 21, 08:03, moderate. Kona.
156-161. Aug. 21, feeble and very feeble. Kona.
162. Aug. 21, 09:38, slight. Kona.
163. Aug. 21, 09:57, strong. Felt from Kona to Volcano district. Kona.
164. Aug. 21, 10:12, strong. Kona.
165-167. Aug. 21, very feeble.
168. Aug. 21, 18:32, strong. Kona.
169. Aug. 21, 21:07, very feeble. Kona.
170. Aug. 21, 22:48, strong. Kona. Felt from Kona to the Volcano district.
171. Aug. 22, 02:14, slight. Kona.
172-174. Aug. 22, feeble and very feeble. Kona.
175. Aug. 22, 06:38, moderate. Kona. Felt from Kona to Kapapala.
176-180. Aug. 22, feeble and very feeble. Kona.
181. Aug. 22, 16:04, slight. Kona.
182. Aug. 22, 16:38, very feeble. Kona.
183. Aug. 22, 17:15, strong. Kona. Felt from Kona to Volcano district.
184. Aug. 22, 17:28, slight. Kona. Felt as far as Naalehu.
185-187. Aug. 22, feeble and very feeble. Kona.
188-190. Aug. 23, feeble and very feeble. Kona.
191. Aug. 24, 00:25, very feeble. Kona, Kealakekua Fault.
192. Aug. 24, 23:59, very feeble. Kona.
193. Aug. 25, 10:22, feeble. Kilauea.
194. Aug. 25, 11:14, very feeble (Kona feeble). Kealakekua Fault.
195. Aug. 26, 03:29, very feeble. Kealakekua Fault.
196. Aug. 26, 08:04, very feeble. Kona, Kaholo Pali.
197. Aug. 26, 08:11, very feeble (Kona slight). Kealakekua Fault.
198. Aug. 26, 19:40, very feeble. Kona, 2.3 miles S 75° E of Napoopoo.
199. Aug. 27, 04:31, very feeble (Kona feeble). Kealakekua Fault.
200. Aug. 27, 16:01, very feeble. Kealakekua Fault.
201. Aug. 27, 21:58, very feeble (Kona slight). Near Keokea.
202. Aug. 28, 11:44, very feeble. Kealakekua Fault.
203. Aug. 28, 14:24, very feeble. Kealakekua Fault.
204. Aug. 28, 17:48, feeble. About 3 miles east-southeast of Mountain View. Felt in Mountain View and Volcano district.
205. Aug. 28, 18:04, very feeble. Southwest rift of Kilauea near Kilauea Iki.
206. Aug. 28, 20:28, very feeble (Kona feeble). Kealakekua Fault.
207. Aug. 29, 06:02, very feeble (Kona feeble). Kealakekua Fault.
208. Aug. 29, 19:43, very feeble (Kona slight). Kona.
209. Aug. 29, 21:25, very feeble (Kona feeble). Kealakekua Fault. Felt in Kona.
210. Aug. 30, 07:23, very feeble (Kona moderate). Kealakekua Fault. Felt strongly in Kona.
211. Aug. 30, 14:23, very feeble. Kona.
212. Aug. 31, 16:08, very feeble (Kona strong, intensity 5). Kealakekua Fault. Felt strongly in Kona.
213. Aug. 31, 18:51, very feeble (Kona feeble). Kona, about 3.5 miles west of Hookena.
214. Sept. 1, 12:29, feeble (Kona slight). Kealakekua Fault.
215. Sept. 1, 23:21, very feeble (Kona feeble). About 0.8 mile north of Kealia.
216. Sept. 2, 18:35, very feeble (Kona feeble).
217. Sept. 3, 00:37, very feeble. Kona.
218. Sept. 4, 00:48, very feeble. Kona.
219. Sept. 4, 05:10, very feeble (Kona moderate).
220. Sept. 4, 14:13, very feeble (Kona strong, intensity 4). Felt strongly in Kona.
221. Sept. 4, 16:16, very feeble. Kilauea Caldera.
222. Sept. 4, 22:28, very feeble (Kona strong, intensity 3). Felt as far as Naalehu.
223. Sept. 6, 01:29, very feeble (Kona slight).
224. Sept. 8, 14:50, very feeble. Kilauea Caldera.
225. Sept. 8, 23:27, tremor (Kona feeble).
226. Sept. 9, 13:58, tremor (Kona moderate).
227. Sept. 10, 01:50, very feeble. Kilauea.
228. Sept. 10, 12:55, very feeble. Kona.
229. Sept. 11, 00:26, feeble. East rift of Kilauea near Puu Huluhulu.
230. Sept. 11, 12:44, very feeble. Kona.
231. Sept. 12, 01:12, very feeble (Kona slight).
232. Sept. 12, 01:27, very feeble (Kona feeble). Felt at Naalehu.
233. Sept. 12, 03:26, moderate. Southwest rift of Kilauea near Pit Craters.
234. Sept. 12, 18:55, very feeble. Kona.
235. Sept. 12, 18:56, very feeble.
236. Sept. 14, 16:49, very feeble.
237. Sept. 15, 16:45, tremor (Kona, very feeble).
238. Sept. 15, 21:33, very feeble. Southwest rift of Mauna Loa near 9,000 feet altitude.
239. Sept. 15, 23:48, very feeble. Felt at Kapapala.
240. Sept. 16, 01:43, strong, intensity 5. Kaoiki fault about 3 miles northeast of Kapapala. Felt from Kona to Hilo.
241-250. Sept. 16, very feeble. Kaoiki fault.
251. Sept. 16, 21:50, tremor (Kona feeble). Kona.
252. Sept. 16, 23:19, very feeble.
253. Sept. 17, 10:17, very feeble (Kona moderate). West slope of Mauna Loa near summit.
254. Sept. 17, 15:19, tremor (Mauna Loa very feeble).
255. Sept. 17, 18:17, very feeble (Kona feeble). Southwest rift of Mauna Loa near 11,000 feet altitude.
256. Sept. 18, 08:47, very feeble.
257. Sept. 19, 19:15, very feeble (Kona slight).
258. Sept. 20, 00:11, tremor (Mauna Loa very feeble).
259. Sept. 20, 00:25, tremor (Kona slight).
260. Sept. 20, 00:42, very feeble (Kona slight).
261. Sept. 20, 03:21, tremor (Kona very feeble).
262. Sept. 21, 07:46, very feeble.
263. Sept. 21, 12:30, tremor (Kona feeble).
264. Sept. 23, 19:01, very feeble (Kona strong). Felt strongly in Kona.
265. Sept. 24, 03:01, very feeble. Kaoiki fault 2 miles northeast of Ainapo.
266. Sept. 24, 03:13, very feeble (Kona slight). Near summit of Hualalai. Felt in Kona.
267. Sept. 24, 03:30, tremor (Kona feeble).
268. Sept. 24, 23:47, very feeble. East rift of Kilauea 10 miles east of Kapoho (?). Felt in Hilo.
269. Sept. 25, 00:56, very feeble (Kona feeble). Northwest rift of Hualalai near 5,000 feet altitude. Felt in north Kona.
270. Sept. 25, 01:23, slight (Kona moderate). Near No. 269. Generally felt in Kona.

