Hawaiian Volcano Observatory
1959 Quarterly Administrative reports

Introductory Note By Thomas L. Wright and Jennifer S. Nakata

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Summary 13
January, February, and March 1959
By Jerry P. Eaton and Harold L. Krivoy

Summary 14
April, May, and June 1959
By Jerry P. Eaton and Harold L. Krivoy

Summary 15
July, August, and September 1959
By Jerry P. Eaton and Harold L. Krivoy

Draft of
Summary 16
October, November, and December 1959
By Harold L. Krivoy, Michael P. Lane, and Jerry P. Eaton

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INTRODUCTORY NOTE

The Hawaiian Volcano Observatory Summaries have been published in the current format since 1956. The Quarterly Summaries (1956 through 1973) and the Annual Summaries (1974 through 1985) were originally published as Administrative Reports. These reports have been compiled and published as U.S. Geological Survey Open-File Reports. The quarterly reports have been combined and published as one annual summary. All the summaries from 1956 to the present are now available as .pdf files at http://www.usgs.gov/pubprod.

The earthquake summary data are presented as a listing of origin time, depth, magnitude, and other location parameters. Network instrumentation, field station sites, and location algorithms are described. Tilt and other deformation data are included until Summary 77, January to December 1977. From 1978, the seismic and deformation data are published separately, due to differing schedules of data reduction.

There are eight quarters—from the fourth quarter of 1959 to the third quarter of 1961—that were never published. Two of these (4th quarter 1959, 1st quarter 1960) have now been published, using handwritten notes of Jerry Eaton (HVO seismologist at the time) and his colleagues. The seismic records for the remaining six summaries went back to California in 1961 with Jerry Eaton. Other responsibilities intervened, and the seismic summaries were never prepared.

Chronology

The following Kīlauea eruption chronology covers the two recent reports and the six missing quarters:

Location	Beginning Date	Ending Date	Comment
Kīlauea Iki crater (Kīlauea's summit)	11/14/1959	12/20/1959	19 eruptive episodes
Kapoho (lower east rift zone)	1/13/1960	2/18/1960	4 eruption stages
Halemaumau (Kīlauea's summit)	2/24/1961	2/24/1961	Intermittent activity during uninterrupted inflation following the 1960 eruption
Halemaumau (Kīlauea's summit)	3/22/1961	3/25/1961	Same as above.
Halemaumau (Kīlauea's summit)	7/10/1961	7/17/1961	Same as above.
Heiheiahulu (middle east rift zone)	9/22/1961	9/25/1961	First historical east rift eruption at this location

The 1959-1960 eruptions were among two of the most spectacular Kīlauea eruptions. The HVO staff was kept busy with acquisition of unusually high quantities of instrumental data and observations of the two sequences, which were separated by less than one month. Even with a year's interval before the beginning of the summit-east rift sequence in 1961, the staff never caught up, and the seismic records were set aside for later study.

A total of 1,672 earthquakes—1,106 for 1960 and 566 for 1961—are part of HVO's cataloged database. The annual listings have been appended to the 1st Quarter Report of 1960 and to the 4th Quarter Report for 1961. The number of earthquakes is probably low, biased toward the larger magnitudes. The entire HVO catalog, including 1960 and 1961, is accessible from the ANSS CATALOG SEARCH site at http://www.ncedc.org/anss/catalog-search.

Thomas L. Wright and Jennifer S. Nakata

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

HAWAIIAN VOLCANO OBSERVATORY

SUMMARY 13

January-March 1959

by

J. P. Eaton and H. L. Krivoy

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HAWAIIAN VOLCANO OBSERVATORY SUMMARY 13

By J. P. Eaton and H. L. Krivoy

Preface

The gradual improvement of instruments and techniques employed in recording events at Hawaiian volcanoes necessitates an occasional revision of the content and format of this summary. In such revision a compromise is sought between the need to summarize current data as fully as possible and the desirability of maintaining continuity in the type of data reported and the nature of its presentation.

In Summary 9 the local earthquake statistical summary was modified to eliminate its arbitrary dependence on the obsolete seismograph at the Whitney station, and the summary of tilting at Kilauea caldera was modified to permit a simpler, more useful presentation of the data. Revisions incorporated into the present summary (13) again involve local earthquakes and tilting. To permit the reporting of epicenters of local earthquakes with the added precision made possible by recent improvements in the seismograph network, epicenter locations will now be given in terms of geographic coordinates; and the map (fig. 2) has been provided with latitude and longitude guides. The pattern of tilting around Kilauea caldera delineated by the newly developed liquid-level tiltmeter bases* will also be displayed in summaries covering quarters during which measurements are made. Weekly indications of tilting at the Whitney station will be discontinued, for they have proved to be so strongly dependent on vagaries of temperature and rainfall as to be generally unreliable as an index to the swelling and shrinking of the volcano.

This summary also describes seismograph installations operated by the U.S. Geological Survey in Hawaii. Changes in the network will be reported in the summary covering the quarter during which they occur, and the entire network will be redescribed in the summary covering the first quarter of each year.

Chronological summary

Measurements made during the first week of February at tilt bases around Kilauea caldera revealed that the ground surface had tilted outward from the south edge of the caldera since October 1958. From a maximum rate of about 3 microradians per month at Uwekahuna and Summer Camp, tilting decreased rapidly at greater distances from the caldera.

*J. P. Eaton, A portable water-tube tiltmeter, Seism. Soc. Amer. Bull., v. 49, no. 4, p. 301-316, October 1959.

Tilting at Uwekahuna vault during the first quarter of 1959 was rather erratic and did not reflect the gentle swelling of the Kilauea summit indicated by the tilt bases around the caldera.

More than 1,000 earthquakes were recorded at Uwekahuna during January. About 400 of these originated at very shallow depths beneath Kilauea caldera. On January 5 and 6 about 600 small to moderate earthquakes and several hours of accompanying tremor from a source about 60 km deep and 10 km northeast of the caldera were registered by seismographs around the summit of Kilauea and at Hilo. Although 29 earthquakes of this swarm were of magnitude 2.5 or larger, none was felt.

The largest earthquake in the Hawaiian region during January occurred beneath the sea about 125 km south of Honolulu at 20°15' N., 157°55' W. on January 12 at 01^h05^m. Although its magnitude was 4.0, it was not felt.

An earthquake with a magnitude of only 1.6 which originated at a very shallow depth beneath Kilauea caldera was felt at the caldera at 16^h11^m on January 29. A magnitude 2.9 earthquake from an epicenter about 12 km east-northeast of Apua Point was felt in Hilo at 05^h33^m on January 30.

Only 175 earthquakes were recorded at Uwekahuna during February, marking a sharp decline in the number of shallow earthquakes beneath the caldera.

At 23^h29^m on February 9 a magnitude 3.5 earthquake from a source about 5 km south of the caldera and 10 km deep was felt at Kilauea caldera and at Hilo.

On the evening of February 19 three earthquakes from an origin about 12 km northeast of Apua Point and 5 km deep were felt at scattered points over most of the island of Hawaii. The first of these earthquakes, with a magnitude of 4.0, occurred at 19^h58^m. It was followed, at 20^h00^m, by a magnitude 4.5 earthquake, the largest earthquake in the Hawaiian region during February, which was felt at least as far away as Honokaa. The third earthquake, with a magnitude of 3.5, occurred at 20^h35^m.

The number of earthquakes recorded at Uwekahuna declined to 130 for March. Five of these were felt.

At 05^h32^m on March 5 a magnitude 3.5 earthquake from a focus 5 km deep and 10 km north-northwest of Apua Point was felt from the vicinity of the Desert seismograph station to Hilo.

The earthquake felt in Capt. Cook at 16^h45^m on March 6 originated beneath the ocean about 15 km west of Keahole Point. Its magnitude was 4.0.