271. Sept. 26, 20 : 20, very feeble (Kona slight). South slope of Hualalai about 4 miles southeast of Holualoa. Felt in Kona.
272. Sept. 26, 23 : 21, very feeble.
273. Sept. 30, 06 : 21, very feeble. Kilauea.
274. Sept. 30, 11 : 17, very feeble. Kilauea.
275. Sept. 30, 16 : 06, very feeble. Kilauea.

TELESEISMS

Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. Time is Hawaiian Standard.

August 31, 23 : 16, slight. Easter Island region.
September 27, 09 : 40, moderate. Vancouver Island.

VOLCANO NOTES AND NEWS

Eruption of Oshima Volcano

The last issue of the Volcano Letter carried a brief account of the 1950 eruption of Oshima volcano, Japan. That eruption ended on September 23, 1950. A new eruption commenced early in 1951. The following notes on the new eruption were furnished by Dr. Hisashi Kuno, of Tokyo University, during a brief visit at the Hawaiian Volcano Observatory during his journey to Princeton University, where he will spend the next year in research on the pyroxene group of minerals.

The eruption started on February 4, 1951. Pyroclastic activity built a new cinder cone overlapping the northwest side of the 1950 cinder cone, on the rim of Mihara crater. On February 27 lava issued at the foot of the cone, filled the crater of Miharayama, and overflowed the rim. A fluid pahoehoe flow spread over the floor of the Oshima caldera. This flow continued for 2 or 3 days, then the outpouring of lava ceased, although weak Strombolian pyroclastic activity continued at the cone.

On March 10 another flow spread over the caldera floor, and barely passed the western margin of the caldera. At about this time the inhabitants of the village of Nomashi erected a wall 10 feet high across a low gap in the caldera wall in an attempt to prevent the lava from spilling out through this gap and pouring down onto the village. The lava level did not rise quite to the wall, so that the effectiveness of the wall was not tested.

On March 25 another small flow issued, pyroclastic activity continued at the cone until about June 30, but there were no more lava flows.

The old inner pit of the Mihara crater had been completely filled. Just before the end of the eruption, in June, collapse occurred at the site of the former inner pit, forming a new pit. On July 22 the volcano was quiet. The new inner pit was approximately 150 meters deep. The new cinder cone had been broken into two parts by subsidence, and the southern part had collapsed to form a small collapse crater.

Eruption in Tonga Islands

Captain R. J. Jensen, Pan American World Airways, reports observing volcanic activity on the island of Fonualei, in the Tonga group, on August 21. He writes, "The volcanic activity seemed to be located in the north-central portion of the island, with considerable smoke and a little flame. Large lava flows were evident, some of which were entering the sea. The smoke column rose to about 5,000 feet and was carried to the northwest by a southeasterly wind."

Eruption of Mt. Etna

A brief dispatch by Associated Press states that an eruption of Mt. Etna commenced on the night of September 28, 1951, at a vent about 9,300 feet above sea level. However, on September 29 the lava flow appeared to have halted. The last previous eruption of Etna was in November, 1950.

Eruption of Mt. Lamington

Reports on the catastrophic eruption of Mt. Lamington, in New Guinea, have thus far been vague and incomplete. The greatest amount of information on it yet seen by the writer is contained in an article in the June, 1951, number of *Walkabout* magazine by Dr. N. H. Fisher, chief geologist of the Australian Dominion Geological Survey and formerly in charge of the volcanological observatory at Rabaul. Accompanying the article is a series of photographs of Mt. Lamington and its vicinity, taken by the Royal Australian Air Force.

Mt. Lamington is situated near the northeast coast of Papua about N 75° E of Port Moresby. It is about 7 miles west of the west end of the Hydrographer's Range, which also is of volcanic origin. The volcanic chain extends on southeastward to Normanby and Ferguson islands. In 1943 and 1944 explosive eruptions occurred in the Goropu Mountains, 80 miles southeast of Mt. Lamington, but Lamington itself had not previously been active in historic time.