An earthquake with a magnitude of 3.5 from a source 5 km southeast of Waikii and 15 km deep was felt at Pohakuloa at 04^h26^m on March 9. At 07^h45^m on March 12 a magnitude 4.0 earthquake with an epicenter 10 km southeast of Honokaa and a focal depth of about 15 km was felt at Kukuihaele (10 km northwest of Honakaa).

The earthquake which was felt at Kilauea caldera and Capt. Cook at 07^h49^m on March 17 emanated from a focus 10 km southeast of Mokuaweoweo and 5 km deep. Its magnitude was 3.5.

Briefly, this quarter may be summarized as a period of continuing, slow inflation of the summit of Kilauea. The swarm of tiny shallow earthquakes beneath Kilauea caldera which was so pronounced in January declined greatly during February and March.

Tilting of the ground around Kilauea caldera

Tilting of the ground around the summit of Kilauea is monitored daily by a short-base water-tube tiltmeter in Uwekahuna vault, and at irregular intervals it is measured on a regional scale by means of a network of field tilt bases and a portable water-tube tiltmeter (tables 1 and 2). The attitude of the ground surface at each tilt base is reported in terms of north-south and east-west tilt coordinates. Both coordinates at each station were arbitrarily set equal to 500 when measurements at that station were bugun. Increasing tilt coordinates correspond to northward and eastward tilting of the earth's surface, that is, to a relative subsidence toward the north and east. A 1-unit change in coordinate corresponds to a 1-microradian (1 mm per km) tilt in the direction indicated.

Seismic summary

Events recorded by the U.S. Geological Survey seismograph network in Hawaii fall into two categories: local earthquakes and tremor originating in the region of the Hawaiian Islands, usually within 100 km of the Observatory, and distant earthquakes originating farther than 3,000 km from Hawaii. As an index of seismic activity at Hawaiian volcanoes, weekly totals of earthquakes with magnitudes of 2.5 or greater, earthquakes with magnitudes less than 2.5, and minutes of continuous tremor, all recorded on the HVO-1 seismograph at Uwekahuna, are reported in table 3. Earthquakes of magnitude 2.5 or greater are generally sufficiently well recorded to be located; they are listed individually in table 4. Data on identifiable phases from distant earthquakes are listed in table 5.

Locations of the seismograph stations are shown on figure 2, and essential data on the stations are given in table 6.

Table 1.--Tilt coordinates at Uwekahuna vault, January-March 1959

Date	N-S	E-W	Date	N-S	E-W
Jan. 4	511	455	Feb. 22	506	456
11	513	457	Mar. 1	504	458
18	508	457	8	505	459
25	504	458	15	507	460
Feb. 1	506	456	22	507	464
8	504	457	29	511	466
15	504	458			

Table 2.--Tilt coordinates and changes at tilt bases around Kilauea caldera (see fig. 1)

Tilt base (location)	Date (1959)	Tilt coordinates		Direction and rate of tilting since last reading (10^{-6} rad/mo)		Date of last reading (1958)
		N-S	E-W			
Uwekahuna (19°25.5' N., 155°17.4' W.)	Feb. 2	543.9	472.7	3.3	N. 33° W.	Oct. 2
Tree Molds (19°26.3' N., 155°17.3' W.)	Feb. 5	508.6	499.0	2.2	N. 7° W.	Oct. 9
Summer Camp (19°24.6' N., 155°15.6' W.)	Feb. 8	508.4	427.1	3.1	N. 77° E.	Oct. 7
Sand Spit (19°24.1' N., 155°16.8' W.)	Feb. 8	505.1	494.1	2.4	N. 49° W.	Oct. 31
Kalihipaa (19°21.4' N., 155°15.3' W.)	Feb. 9	495.9	503.3	0.9	S. 42° E.	Oct. 6
Keamoku (19°25.1' N., 155°19.0' W.)	Mar. 2	500.0	500.0	---	---------	-------
Kamokukolau (19°22.7' N., 155°16.6' W.)	Mar. 4	500.0	500.0	---	---------	-------

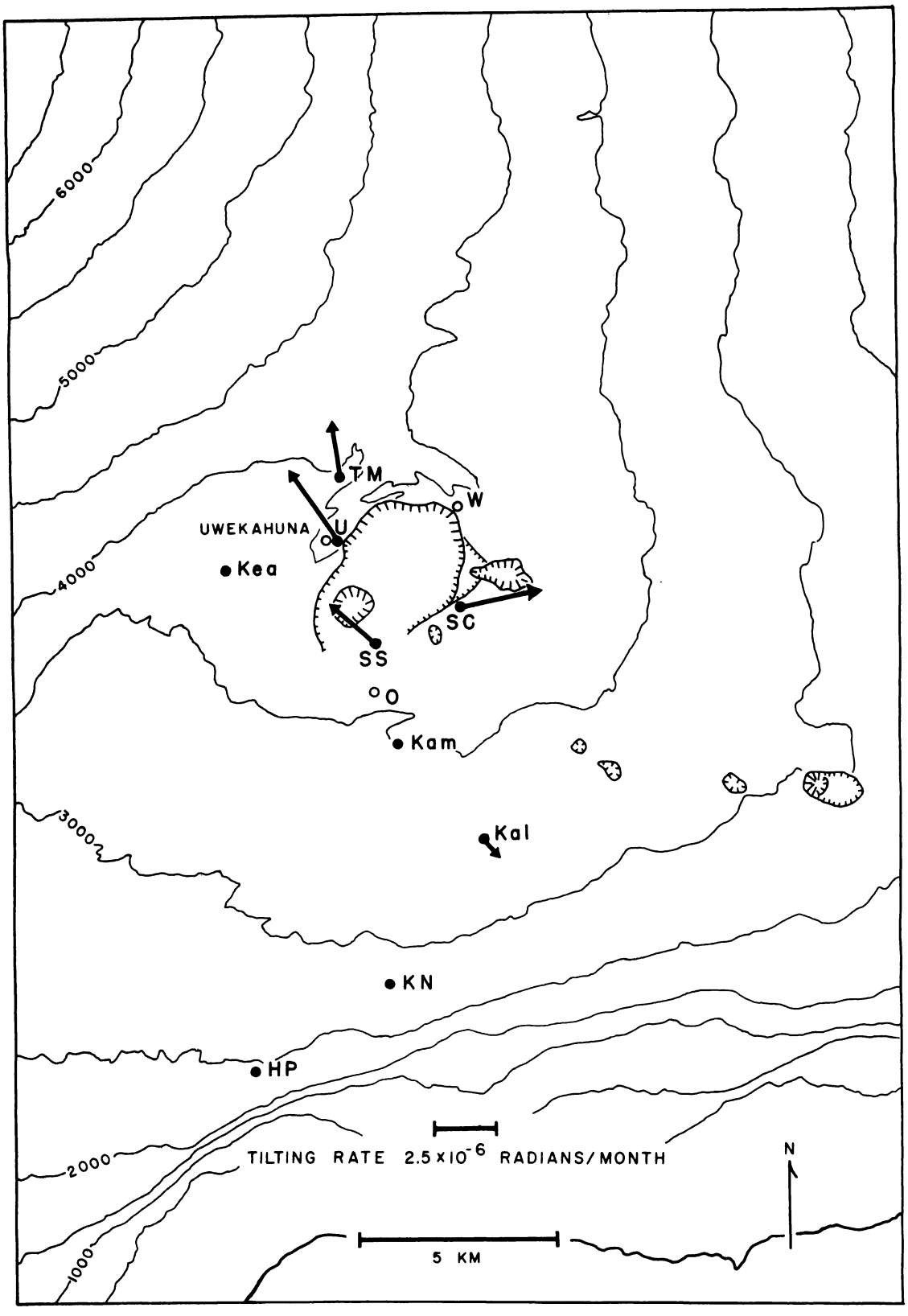

Figure 1.--Tilting of the ground around Kilauea caldera, Oct. 6, 1958, to Feb. 6, 1959. The vector depicting tilting at a given tilt base points in the direction of maximum relative subsidence and has a length proportional to the rate of tilting during the measurement interval. Closed circles represent field tilt bases; open circles, short-base water-tube tiltmeters.

Table 3.--Local earthquakes and tremor recorded by the HVO-1 seismograph at Uwekahuna, January-March 1959

Week beginning	Number of earthquakes		Minutes of continuous tremor
	Magnitude ≥2.5	Magnitude <2.5	
Jan. 4	33	ca. 700	ca. 400
11	1	57	106
18	0	115	14
25	4	84	68
Feb. 1	1	37	3
8	4	45	0
15	5	39	30
22	3	40	0
Mar. 1	2	23	0
8	4	35	33
15	2	32	0
22	5	18	64
29	3	26	0

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, January-March 1959

[Except for smaller earthquakes of special interest, only earthquakes with magnitudes of 2.5 or greater are listed. Time is Hawaiian standard]

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Latitude	Longitude	Description	
					N	W		
Jan. 1	18	36	00	2.5	19°21'	155°56'	5 km SW of Hookena-------	Depth about 15 km.
2	00	19	39	2.8	19°25'	155°26'	10 km NW of Desert seismograph.	Depth about 5 km.
2	04	15	08	2.8	19°29'	155°56'	5 km SSW of Kealakekua---	Do.
3	03	04	35	2.5	19°26'	155°56'	4 km WNW of Honaunau-----	Depth about 10 km.
3	18	25	38	2.9	19°26'	155°16'	Beneath NE rim of Kilauea caldera.	30 km deep.
5	07	35	17	2.6	19°33'	155°39'	10 km NW of Mokuaweoweo--	At shallow depth.
5	15	41	34	2.5	19°29'	155°13'	10 km NE of Uwekahuna----	Depth about 60 km. One of several hundred small earthquakes from this source Jan. 5-6.
5	16	25	26	2.9	--do---	---do---	-----do-----------	Do.
5	16	35	31	2.5	--do---	---do---	-----do-----------	Do.
5	18	00	10	2.5	--do---	---do---	-----do-----------	Do.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, January-March 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Latitude	Longitude	Description	
					N	W		
Jan. 5	18	07	22	2.6	19°29'	155°13'	10 km NE of Uwekahuna----	Depth about 60 km. One of several hundred small earthquakes from this source Jan. 5-6.
5	19	30	42	3.2	--do---	---do---	-----do----------	Do.
5	20	55	13	2.7	--do---	---do---	-----do----------	Do.
5	21	13	04	2.8	--do---	---do---	-----do----------	Do.
5	22	03	46	2.5	--do---	---do---	-----do----------	Do.
5	22	09	04	2.5	--do---	---do---	-----do----------	Do.
5	22	33	17	2.5	--do---	---do---	-----do----------	Do.
5	22	34	03	2.5	--do---	---do---	-----do----------	Do.
5	22	54	53	2.9	--do---	---do---	-----do----------	Do.
5	23	01	02	2.9	--do---	---do---	-----do----------	Do.
6	00	21	24	2.5	--do---	---do---	-----do----------	Do.
6	02	39	24	3.0	--do---	---do---	-----do----------	Do.
6	04	01	32	2.7	--do---	---do---	-----do----------	Do.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey,

January-March 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Latitude	Longitude	Description	
					N	W		
Jan. 6	04	09	21	2.9	19°29'	155°13'	10 km NE of Uwekahuna---	Depth about 60 km. One of several hundred small earthquakes from this source Jan. 5-6.
6	04	25	13	2.5	---do---	---do---	-----do-----------	Do.
6	04	35	18	2.5	---do---	---do---	-----do-----------	Do.
6	05	13	03	2.8	---do---	---do---	-----do-----------	Do.
6	05	46	49	2.9	---do---	---do---	-----do-----------	Do.
6	06	36	26	2.8	---do---	---do---	-----do-----------	Do.
6	06	42	17	2.5	---do---	---do---	-----do-----------	Do.
6	10	38	20	2.5	---do---	---do---	-----do-----------	Do.
6	11	50	24	2.8	---do---	---do---	-----do-----------	Do.
6	12	08	35	3.6	20°45'	155°32'	120 km east of Hana, Maui.	Depth about 15 km.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey,

January-March 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Latitude	Longitude	Description	
					N	W		
Jan. 6	13	20	54	2.5	19°29'	155°13'	12 km NE of Uwekahuna---	Depth about 60 km.
6	14	51	12	2.7	---do---	---do----	-----do----------	Do.
6	19	03	14	2.7	---do---	---do----	-----do----------	Do.
7	17	37	43	2.5	19°26'	155°28'	10 km SW of Mauna Loa seismograph.	Depth about 5 km.
10	08	58	32	3.2	19°19'	155°10'	7 km NNE of Apua Point--	At shallow depth.
12	01	05	15	4.0	20°15'	157°55'	125 km south of Honolulu.	Depth about 15 km.
26	00	36	43	2.6	19°24'	155°29'	13 km NW of Desert seismograph.	Depth about 5 km.
29	16	10	45	1.6	19°25'	155°17'	Felt at Kilauea caldera-	At shallow depth.
30	01	16	17	2.7	19°22'	155°25'	5 km NW of Desert seismograph.	Depth about 10 km.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, January-March 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Latitude	Longitude	Description	
					N	W		
Jan. 30	05	32	41	2.9	19°19'	155°07'	12 km ENE of Apua Point. Felt in Hilo.	Depth about 10 km.
Feb. 5	13	28	12	2.7	20°00'	155°34'	10 km east of Kamuela---	Depth about 15 km.
9	23	28	51	3.5	19°21;	155°17'	5 km south of Outlet seismograph. Felt at Kilauea caldera and Hilo.	Depth about 10 km.
10	14	01	44	2.6	19°23'	155°25'	7 km NW of Desert seismograph.	Depth about 5 km.
10	19	10	27	2.5	19°13'	155°13'	5 km SW of Apua Point---	Do.
13	02	30	40	2.5	19°22'	155°19'	5 km SW of Outlet seismograph.	Do.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey,

January-March 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Latitude	Longitude	Description	
					N	W		
Feb. 17	19	50	53	3.0	19°45'	156°12'	15 km west of Keahole Point.	Depth about 15 km.
19	19	58	01	4.0	19°21'	155°09'	12 km NE of Apua Point. Felt at scattered points over the Island of Hawaii (Capt. Cook, Honokaa, Hilo, Hawaii National Park).	Depth about 5 km.
19	20	00	28	4.5	--do---	---do---	-----do----------	Do.
19	20	35	04	3.5	--do---	---do---	-----do----------	Do.
20	16	04	08	3.4	19°13'	156°23'	50 km west of Milolii--	Depth about 10 km.
26	00	10	27	3.4	19°29'	156°28'	60 km west of Kealakekua Bay.	Depth about 15 km.
28	00	24	17	3.2	19°13'	155°32'	7 km west of Pahala----	At shallow depth.
28	06	54	54	3.2	19°26'	155°29'	20 km west of Uwekahuna	Depth about 5 km.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, January-March 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Latitude	Longitude	Description	
					N	W		
Mar. 5	05	32	10	3.5	19°20'	155°13'	10 km NNW of Apua Point. Felt from Kapapala (10 km SW of Desert seismograph) to Hilo.	Depth about 5 km.
6	16	45	15	4.0	19°44'	156°12'	15 km west of Keahole Point. Felt at Capt. Cook.	Depth about 15 km.
9	04	25	42	3.5	19°50'	155°38'	5 km SE of Waikii. Felt at Pohakuloa.	Do.
9	10	16	33	2.8	19°22'	155°26'	7 km NW of Desert seismograph.	Depth about 10 km.
10	21	08	58	2.5	19°23'	155°20'	7 km SW of Uwekahuna on SW rift zone of Kilauea.	Do.
12	07	44	55	4.0	20°01'	155°25'	10 km SE of Honokaa. Felt at Kukuihaele (10 km NW of Honokaa).	Depth about 15 km.
17	07	49	07	3.5	19°24'	155°32'	10 km SE of Mokuaweoweo caldera. Felt at Kilauea caldera and Capt. Cook.	Depth about 5 km.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, January-March 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Latitude	Longitude	Description	
					N	W		
Mar. 21	05	37	31	2.7	19°26'	155°33'	7 km SE of Mokuaweoweo caldera.	Depth about 15 km.
22	00	40	19	3.0	19°26'	155°16'	Beneath NE rim of Kilauea caldera.	35 km deep.
22	00	58	01	2.6	19°26'	155°30'	20 km west of Uwekahuna-	At shallow depth.
24	01	16	52	2.6	19°23'	155°16'	2 km east of Outlet seismograph.	Depth about 10 km.
25	07	27	14	2.7	20°02'	155°25'	8 km SE of Honokaa----	Depth about 15 km.
25	12	51	13	3.0	19°14'	155°11'	3 km south of Apua Point.	Do.
29	10	52	31	2.6	19°23'	155°18'	2 km west of Outlet seismograph.	Depth about 10 km.
30	01	39	01	3.2	19°12'	155°33'	15 km north of Naalehu--	At shallow depth.