On January 21, 1951, the volcano burst into violent explosive activity. The writer has been informed that some earthquake activity preceded the outburst. Editorial comment accompanying the aerial photographs in *Walkabout* magazine states that 2,000 feet of the mountain disappeared during the eruption. It is estimated that about 4,000 persons lost their lives. Dr. Fisher briefly characterizes the eruption as a classic example of the pelean type of eruption, accompanied by glowing clouds, and he remarks on the similarity of events to those at Mount Pelée in 1902. Photographs show devastation of the type typical of glowing clouds, with trees laid over in subparallel alignment by the blasts and large areas covered with ash. An excellent photograph by G. A. Taylor on the cover of the magazine shows the fuming crater of Mt. Lamington and the dome which apparently rose in it during the eruption. Mr. Taylor, the resident volcanologist, is keeping a continuous photographic and seismic record of the eruption.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In cooperation with the UNIVERSITY OF HAWAII

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

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

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

THE VOLCANO LETTER

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DESTRUCTION OF WATER TANKS DURING THE KONA EARTHQUAKE OF AUGUST 21, 1951

By CHESTER K. WENTWORTH

INTRODUCTION

The following report on damage to water tanks in Kona during the earthquake of August 21, 1951, is based partly on field examination of the results of the earthquake and partly on an analysis, submitted to the Hawaiian Volcano Observatory by tank owners and builders, of 90 completed questionnaires giving data on individual damaged tanks. It is expected that much additional data will be transmitted as repairs proceed. The writer wishes to thank all those who have aided the study by submitting their reports or contributing information on tank damage. Special mention should be made of John Iwane, Extension Service, University of Hawaii; Mark Sutherland, Principal of Konawaena School; George T. Imai, Hawaii Road Department; and M. Nagai, Captain Cook Coffee Company, each of whom furnished information on a large group of tanks. The present report is only a summary statement of the results of the study. A more detailed report is planned for presentation elsewhere. For an account of other damage during the earthquake, see Volcano Letter No. 513.

WATER TANKS IN KONA

No accurate count of water tanks in Kona is known. From the recorded population of North and South Kona, which approaches 10,000, and from the total dependence on tank storage, it is a fair assumption that the number of tanks may be nearly 2,000. Many dwellings have two or more tanks. In addition to these, tanks at schools and other such buildings and tanks supplying range cattle must total several hundred.

Reliance on roof catchment and water tanks for water supply in the Kona district has been general since the building of frame structures and the replacement of native Polynesian living patterns. The native economy was supplied by a few sources of brackish water along the coast at a very small per capita daily consumption, with general use of coconut juice for drinking and of rainfall when it came. The annual rainfall along the coast is about 25 to 30 inches, but, owing to the great height and mass of Mauna Loa, the dryness of the leeward (kona) slope is ameliorated by rains due to the daytime sea-to-land breeze, which produce an annual amount of around 100 inches in a narrow belt at the 3,000 foot contour. However, the porosity of the surface rocks and the seasonality of rains are such that there are no perennial streams which reach to low altitudes, and geologic studies have indicated that adequate ground-water bodies do not exist within depths accessible under present economic conditions.

Small tanks might suffice for the few dwellings in the high-rainfall belt, but in the chief populated areas family storage of 8,000 or 10,000 gallons is usual, and many dwellings have more. Use of various urban facilities plus requirements of home gardens and attendant processing, without reference to general agriculture or stock-raising, raises the per capita consumption to 50 or more gallons per day, or perhaps 8,000 gallons per month, for a family of five. Large tanks are required to support such usage over periods when rainfall can supply only part of the required amount. Occasional water shortage, starting with larger and less foresighted families, is an almost chronic state of affairs.

DAMAGE TO TANKS

From data not yet completely gathered, it appears that about 200 tanks were seriously damaged by the earthquake. Many of these were either demolished or so displaced and distorted that they cannot be restored to use. In many cases, failure of the bottom or development of large side leaks resulted in total loss of water. Unless prompt action has been taken to repair and refill these tanks, a large proportion of them will be lost through drying and further deterioration.

The principal direct cause of damage was failure of footings. It is quite evident that the footings, while adequate to support the direct static load, were in most cases not sufficiently fixed in position, nor were the columns of the understructure adequately tied to the footings. The usual footing block is likely to move during the rocking to which the whole frame is subjected during an earthquake, with progressive yielding and increase of movement to a point where the frame itself fails.

Next in importance as a cause of failure was yielding of the frame to diagonal deformation and shifting of the tank on its joists. The cylindrical, barrel-type tank depends on the tangential tension in the hoop rods both to hold the staves in watertight contact and to hold the periphery of the bottom planks tightly in the groove of the lower end of the staves. This mode of construction provides at best a very effective watertight container in continuous tension, supported directly on the joists under its floor planking. It does not provide, and would be seriously impaired by, bracing or local tying to the supports. Such a tank is best for static load; it would not be suitable for installation on a vehicle or on a ship.

MODE OF CONSTRUCTION AND PLACEMENT

The common household tank is erected with its upper edge just under the level of the eaves of the building whose roof provides the catchment. In a one-story house, the sink and wash-basin taps are often no more than 5 feet below this level, and the water of a tank more than 5 feet deep is only partly available for gravity flow to such fixtures and is not able to supply a shower bath on the same floor. Not uncommonly, small houses are built with an upper, main dwelling floor and a paved, open basement, in which laundry fixtures and a toilet or bathroom can receive water from the whole tank, even when, at some seasons, the water may be too low to supply the upstairs kitchen sink. Such hydraulic requirements necessitate placing the tank where its bottom is 6 or 8 feet and its top as much as 15 feet or more above ground.