Table 5.--Distant earthquakes

[Times are reported in Greenwich civil time, which is 10 hours faster than Hawaiian standard time. A "c" following the time of P indicates that the first motion was a compression; a "d", that it was a dilatation. Station symbols, locations, and instrumentation are presented in table 6. Locations of epicenters, origin times, focal depths, and magnitudes are from the notices of Preliminary Determination of Epicenters published by the U.S. Coast and Geodetic Survey.]

Jan. 5				
M	Z	iP	09:56:03.1	c
O	Z	iP	09:56:02.5	c
D	Z	iP	09:56:01.6	c
U	Z	iP	09:56:02.5	c
U	PEZ	eS	10:03:35	
U	PEZ	eR	10:11:07	
171-1/2° E., 22° S., 09:46:42 Loyalty Is. region Magnitude 6-1/2 to 6-3/4				
Jan. 13				
U	PEZ	eR	01:41:16	
13-1/2° N., 146° E., 01:15:25 Mariana Is. Magnitude 6-3/4				
Jan. 13				
O	Z	eP	08:45:20.7	
9° N., 33-1/2° W., 08:34:08 Costa Rica region h = 100				
Jan. 15				
M	Z	iP	21:28:45.3	c
O	Z	eP	21:28:45.6	c
D	Z	eP	21:28:44.7	c
U	Z	iP	21:28:44.7	c
Hi	Z	iP	21:28:47.6	c
25-1/2° S., 180° South of Fiji Is. h = 500 Magnitude 6-1/2				
Jan. 16				
M	Z	eP	01:38:16.4	
D	Z	e	01:38:16.7	
U	Z	eP	01:38:20.6	
U	PEZ	eS	01:43:29	
U	PEZ	eR	01:47:36	
52° N., 171° W., 01:31:25 Fox Is. Aleutian Is. h = 60				

Table 5.--Distant earthquakes--Continued

Jan. 16

M	Z	T	17:37	
O	Z	T	17:37	
D	Z	T	17:37	
U	Z	T	17:37	
Hi	Z	T	17:37	
Ha	Z	T	17:36	

52° N., 131-1/2° W.
Queen Charlotte Is.

Jan. 22

M	Z	eP	05:20:11.3	
O	Z	e	05:20:15.9	
D	Z	e	05:20:10.9	
U	Z	eP	05:20:13.7	c
U	PEZ	iP	05:20:13.5	d
U	PEZ	iS	05:28:06	
U	PEN	eQ	05:33:36	
U	PEZ	iR	05:36:02	
Hi	Z	eP	05:21:04.8	d
Ha	Z	e	05:21:04.8	

34° N., 142° E., 05:10:25
Coast of Honshu, Japan
Magnitude 6-3/4 to 7

Jan. 24

M	Z	iP	05:18:23.6
O	Z	e	05:18:23.3
D	Z	e	05:18:23.8
Hi	Z	eP	05:18:23.1
Hi	Z	ipP	05:18:46.9

37-1/2° N., 141° E., 05:08:35
Coast of Honshu, Japan
h = 100

Jan. 24

O	Z	eP	19:52:28.9
D	Z	e	19:52:29.4

15° N., 92-1/2° W., 19:42:20
Mexico-Guatemala border
Magnitude 6-1/4

Jan. 26

U	Z	iP	05:55:42.9

16-1/2° S., 174-1/2° W., 05:48:27
Samoa Is. region
H = 300

Jan. 29

U	Z	eP	20:28:18.7
U	PEZ	eR	20:37:26

52° N., 174° W., 20:21:27
Andreanof Is. Aleutian Is.
Magnitude 5-3/4 to 6

Table 5.--Distant earthquakes--Continued

Jan. 30

M	Z	iP	00:28:38.5	c
O	Z	iP	00:28:37.6	c
D	Z	iP	00:28:38.5	c
U	Z	iP	00:28:38.3	c
U	PEZ	eR	00:42:52	
Hi	Z	iP	00:28:38.6	c
Ha	Z	iP	00:28:38.6	c

10° S., 161° E., 00:19:25
Solomon Is.
Magnitude 6-3/4

Jan. 30

M	Z	iP	18:18:49.6	d
O	Z	iP	18:18:49.2	d
D	Z	iP	18:18:48.3	d
U	Z	iP	18:18:49.5	d
Hi	Z	iP	18:18:51.9	d
Ha	Z	iP	18:18:55.0	d

31° S., 179° W., 18:09:02
Kermadec Is.

Jan. 30

U	PEZ	eR	21:04:17

44° N., 144° E., 20:38:58
Hokkaido, Japan
Magnitude 5-3/4 to 6

Jan. 30

M	Z	iP	22:26:27.6
U	PEE	iS	22:34:19
U	PEZ	iR	22:41:59

44° N., 144° E., 22:16:47
Hokkaido, Japan
Magnitude 6-1/4

Feb. 2

M	Z	iP	04:08:18.1	d
O	Z	iP	04:08:18.5	d

6-1/2° S., 126° E., 03:56:12
Banda Sea
h = 150

Feb. 5

M	Z	iP	01:12:01.9	
O	Z	iP	01:12:02.4	
D	Z	iP	01:12:02.7	
Hi	Z	iP	01:12	

57-1/2° N., 157-1/2° W., 01:40:50
Alaska Peninsula
h = 100

Table 5.--Distant earthquakes--Continued

		Feb. 6		
M	Z	iP	14:40:03.1	c
O	Z	iP	14:40:03.6	c
D	Z	iP	14:40:03.7	c
U	Z	iP	14:40:03.1	d
U	Z	i	14:40:18.0	
U	Z	Tmax	15:18:42	
U	PEZ	eS	14:45:49	
U	PEZ	eR	14:48:48	
Hi	Z	eP	14:40:02.2	c
Hi	Z	i	14:40:16.6	
Ha	Z	eP	14:39:49.1	c
Ha	Z	i	14:40:04.8	
Ha	Z	Tmax	15:16:25	
51-1/2° N., 175-1/2° W., 14:33:02 Andreanof Is. Aleutian Is. Magnitude 6				

		Feb. 7		
M	Z	iP	09:48:43.8	c
M	Z	i	09:48:57.8	
O	Z	iP	09:48:43.0	c
O	Z	i	09:48:57.1	
D	Z	iP	09:48:43.6	c
D	Z	i	09:48:57.5	
U	Z	eP	09:48:42.8	d
U	Z	i	09:48:56.7	
U	PEZ	iP	09:48:42.0	c
U	PEE	iS	09:58:23.8	
U	PEN	iS	09:58:26.6	
U	PEZ	iS	09:58:27.8	
U	PEN	iG	10:08:29	
U	PEZ	iR	10:11:11	
Hi	Z	iP	09:48:42.2	d
Ha	Z	eP	09:48:52.1	c
4° S., 81-1/2° W., 09:36:51 Coast of Peru Magnitude 7-1/4				

Table 5.--Distant earthquakes--Continued

Feb. 7

M	Z	iP	10:21:22.0	d
O	Z	iP	10:21:22.6	d
D	Z	iP	10:21:22.0	d
U	Z	iP	10:21:24.1	d
Hi	Z	iP	10:21:24.1	
Ha	Z	iP	10:21:15.9	d

16° N., 146° E., 10:11:39
Mariana Is.

Feb. 8

M	Z	iP	05:54:13.2	c
O	Z	iP	05:54:13.0	c
U	Z	iP	05:54:13.5	c
Hi	Z	iP	05:54:16.7	c
Ha	Z	iP	05:53:19.8	c

23° S., 180°, 05:46:15
South of Fiji
h = 600

Feb. 9

M	Z	eP	04:49:28.9
O	Z	eP	04:49:33.3
D	Z	e	04:49:34.3
U	Z	iP	04:49:33.2
Hi	Z	eP	04:49:28.0

50-1/2° N., 177-1/2° W., 04:42:33
Andreanof Is. Aleutian Is.

Feb. 9

M	Z	eP	21:22:55.9
O	Z	e	21:22:55.6
D	Z	e	21:22:55.5
U	PEZ	eR	21:38:37
Hi	Z	iP	21:22:57.6
Hi	Z	epP	21:23:18.1
Ha	Z	eP	21:22:53.5

5° S., 154° E., 21:13:18
Solomon Is.
h = 100

Table 5.--Distant earthquakes--Continued

Feb. 11

M Z iP 14:16:50.4 c

O Z iP 14:16:49.5 c

16° N., 97° W., 13:52:13
Coast of Oaxaca, Mexico
Magnitude 6

Feb. 11

U PEZ eR 21:53:39

15° S., 173-1/2° W., 21:36:46
Samoa Is. region

Feb. 15

U PEZ eR 04:59:12

59-1/2° S., 26° W., 04:42:35
Sandwich Is.
Magnitude 6-3/4

Feb. 17

M Z iP 12:09:52.1 c

O Z iP 12:09:53.0 c

D Z iP 12:09:53.1 c

U Z eP 12:09:52.7 d

U PEZ iS 12:15:21

U PEE iQ 12:16:59

U PEZ iR 12:17:08

51-1/2° N., 171° W., 12:03:05
Fox Is., Aleutian Is.
Magnitude 6 to 6-1/4

Feb. 23

U PEZ eR 02:26:05

5-1/2° S., 150° E., 01:58:38
New Britain

Feb. 23

M Z iP 10:39:53.6

53-1/2° N., 159° E., 10:31:14
Kamchatka
h = 100

Feb. 27

M Z eP 21:07:43.1

U PEZ eR 21:28:13

27-1/2° N., 129° E., 20:56:30
Ryukyu Is.