This placement means that tanks carrying from 8 tons (2,000 gallons) to 20 tons (5,000 gallons), or even 50 tons (10,000 gallons), of water are often supported with their center of gravity 10 or 12 feet above the ground and on a base which may be little more than that dimension from side to side. A 2,000-gallon tank on six footings results in a load of about 2,700 pounds per footing; a 5,000-gallon tank on 12 footings imposes a load of about 3,300 pounds per footing. From data reported, it appears that many of the tanks of 10,000- to 25,000-gallon capacity have loads on individual footings of 4, 5, or even 6 tons! Such loads are several times that commonly carried by the columns under a small frame house, and the height of the tank is much greater in comparison to the breadth of the whole base. Tanks that are close enough to the ground to require no legs or columns may have no systematic arrangement of footings under the sills, and, in some instances, the bottom planks of the tank rest on joists (or beams) that in turn lie directly on the ground or on concrete or rock footings with no cross members parallel to the bottom planks. In such an arrangement, the bottom of the tank is in a precarious position if there is any differential movement of the footings and is ill-protected against even ordinary settling, much less a severe earthquake.

Most of the larger tanks, because of need to support the ends of the joists within the circle of the tank chimes, are supported on a sill or beam pattern that is six- or eight-sided, and the outer columns are six, eight, or more in number. These columns are usually braced from near the bottoms to the tops of adjacent columns and may or may not have bracing toward the center of the tank. Most commonly the bracing is spiked or bolted to either the outside or inside of the columns, resulting in an off-center effect which tends to develop a torque in the columns.

CAUSES OF DAMAGE

Of 90 tanks for which complete data have been received, 43 are reported demolished or totally destroyed. Of the others, a number of bottoms collapsed, other tanks developed general leakage which caused total loss of water, and many were sufficiently dislodged and deformed to necessitate complete and expensive rebuilding. In some instances, breaking of pipe fittings released all the water but could be repaired without great expense.

There is very little eye-witness account of the progressive destruction of individual tanks, but it is clear that the interrelated failure of bracing and footings was the chief cause of destruction. A few persons heard slopping of water in and from the tanks for an appreciable interval before final collapse. No marked correlation could be shown between age of the tank and damage, and only in a few instances was it clear that pre-existing impairment was responsible. So many nearly new tanks (all in good condition) were destroyed that it appears that the stresses developed by general shaking, with lateral components up to 0.2 or 0.3 of the value of gravity, could not be met by the existing bracing, and that, likewise, the footings became progressively displaced and hastened the destruction. Such stresses are comparable to tilting the tank and understructure to an angle of about 16 degrees and submitting them to repeated vertical loading and unloading. Under such conditions, it is not surprising that many of the structures failed.

The possibility of failure was further indicated by the general loads carried by the footings. In some small tanks the load per footing was as little as 1 ton, but the usual load, as in a 5,000-gallon tank on 9 footings, was 2 tons or more. In some of the larger tanks, as, for example, one at Honaunau School (Fig. 1), the load per footing was more than 12,000 pounds, or 6 tons. Lateral shaking of a mass imposing such heavy unit loads was too much for the bracing, and, after initial displacement of critical bracing or footings, the whole structure was quickly thrown down, and the tank was demolished.

RECOMMENDED CONSTRUCTION

As it is planned to present elsewhere a more detailed statement on damage to tanks and possible improvement in the design of tanks and foundation, only a few comments are included here. It is not likely that any feasible modes of construction will entirely eliminate damage from earthquakes which may occur in the Kona district. It is believed, however, that marked improvement is possible without an expenditure disproportionate to the value of the tank, if earthquake risk is kept in mind.

(1) Whenever possible, water-storage tanks should be based on the ground on a leveled, preferably concreted, surface. Founding wholly or partly on fill should

FIGURE 1. Wreckage of 23,500-gallon water tank at Honaunau School. The tank, approximately 20 years old, stood at the southwest corner of the main school building. The concrete footings seen in the background each bore a load of more than 6 tons. The tank appears to have collapsed because of failure of the supporting structure, probably due to inadequate bracing. Photo by G. A. Macdonald.

be avoided unless the entire filled area is enclosed in carefully designed, solid retaining walls and is prepared for unit loads of two or three times those from the tank. Lacking such preparation, the tank should be carried on an over-all timber crib or mat of adequate size and spacing. Increased availability of electricity and domestic-service pressure installations makes possible the basing of more large tanks on the ground.

(2) If the understructure consists of sills on columns, the lower ends of the columns should be completely tied together for compression and tension up to at least half the unit load. In the case of a simple square deck on four columns, the columns should be tied at their feet and each of the four sides braced diagonally from column bottoms to tops and through the center between opposite columns. As far as possible, bracing and cross tying should be kept in the two planes parallel to the sills and joists, respectively, with secondary truncating sills to approximate the form of a circle under large tanks. Without adequate internal bracing in the two rectangular directions, the bracing of a six- or eight-sided array of columns around the periphery results in off-center reactions and is likely to cause structural failure and destruction of the tank.

(3) Footings of concrete or large flat stones should be anchored in the ground or to the rock by imbedding them to a depth equal to their area or by rods and grouting which develop bearing resistance against lateral stresses of half the unit vertical load. Concrete piers should be tied pier to pier unless they are deeply imbedded.

(4) Wherever possible, the footing surface should be level. If this is not possible, the long columns should be tied at the level of the footings of the short columns, and the bracing should be completed at this level.