Mar. 1

M Z eP 17:00:33.6

U Z iP 17:00:35.2

U PEZ eP 17:00:38

U PEN eS 17:10:00

U PEN iQ 17:18:44

U PEZ iR 17:21:55

Hi Z iP 17:00:39.5

Ha Z iP 17:00:33.7

1/2° S., 134-1/2° E., 16:49:13
Coast of New Guinea
Magnitude 7
h = 100

Table 5.--Distant earthquakes--Continued

Mar. 3

Ha Z Tmax 00:09:41

37-1/2° N., 122° W., 23:27:15
Coast of California
Magnitude 4.9

Mar. 12

U PEZ eS 01:47:32

U PEN eQ 01:53:10

U PEZ iR 01:56:20

7° N., 145° E., 01:29:07
Caroline Is.
Magnitude 6

Mar. 17

M Z eP 08:36:27.8

O Z iP 08:36:26.2 d

D Z iP 08:36:25.5 d

U Z eP 08:36:26 d

U PEZ eP 08:36:27 d

U PEZ eR 09:01:37

Hi Z eP 08:36:27.4 c

27-1/2° N., 130° E., 08:25:22
Ryuku Is.
Magnitude 5-3/4 to 6

Mar. 19

U PEZ eR 09:13:20

35° N., 36° W., 08:25:32
North Atlantic
Magnitude 6-1/4

Mar. 23

U PEN eQ 07:26:43

40° N., 118° W., 07:10:22
Western Nevada
Magnitude 6-1/4

Mar. 24

U PEZ eR 17:45:17

34° N., 142° E., 17:18:24
Coast of Honshu, Japan

Mar. 28

Hi Z iP 19:54:40.2

20° S., 178-1/2° W., 19:47:07
Fiji Is.
Magnitude 5-3/4 to 6
h = 600

Mar. 31

U PEE eQ 07:38:45

15° S., 173° W., 07:20:45

Samoa Is.
Magnitude 6

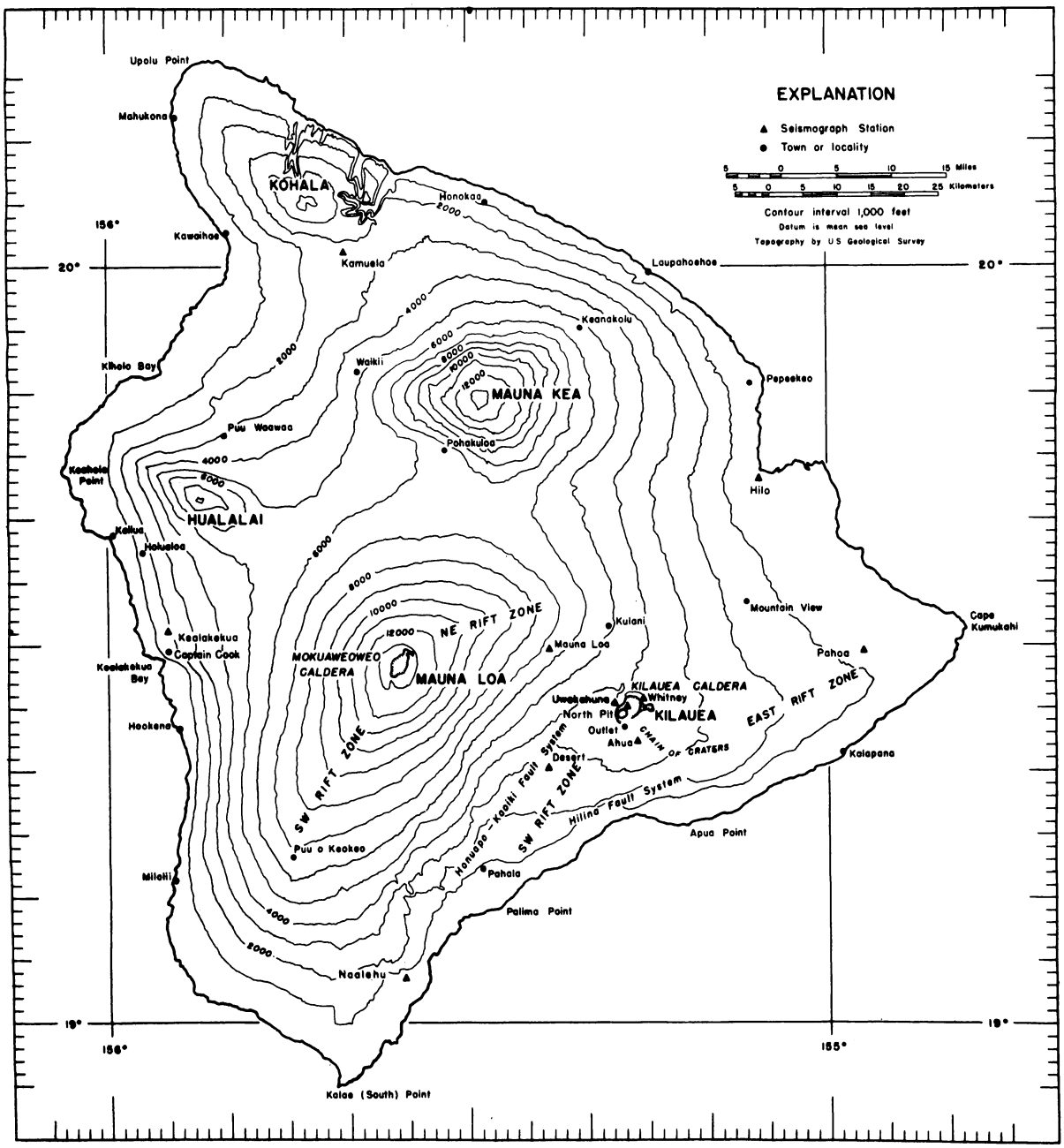

Figure 2.--Map of the Island of Hawaii showing seismograph stations operated by the Geological Survey and localities mentioned in the text. Epicenters of local earthquakes are given in terms of geographic coordinates, which are indicated at the edges of the map.

Table 6.--U.S. Geological Survey seismograph stations in Hawaii

Station	Symbol	Location		Altitude (m) above sea level	Equipment (Z, vertical; N, north-south; E, east-west)
		Latitude N.	Longitude W.		
Uwekahuna (Hawaiian Volcano Observatory).	U	19°25.4'	155°17.6'	1,240	Long-period Press-Ewing: N, E, Z; (seismometer and galvanometer periods are 15 and 90 seconds, respectively). Short-period Sprengnether: E, Z. HVO-1: Z1/. Short-base liquid-level tiltmeter.
Mauna Loa----------	M	19°29.8'	155°23.3'	2,010	Remote recording HVO-2: Z2/.
Outlet----------	O	19°23.4'	155°16.9'	1,080	Remote recording HVO-2: Z. Short-base liquid-level tiltmeter.
Desert----------	D	19°20.2'	155°23.3'	815	Remote recording HVO-2: Z.
North Pit----------	N	19°24.9'	155°17.0'	1,115	Remote recording HVO-2: Z.
Whitney----------	W	19°25.9'	155°15.7'	1,210	Bosch-Omori: N, E; (seismometer period 9 seconds). Short-base liquid-level tiltmeter.
Hilo----------	Hi	19°43.2'	155°05.3'	20	HVO-1: Z. Wood-Anderson: N, E. Operated by Sister Thecla at St. Joseph's School.

Table 6.--U.S. Geological Survey seismograph stations in Hawaii--Continued

Station	Symbol	Location		Altitude (m) above sea level	Equipment (Z, vertical; N, north-south; E, east-west)
		Latitude N.	Longitude W.		
Naalehu----------	Na	19°03.8'	155°35.2'	205	Loucks-Omori: N, E; (seismometer period 3 seconds). Operated by Mr. Alfred Kahakua at Naalehu School.
Pahoa----------	Pa	19°29.7'	154°56.8'	205	Loucks-Omori: N, E; (seismometer period 3 seconds). Operated by Mr. Kongo Kimura at Pahoa School.
Kamuela----------	Ka	20°01.3'	155°40.3'	815	Loucks-Omori: N, E; (seismometer period 3 seconds). Operated by Mr. T. C. Mills at Waimea School.
Konawaena----------	Ko	19°30.8'	155°55.1'	495	Hawaiian-type seismograph: N, E; (seismometer period 9 seconds). Operated by Mr. Howard Tatsuno at Konawaena School.
Haleakala, Maui----	Ha	20°46.0'	156°15.0'	2,090	HVO-1: Z. Wood-Anderson: N, E. Operated by the staff of Hawaii National Park at Haleakala, Maui.

1/ HVO-1 is a moving-coil, hinged, vertical-component seismograph with seismometer and galvanometer periods of 0.5 second. Overdamping of both seismometer and galvanometer is used to control the strong galvanometer reaction. This seismograph has a peak magnification of about 20,000 at a period of 0.25 second. Recording is optical, on photographic paper.

Table 6.--U.S. Geological Survey seismograph stations in Hawaii--Continued

2/ HVO-2 is a moving-coil, vertical-component seismograph with a seismometer period of 0.8 second. Its signal is transmitted over telephone wires to the Hawaiian Volcano Observatory, where it is recorded on smoked paper. The response of this seismograph is similar to that of HVO-1. Records from these seismographs at the M, O, and D stations are recorded on a 3-component drum to permit an accurate comparison of arrival times at these stations.

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

HAWAIIAN VOLCANO OBSERVATORY

SUMMARY 14

April-June 1959

by

J. P. Eaton and H. L. Krivoy

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HAWAIIAN VOLCANO OBSERVATORY SUMMARY 14

By J. P. Eaton and H. L. Krivoy

Chronological summary

Releveling of tilt bases around Kilauea caldera in late April and early May disclosed that the pattern of tilting around the caldera during February, March, and April was somewhat more complicated than during the preceding few months. Tilting rates were moderate at all stations, averaging about 4 microradians per month, with a maximum of 10.3 at Sand Spit and a minimum of 1.1 at Uwekahuna. All stations except Uwekahuna and Tree Molds, both on the northwest rim of the caldera, tilted away from an east-northeast to west-southwest axis just southeast of the caldera. Moderate tumescence along this axis and a slight relative collapse along the northwest rim of the caldera are suggested by the tilt pattern.

During April, 138 earthquakes were recorded at Uwekahuna. Three of these, with magnitudes between 2 and 2.5, occurred beneath the summit of Kilauea at depths of 10 to 30 km.

The largest earthquake in the Hawaiian region during April came from a focus 35 km deep and 20 km east of the summit of Haleakala volcano on Maui at 17^h34^m on April 24. It has a magnitude of 3.5.

No earthquakes were reported felt during April.

Only 137 earthquakes were recorded at Uwekahuna during May, and none was reported felt.

On May 5 a small swarm of tiny, deep earthquakes accompanied by about 4 hours of very weak spasmodic tremor stemmed from a zone about 10 km north of Kilauea caldera and 65 km deep. The largest of these earthquakes occurred at 17^h51^m and had a magnitude of only 2.2. About 60 distinct earthquakes from this swarm appeared on the Mauna Loa seismograph.

At 14^h28^m on May 7 a magnitude 3.1 earthquake originated about 5 km southwest of Halemaumau at a depth of about 30 km. The largest earthquake in Hawaii during May originated about 3 km southwest of Halemaumau at a depth of about 30 km at 06^h35^m on the 20th. Although it had a magnitude of 3.5, it was not reported felt.

The number of earthquakes recorded at Uwekahuna declined to 95 during June. Five of these, with magnitudes between 2 and 2.5, occurred beneath the summit region of Kilauea at depths ranging from 15 to 30 km.

Four earthquakes were felt in Hawaii during June. The earthquake felt on Maui at 04^h31^m on June 3 originated beneath the sea about 5 km east of Huelo Point. Its magnitude was 3.3. A magnitude 2.8 earthquake that occurred about 5 km northwest of the Desert seismograph at 21^h26^m on June 9 was felt at Kilauea caldera. An earthquake from a focus 15 km deep beneath the southwest end of Mokuaweoweo caldera at 20^h01^m on June 24 was felt from Kilauea caldera to Capt. Cook. It had a magnitude of 3.7.