(5) Sills should be fixed at the top by drift pins, and bolts and timber fasteners should be used in the framing of supports for all but the smallest tanks. Whenever possible, braces should be paired or framed into the plane of the columns to avoid introducing torque into the stresses.

(6) Frequent inspection, painting or creosoting, and repair of defective parts will provide longer assurance of reasonable safety, as with any other structures.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER–DECEMBER, 1951

VOLCANOLOGY

October

Uneasiness, which was manifest at Mauna Loa during September, continued throughout October. Earthquakes originated beneath the summit area of the mountain and along both the northeast and southwest rift zones, as well as on the Kealakekua fault near Napoopoo and the Kaoiki fault from Honuapo to Ohaikea. Starting at 22:03 on October 8, Volcano Observatory seismographs recorded 16 minutes of continuous volcanic tremor probably caused by movement of molten lava underground. This was followed at 4:45 on October 9 by a moderate earthquake which appears to have originated at a depth of 25 to 30 miles beneath the summit area of Mauna Loa. This earthquake was felt by some persons in all parts of the southern portion of the island of Hawaii, from Kealakekua to Hilo. A smaller earthquake at 5:23 on the same morning originated deep beneath the upper end of the southwest rift of Mauna Loa.

During most of the month, eastward tilting at the Whitney Laboratory of Seismology at the Volcano House was at a rate about normal for that season of the year. However, from October 28 to 30 it was much more rapid than usual. The rapid tilt may have been caused by a heavy rainfall just preceding it, or it may have resulted from an increase of volcanic pressure beneath Mauna Loa. Abnormally rapid northward tilting during the same period may have been caused by an increase of pressure beneath Kilauea.

On October 24, I. C. Manus, Superintendent of Construction and Maintenance for the Kulani project, reported a long period of continuous trembling of the ground at the summit of Mauna Loa. This appeared on the seismographs as a series of closely spaced, but separate, small earthquakes. Mr. Manus also reported an apparent increase in the amount of steam being liberated at vents within Mokuaweoweo Caldera. On October 31, aircraft reported a large cloud of steam rising from the southwest rift of Mauna Loa between 8,000 and 12,000 feet altitude. This is the area in which the vents of the 1950 eruption are situated. Fume liberation at the vents has been continuous since the end of the eruption. On October 20, Acting Superintendent I. J. Castro and Ranger Elroy Bohlin, of Hawaii National Park, observed from the air steam and fume rising at eight localities along the rift between 9,000 and 12,000 feet altitude. The reported increase of the steam cloud on October 31 probably resulted from the heavy rains of October 26 to 28 coming in contact with still-hot lava near the vents, coupled with better than usual visibility of the steam because of the unusually high humidity.

During October, the seismographs at Kilauea Caldera recorded a total of 73 earthquakes. That at Konawaena School recorded 139 earthquakes, most of them aftershocks of the big earthquake of August 21.

November

Hawaiian volcanoes continued uneasy through the month of November. During the month, 73 earthquakes were recorded at the stations on the rim of Kilauea Caldera, which is more than twice the average number recorded during times of quiet. The seismograph at the Mauna Loa station recorded 53 earthquakes. Ground tilting during the month was, at an average rate, approximately normal for that season of the year. However, moderately strong oscillations of tilt in the east-west direction suggest fluctuations in pressure beneath Mauna Loa.

An earthquake of about intensity 6 in the modified Mercalli scale occurred on the morning of November 8. The time of arrival of the first waves at the Whitney Laboratory was

09:34:24, and the time of origin of the quake was approximately 09:34:12. All of the seismographs operating on the island of Hawaii were dismantled by the quake, the Mauna Loa instrument being dismantled by the preliminary waves. The earthquake was felt over all of the island, strongly over the southwest part. At Kahuku Ranch headquarters, 9.5 miles north of South Point, dishes were thrown from shelves and stone walls were extensively damaged. The intensity decreased very rapidly away from the epicenter. At South Point and at Kaalualu, 10 miles southeast of Kahuku Ranch headquarters, there was no damage to stone walls, and, even in the homestead area 4 miles southeast of ranch headquarters, the damage was very small. The decrease was even more rapid westward. Two and a half miles west of the ranch headquarters, stone walls along the highway were undamaged. Instrumental data and field investigations place the epicenter of the earthquake on the southwest rift zone of Mauna Loa at about 4,500 feet altitude, approximately 5 miles north of Kahuku Ranch headquarters. The Kahuku fault, one of the major fractures in the southwest rift zone, trends nearly north and south just west of the ranch headquarters. The area of damage to stone walls was distinctly elongated parallel to the Kahuku fault, suggesting that the earthquake was caused by movement on that fault. The rapid decrease of damage at increasing distance from the epicenter suggests a very shallow origin of the quake, but no surface fault displacement has been found.

During November, the seismograph at Konawaena School in Kealakekua recorded a total of 110 earthquakes. Most of them originated within 10 miles of the seismograph station, and the majority probably resulted from movement along the Kealakekua fault. On November 7, at 20:11, a small quake originated beneath the summit region of Hualalai volcano. On November 21, at 9:59, a small earthquake occurred beneath the Waimea Plain a few miles west of Kamuela. Nearly all the other local earthquakes recorded during the month had their origins in Kilauea and Mauna Loa volcanoes.

On November 23, two observers in the Kona area reported what appeared to them to be smoke near the summit of Mauna Loa. E. K. Field, Chief Ranger, and R. L. Jeffery, Superintendent of Construction and Maintenance, of Hawaii National Park, were at the summit of Mauna Loa at the time and reported conditions at and near the summit to be normal. The "smoke" observed from Kona appears to have been steam rising in the vicinity of the vents of the 1950 lava flows, probably caused by heavy rain on November 20 to 22.