The largest earthquake in the Hawaiian region during June originated beneath the sea about 50 km west of Milolii at 12^h17^m on the 26th. It had a magnitude of 4.2 and was felt in Capt. Cook.

Tilting of the ground around Kilauea caldera

Tilting of the ground around the summit of Kilauea is monitored daily by a short-base water-tube tiltmeter in Uwekahuna vault, and at irregular intervals it is measured on a regional scale by means of a network of field tilt bases and a portable water-tube tiltmeter (tables 1 and 2). The attitude of the ground surface at each tilt base is reported in terms of north-south and east-west tilt coordinates. Both coordinates at each station were arbitrarily set equal to 500 when measurements at that station were begun. Increasing tilt coordinates correspond to northward and eastward tilting of the earth's surface, that is, to a relative subsidence toward the north and east. A 1-unit change in coordinate corresponds to a 1 microradian (1 mm per km) tilt in the direction indicated.

Seismic summary

Events recorded by the U.S. Geological Survey seismograph network in Hawaii fall into two categories: local earthquakes and tremor originating in the region of the Hawaiian Islands, usually within 100 km of the Observatory, and distant earthquakes originating farther than 3,000 km from Hawaii. As an index of seismic activity at Hawaiian volcanoes, weekly totals of earthquakes with magnitudes of 2.5 or greater, earthquakes with magnitudes less than 2.5, and minutes of continuous tremor, all recorded on the HVO-1 seismograph at Uwekahuna, are reported in table 3. Earthquakes of magnitude 2.5 or greater are generally sufficiently well recorded to be located; they are listed individually in table 4. Data on identifiable phases from distant earthquakes are listed in table 5.

Locations of the seismograph stations are shown on figure 2; and essential data on the stations were given in Summary 13, table 6.

Table 1.--Tilt coordinates at Uwekahuna vault, April-June 1959

Date	N-S	E-W	Date	N-S	E-W
Apr. 5	512	464	May 24	515	470
12	512	466	31	515	469
19	513	468	June 7	515	466
26	513	469	14	515	470
May 3	513	471	21	515	474
10	515	469	28	518	474
17	514	471			

Table 2.--Tilt coordinates and changes at tilt bases around Kilauea caldera (see fig. 1)

Tilt base (location)	Date (1959)	Tilt coordinates		Rate and direction of tilting since last reading (10^{-6} rad/mo)		Date of last reading (1959)
		N-S	E-W			
Uwekahuna (19°25.5' N., 155°17.4' W.)	Apr. 27	544.2	469.8	1.1	N. 84° W.	Feb. 2
Tree Molds (19°26.3' N., 155°17.3' W.)	Apr. 28	502.1	498.7	2.4	S. 2° W.	Feb. 5
Summer Camp (19°24.6' N., 155°15.6' W.)	May 4	517.7	528.0	3.3	N. 5° E.	Feb. 8
Sand Spit (19°24.1' N., 155°16.8' W.)	May 4	531.1	482.8	10.0	N. 23° W.	Feb. 8
Kalihipaa (19°21.4' N., 155°15.3' W.)	Apr. 28	487.3	502.4	3.4	S. 6° W.	Feb. 9
Keamoku (19°25.1' N., 155°19.0' W.)	May 12	512.8	498.6	5.4	N. 6° W.	Mar. 2
Kamokukolau (19°22.7' N., 155°16.6' W.)	May 5	489.2	506.5	6.1	S. 31° E.	Mar. 4

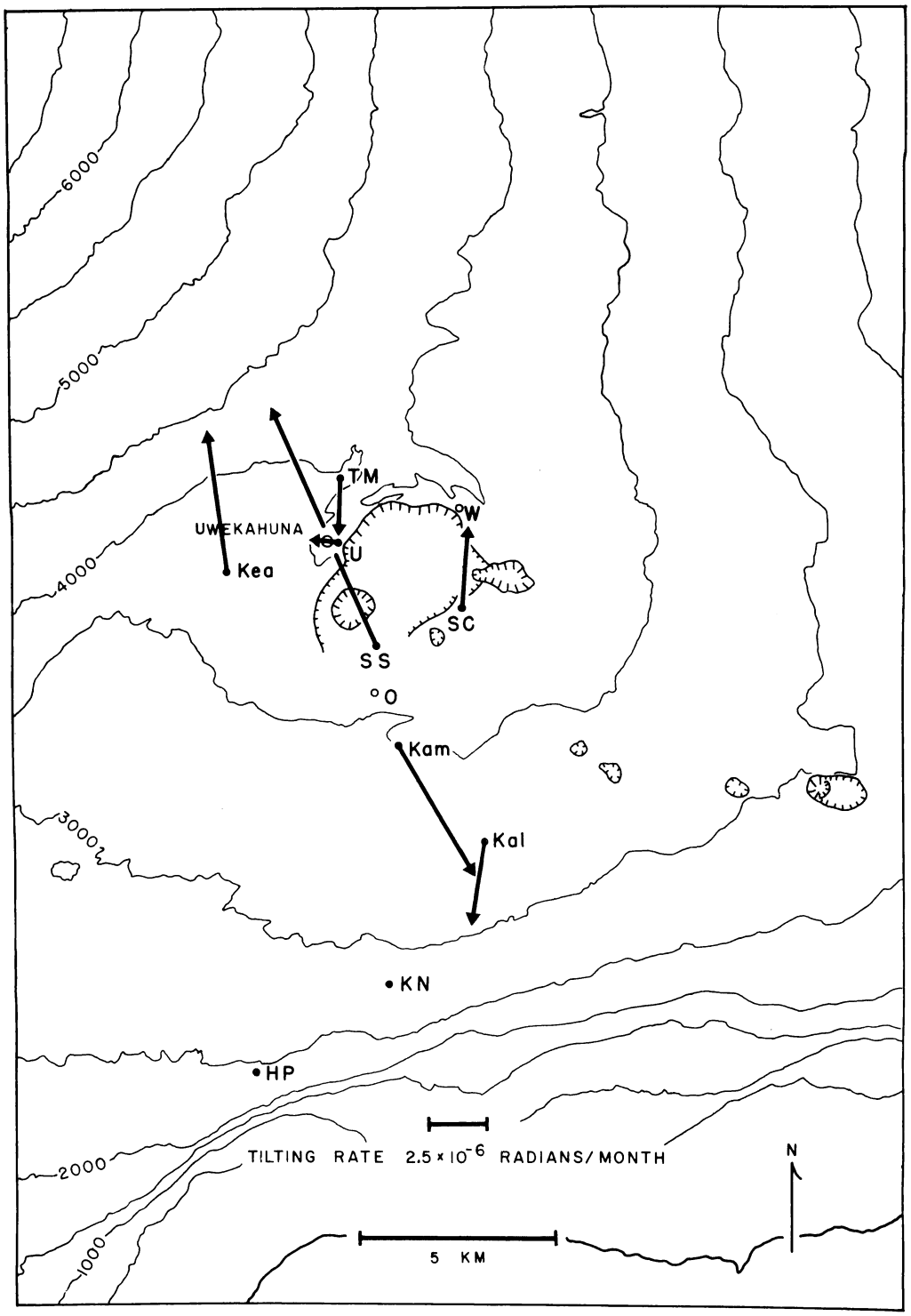

Figure 1.--Tilting of the ground around Kilauea caldera, Feb. 6, 1959, to May 5, 1959. The vector depicting tilting at a given tilt base points in the direction of maximum relative subsidence and has a length proportional to the rate of tilting during the measurement interval. Closed circles represent field tilt bases; open circles, short-base water-tube tiltmeters.