December

The uneasiness of Mauna Loa and Kilauea during October and November persisted into early December. During the latter part of the month, the volcanoes were relatively quiet although oscillations in east-west tilting at the Whitney Laboratory still suggested some fluctuation in pressure beneath Mauna Loa.

Between December 3 and 7, the ground surface at the Whitney Laboratory tilted rapidly southward by an amount of 4.4 seconds of arc, and by December 16 an additional tilting of 0.6 seconds had taken place. This was followed, however, by a rapid partial recovery of 2.6 seconds by December 25. The net southward tilt during the month was 2.2 seconds of arc. This suggests a decrease of pressure beneath Kilauea.

During December, most of the earthquake activity originated at Kilauea volcano. The seismograph at the Whitney Laboratory, on the northeast rim of Kilauea Caldera, recorded 37 earthquakes. This number only slightly exceeds the average during quiet periods. The Mauna Loa seismograph recorded only 21 earthquakes. The Kona seismograph recorded 62 earthquakes during the month. Most of these originated close to the station, many of them probably on the Kealakekua fault.

At 20:19 on December 6, a strong earthquake was felt over all of the southeast part of the island. It originated at a depth of 3 or 4 miles on the east rift zone of Kilauea volcano, about 14 miles east of the caldera and 7 miles southwest of Pahoa.

TELESEISMS

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is Hawaiian Standard time.

October 21,	11:46,	slight. Formosa.
October 21,	17:41,	slight. Formosa.
November 6,	06:53,	slight. Kurile Islands.
November 8,	04:02,	moderate. Aleutian Islands.
December 7,	18:35,	slight. Indian Ocean, about 900 miles southeast of Madagascar.
December 25,	15:03,	slight. Off coast of southern California.
December 27,	23:34,	slight. Guerrero, Mexico.
December 30,	12:50,	moderate. Pacific Ocean, west of Easter Island.

The data for the following local disturbances were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The arrival times are given to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich 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 at the northeast rim of Kilauea Caldera. If the intensity was greater at one of the other stations, the name of that station and the intensity rating are given in parentheses after the rating at the Whitney station, except that where the earthquake was not recorded at the Whitney station the parentheses are omitted.

276.	Oct. 1,	09:17,	tremor (Kona very feeble). Central Kona.
277.	Oct. 3,	22:56,	tremor (Kona very feeble). Central Kona.
278.	Oct. 4,	06:01,	very feeble (Kona feeble). Central Kona.
279.	Oct. 4,	19:03,	tremor (Kona very feeble). Central Kona.
280.	Oct. 5,	02:09,	tremor (Kona very feeble). Central Kona.
281.	Oct. 5,	08:42,	very feeble, felt at Kapapala and Naalehu. Kaoiki fault near Hilea.
282.	Oct. 6,	02:44,	very feeble (Kona feeble). East edge of Kealakekua Bay.
283.	Oct. 6,	04:36,	feeble, felt at Kapapala and Naalehu. Kaoiki fault, about 4 miles northeast of Kapapala.
284.	Oct. 6,	08:35,	very feeble (Mauna Loa slight). Kaoiki fault, about 3 miles northeast of Kapapala.
285.	Oct. 6,	13:34,	tremor (Kona very feeble). Central Kona.
286.	Oct. 7,	01:28,	very feeble, felt at Naalehu. Near Hilea.
287.	Oct. 7,	05:14,	tremor (Kona very feeble). Central Kona.
288.	Oct. 8,	07:16,	Kona, feeble, no record on other instruments.
289.	Oct. 9,	01:40,	Kona, feeble, no record on other instruments.
290.	Oct. 9,	04:45,	slight, felt from Kona to Hilo. Central Kona.
291.	Oct. 9,	05:23,	feeble (Kona moderate), felt at Kealakekua. Central Kona.
292.	Oct. 10,	02:31,	tremor (Kona very feeble).
293.	Oct. 11,	15:05,	very feeble. Kilauea (?).
294.	Oct. 11,	21:30,	very feeble (Kona moderate), felt at Kealakekua. Central Kona.
295.	Oct. 12,	10:12,	very feeble (Kona slight). Central Kona.
296.	Oct. 12,	16:06,	tremor (Kona very feeble).
297.	Oct. 14,	16:37,	very feeble. Kilauea.
298.	Oct. 14,	19:52,	very feeble, felt at Naalehu.
299.	Oct. 15,	02:43,	very feeble. Central Kona.
300.	Oct. 15,	19:47,	very feeble.
301.	Oct. 17,	08:49,	tremor (Kona very feeble). Central Kona.
302.	Oct. 17,	21:12,	slight (Mauna Loa moderate), felt at Volcano and Hilo. Northeast rift of Mauna Loa, near the 3,000-foot contour.
303.	Oct. 19,	01:00,	very feeble, felt at Volcano. Northeast rift of Mauna Loa (?).
304.	Oct. 20,	11:58,	very feeble.
305.	Oct. 20,	19:10,	tremor (Kona very feeble).
306.	Oct. 20,	21:01,	very feeble (Kona feeble). Central Kona.
307.	Oct. 23,	10:42,	tremor (Kona slight), felt at Kealakekua. Central Kona.
308.	Oct. 24,	13:14,	very feeble (Kona feeble). Central Kona.
309.	Oct. 24,	13:15,	very feeble, felt at summit of Mauna Loa.
310.	Oct. 25,	02:42,	very feeble.
311.	Oct. 25,	05:22,	very feeble.
312.	Oct. 27,	21:05,	very feeble.
313.	Oct. 28,	06:53,	tremor (Kona very feeble). Central Kona.
314.	Oct. 29,	02:07,	very feeble. Central Kona.
315.	Oct. 29,	23:49,	very feeble. Kaoiki fault, about 3 miles northeast of Hilea.

316. Nov. 1, 20:48, very feeble.
317. Nov. 3, 06:26, very feeble.
318. Nov. 4, 19:24, very feeble. Northeast rift of Mauna Loa.
319. Nov. 6, 10:44, very feeble. Kilauea.
320. Nov. 6, 11:08, very feeble. Kilauea.
321. Nov. 7, 20:11, very feeble. Near summit of Hualalai.
322. Nov. 7, 22:46, very feeble.
323. Nov. 8, 09:34, strong. Intensity 6 at Kahuku. Felt all over southern part of island. Epicenter on southwest rift of Mauna Loa at about 4,500 feet altitude.
324. Nov. 8, 10:16, very feeble.
325. Nov. 8, 14:10, tremor (Kona slight). Central Kona.
326. Nov. 8, 14:22, very feeble, felt at Kealakekua.
327. Nov. 8, 16:33, very feeble. Kilauea.
328. Nov. 8, 23:27, tremor (Kona very feeble). Central Kona.
329. Nov. 9, 00:55, very feeble. Hilina fault, near Puu Kapukapu.
330. Nov. 10, 14:16, very feeble. Southwest rift of Mauna Loa at about 11,000 feet altitude.
331. Nov. 11, 03:52, very feeble.
332. Nov. 11, 07:08, slight, felt in Hilo. East rift of Kilauea, near Pauahi Crater.
333. Nov. 12, 07:01, very feeble. Kaoiki fault near Ainapo.
334. Nov. 13, 00:41, very feeble. Kilauea.
335. Nov. 16, 02:57, very feeble. Kilauea.
336. Nov. 16, 20:54, very feeble.
337. Nov. 17, 14:50, Kona feeble, no record on other instruments; felt in Kealakekua.
338. Nov. 18, 01:31, tremor (Kona very feeble), felt at Kealakekua.
339. Nov. 18, 02:47, tremor (Kona slight), felt at Kealakekua. Central Kona.
340. Nov. 18, 11:18, very feeble. Kilauea Caldera, near Uwekahuna.
341. Nov. 19, 18:58, very feeble.
342. Nov. 20, 17:43, tremor (Kona very feeble.) Central Kona.
343. Nov. 21, 06:22, very feeble.
344. Nov. 21, 10:00, very feeble. Waimea Plain, near Kamuela.
345. Nov. 21, 22:23, very feeble.
346. Nov. 22, 17:37, very feeble. East slope of Mauna Loa, about 3 miles east of Kulani Cone.
347. Nov. 23, 08:22, slight (Kona moderate), felt from central Kona to Kahuku. Kealakekua fault, about 5 miles west of Napoopoo.
348. Nov. 25, 06:17, tremor (Kona very feeble).
349. Nov. 25, 21:41, tremor (Kona very feeble). Central Kona.
350. Nov. 26, 12:35, very feeble. East rift of Kilauea, near Makaopuhi Crater.
351. Nov. 26, 21:25, tremor (Kona very feeble). Central Kona.
352. Nov. 28, 09:36, very feeble.
353. Nov. 28, 11:41, very feeble.
354. Dec. 1, 06:09, very feeble. Central Kona.
355. Dec. 2, 12:00, very feeble.
356. Dec. 3, 08:33, very feeble.
357. Dec. 5, 05:20, very feeble. Kilauea Caldera.
358. Dec. 6, 20:19, strong, felt from Kapapala to Hilo and east Puna. East rift of Kilauea, about 7 miles southwest of Pahoa.
359. Dec. 9, 16:37, feeble. Near Kilauea Caldera.
360. Dec. 11, 02:12, very feeble.
361. Dec. 11, 13:58, very feeble.
362. Dec. 12, 16:51, very feeble.
363. Dec. 13, 03:06, tremor (Kona feeble). Central Kona.
364. Dec. 13, 21:54, very feeble. Kilauea Caldera.
365. Dec. 14, 19:22, tremor (Kona very feeble). Central Kona.
366. Dec. 15, 01:36, very feeble.
367. Dec. 15, 23:16, very feeble.
368. Dec. 17, 15:48, very feeble.
369. Dec. 19, 05:30, very feeble.
370. Dec. 23, 09:31, very feeble. Kilauea Caldera.
371. Dec. 25, 09:50, very feeble.
372. Dec. 26, 23:06, very feeble.
373. Dec. 28, 16:17, tremor (Kona very feeble). Central Kona.
374. Dec. 29, 08:45, Kona feeble, no record on other instruments. Central Kona.
375. Dec. 29, 17:32, very feeble, felt at Naalehu and Kapapala. Kaoiki fault, near Pahala.
376. Dec. 30, 02:00, Kona feeble, no record on other instruments. Central Kona.
377. Dec. 31, 15:49, tremor (Kona feeble). Central Kona.

SEISMOLOGY

Earthquake Data, October–December, 1951

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

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Oct. 7	6	4	1	1	0	0	6.5	0
14	3	6	0	1	0	0	5.75	0
21	10	5	0	0	0	0	5.0	2
28	16	4	1	0	0	0	7.0	0
Nov. 4	11	10	0	0	0	1	11.75	2
11	8	5	0	1	0	0	6.5	0
18	10	7	0	1	0	0	8.0	0
25	11	4	0	0	0	0	4.75	0
Dec. 2	5	3	0	0	0	1	6.75	1
9	5	6	1	0	0	0	5.25	0
16	9	2	0	0	0	0	3.25	0
23	3	4	0	0	0	0	2.75	2
30								1

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

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning	Whitney Vault (Northeast rim)		Uwekahuna Vault (West rim)	
	Amount	Direction	Amount	Direction
October 7	0.3″	N 45° E	0.4″	S 45° E
14	0.7″	N	1.0″	N 18° W
21	1.2″	N 6° E	5.1″	N 22° W
28	0.7″	S 31° E	5.2″	N 10° W
November 4	0.6″	N 22° E	4.8″	S
11	0.2″	S 45° W	3.0″	S 18° E
18	0.9″	N 74° E	2.3″	N 8° W
25	1.4″	N 25° W	3.0″	S 13° E
December 2	4.2″	S 5° W	2.0″	N 10° W
9	0.9″	S 23° E	2.0″	N 10° W
16	2.8″	N 23° E	4.2″	S 5° E
23	0.4″	S 72° E	1.2″	S 34° E
30				

VOLCANO NOTES AND NEWS

ACTIVITY OF PARICUTIN VOLCANO

Paricutin volcano began its spectacular life on February 20, 1943, in the state of Michoacán, western Mexico. The new volcano is situated in the midst of a volcanic field containing hundreds of older, but geologically young, cinder cones and lava cones. During its first weeks, the activity of Paricutin was largely pyroclastic, and, by the time it was a year old, the resulting cinder cone was 1,100 feet high. Since then the upward growth of the cone has been slow, and on February 21, 1950, the summit of the cone stood approximately 1,300 feet above its original base. Lava flows commenced early in the history of the volcano and have continued intermittently ever since. At the end of June, 1950, the total area covered by Paricutin lava was about 24.2 square kilometers.*

* Carl Fries, Jr., and Celedonio Gutiérrez, Activity of Paricutin Volcano from January 1 to June 30, 1950. Amer. Geophys. Union Trans. 32: 227–230. 1951.

Brief summaries of the activity of Paricutin volcano appear at approximately 6-month intervals in the American Geophysical Union Transactions. Carl Fries, Jr., of the U. S. Geological Survey, has kindly supplied a statement on the current state of activity of Paricutin. The Mexican Institute of Scientific Investigation and the U. S. Geological Survey are maintaining a watch over Paricutin on a cooperative basis. Two Mexican observers are constantly at the observatory, gathering data on eruptive activity, lava movement, weather, and any other pertinent occurrences. Mr. Fries visits the volcano every 2 months to gather the data sheets, make special measurements, and collect lava samples. His last visit was in mid-November, 1951.

In May, 1951, a new pyroclastic eruptive vent formed low on the northeast flank of the main cone. This new vent was very active and formed a separate crater on that flank of the cone. During the following months, the vent gradually moved up the flank, and its crater coalesced with the main crater. By November the depression on the northeast flank had been filled by deposition of pyroclastic fragments, and the profile was once again that of a simple cone.

Lava has continued to issue from the Nuevo Juatita vent at the northeast base of the cone, flowing northeastward around the Equijuata and Capatzun cinder cones. By October it had reached a point about 2½ miles from the vent, near the site of the former town of San Juan Parangaricutiro, when the flow of lava was interrupted at the vent, and the flow front ceased advancing. Solidification at the vent caused the formation of a new lava cascade just west of the former one, and during November two prongs of Lava were invading the base of Equijuata cinder cone near Tourist Lookout.

Activity of the eruptive vents in the crater of the main cone has, for the past 6 months, been of such an intermittently explosive nature that it has not been possible to climb the cone with any probability of safety. It has been dangerous even to approach the base of the cone.

ALEUTIAN-ALASKAN VOLCANO STUDIES

Dr. H. A. Powers, who is in charge of the U. S. Geological Survey's volcanological program in the Aleutian Islands, reports that the field team from the General Geology Branch, which is studying and mapping the volcanoes of the Aleutian Islands and Alaska Peninsula, completed the reconnaissance mapping of the Rat Group during the summer of 1951. This completes the mapping of all the American Aleutians west of the 180th meridian. Eastward, work has been completed on northern Kanaga, northern Adak, Great Sitkin, Umnak, and the Pavlof Group. The investigation will be continued until all the young volcanic areas have been studied.

ALEUTIAN VOLCANIC ACTIVITY

Great Sitkin volcano, in the Andreanof Group of the Aleutian Islands, has continued to steam throughout the past year, according to observations by Austin E. Jones, seismologist in charge of the seismological observatory maintained on Adak Island by the Geophysics Branch of the U. S. Geological Survey. The steam cloud is visible intermittently from Adak. It is not apparent whether this represents fluctuation in volume of steam output or fluctuation in meteorological conditions that condense the steam.

No fume or ash clouds have appeared from Great Sitkin since the series of eruptions which ended about November 29, 1950. During this eruptive period, which began November 5, 1950, several ash showers and fume were produced. Jones estimated that one ash eruption produced possibly as much as 20,000 cubic meters of ash. Flashes of light were observed several times at night by military personnel on Great Sitkin Island, but they were not seen from Adak. Prior to this activity, the last small ash falls and fume clouds were seen on December 30, 1949, and January 7, 1950.

In spite of the frequency of military air travel along the Aleutian Chain, information on minor activity of the different volcanoes is very random because the cloud and fog screen is so persistent. Minor ash showers and fume emission are known to have occurred during 1951 from Gareloi, Kanaga, Great Sitkin, Akutan, and Shishaldin. Others may have shown minor activity which has not been reported. It is certain, however, that no major eruptions have escaped notice.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

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

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

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