Table 3.--Local earthquakes and tremor recorded by the HVO-1 seismograph at Uwekahuna, April-June 1959

Week beginning	Number of earthquakes		Minutes of continuous tremor
	Magnitude $\geq$2.5	Magnitude $<$2.5	
April 5	1	30	0
12	2	21	0
19	2	37	0
26	1	29	9
May 3	2	35	240
10	0	24	0
17	2	31	10
24	4	27	0
31	2	20	4
June 7	3	17	0
14	1	24	10
21	4	20	0
28	1	14	25

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, April-June 1959

[Except for smaller earthquakes of special interest, only earthquakes with magnitudes of 2.5 or greater are listed. Time is Hawaiian standard]

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Apr. 4	07	23	18	2.8	19°26'	155°27'	10 km SW. of Mauna Loa seismograph.	Depth about 5 km.
Apr. 5	00	10	09	3.3	20°54'	154°57'	About 130 km N. of Hilo---	Depth about 15 km.
Apr. 12	23	49	28	2.8	19°20'	155°14'	8 km SE. of the Outlet seismograph.	Depth about 3 km.
Apr. 13	17	38	30	2.5	19°27'	155°26'	7 km SW. of Mauna Loa seismograph.	Depth about 8 km.
Apr. 20	10	31	42	2.7	19°59'	155°27'	12 km S. of Honokaa-------	Depth about 10 km.
Apr. 24	17	33	50	3.5	20°43'	156°03'	20 km E. of summit of Haleakala, Maui.	Depth about 35 km.
Apr. 28	15	19	55	3.1	20°02'	155°30'	8 km SSW. of Honokaa------	Depth about 10 km.
May 7	14	21	37	3.1	19°22'	155°18'	3 km SW. of the Outlet seismograph.	Depth about 30 km.
May 7	15	16	38	2.5	19°44;	155°23'	15 km E. of Pohakuloa-----	Depth about 15 km.
May 20	06	35	00	3.5	19°23'	155°19'	3 km SW. of Halemaumau----	30 km deep.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, April-June 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
May 23	11	35	03	2.8	19°20'	155°50'	West flank of Mauna Loa about 25 km SW. of Mokuaweoweo.	Depth about 5 km.
May 24	15	28	27	3.0	19°10'	156°20'	About 45 km W. of Milolii-	Depth about 15 km.
May 24	19	59	25	2.7	19°21'	155°34'	13 km. S. of Mokuaweoweo--	Depth about 5 km.
May 26	08	41	03	3.0	19°59'	155°40'	5 km S. of Kamuela-------	Depth about 30 km.
May 26	08	41	02	2.6	20°11'	155°31'	20 km NE. of Kamuela------	Depth about 15 km.
June 3	04	31	29	3.3	20°55'	156°10'	5 km E. of Huelo Point, Maui. Felt on the island of Maui.	Depth about 15 km.
June 6	05	08	28	3.4	20°03'	155°40'	5 km N. of Kamuela beneath the summit region of Kohala Mountain.	35 km deep.
June 7	20	41	01	2.5	19°05'	155°24'	Beneath sea 20 km E. of Naalehu.	Depth about 10 km.
June 7	21	21	05	2.7	19°26'	155°28'	10 km SW. of Mauna Loa seismograph.	Depth about 5 km.
June 9	21	25	50	2.8	19°23'	155°25'	5 km NW. of Desert seismo- graph. Felt at Kilauea caldera.	Depth about 5 km.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, April-June 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
June 16	09	06	15	3.3	19°24'	155°28'	10 km NW. of Desert seismograph.	Depth about 5 km.
June 22	14	28	09	3.0	19°19'	155°45'	10 km N. of Puu o Keokeo--	At shallow depth.
June 24	20	01	18	3.7	19°26'	155°36'	At SW. end of Mokuaweoweo caldera. Felt from Kilauea caldera to Capt. Cook.	Depth about 15 km.
June 25	16	11	30	2.6	19°15'	155°31'	7 km NW. of Pahala--------	Depth about 5 km.
June 26	12	16	34	4.2	19°13'	156°22'	50 km W. of Milolii. Felt in Capt. Cook.	Depth about 15 km.
June 28	02	52	57	2.6	19°29'	155°56'	Kealakekua fault at Kealakekua Bay.	At shallow depth.

Table 5.--Distant earthquakes

[Times are reported in Greenwich civil time, which is 10 hours faster than Hawaiian standard time. A "c" following the time of P indicates that the first motion was a compression; a "d," that it was a dilatation. Station symbols, locations, and instrumentation were presented in Summary 13, table 6. Locations of epicenters, origin times, focal depths, and magnitudes are from the notices of Preliminary Determination of Epicenters published by the U.S. Coast and Geodetic Survey]

Apr. 1

Hi	Z	iP	14:57:29.0	

18-1/2° S., 169° W.
14:48:34.
New Hebrides Is.
h about 200 km.

Apr. 1

Hi	Z	iP	23:43:20.0	

6° S., 154° E.
23:33:45.
Solomon Is.
h about 100 km.

Apr. 5

M	Z	eP	21:14:44.1	
O	Z	eP	21:14:44.1	
U	Z	eP	21:14:43.4	

15-1/2° S., 167-1/2° E.
21:05:54.
New Hebrides Is.
h about 100 km.

Apr. 5

Hi	Z	iP	23:39:56.8	
U	PEN	eQ	23:54:30	
U	PEZ	eR	23:58:00	

5-1/2° S., 146° E.
23:29:25.
Near north coast of New Guinea.

Apr. 6

M	Z	iP	14:25:33.9	
O	Z	iP	14:25:33.7	
D	Z	iP	14:25:33.1	
U	Z	iP	14:25:32.5	
U	PEN	iS	14:36:14	
U	PEN	eSS	14:42:00	
U	PEN	eQ	14:48:40	
U	PEZ	eR	14:53:46	
Hi	Z	eP	14:25:35.1	
Ha	Z	iP	14:25:22.2	

10° S., 120-1/2° E.
14:12:36.
Sumba Is.
Magnitude 6-1/4.

Apr. 8

M	Z	iP	01:32:38.3	d
O	Z	iP	01:32:37.8	d
D	Z	eP	01:32:36.5	d
U	Z	iP	01:32:38.1	d
Hi	Z	iP	01:32:40.5	c
Ha	Z	eP	01:32:42.8	d

Table 5.--Distant earthquakes--Continued

Apr. 8--Continued

32-1/2° S., 179-1/2° E.
01:23:26.
Kermadec Is. region.
h about 400 km.
Magnitude 6 to 6-1/4.

Apr. 9

U	PEZ	eR	07:20:20	

36° S., 77° E.
06:18:34.
Kerguelen Is. region.

Apr. 9

U	PEN	eQ	18:06:18	
U	PEZ	eR	18:08:23	

7° N., 82° W.
17:36:10.
South of Panama.
Magnitude 6-1/4 to 6-1/2.

Apr. 10

M	Z	iP	05:55:53.1	d
O	Z	iP	05:55:53.0	d
D	Z	iP	05:55:52.1	d
U	Z	iP	05:55:53.1	d
Hi	Z	iP	05:55:56.6	d

25° S., 178-1/2° E.
05:47:34.
South of Fiji Is.
h about 600 km.

Apr. 11

M	Z	iP	11:40:51.4
O	Z	iP	11:40:51.4
D	Z	eP	11:40:50.5

1° S., 128° E.
11:28:50
Spice Is.

Apr. 12

M	Z	iP	10:04:30.9
U	Z	eP	10:04:28.6
U	PEZ	eS	10:12:56
U	PEZ	eR	10:20:30
Hi	Z	iP	10:04:28.2

17-1/2° N., 95° W.
09:54:51.
Mexico. Damage at Cordoba.
h about 100 km.
Magnitude 6-1/4.

Apr. 12

M	Z	iP	15:34:09.8
U	Z	eP	15:34:09.7
U	PEE	eS	15:44:26
U	PEZ	eR	15:56:38
Hi	Z	eP	15:34:10.5

4-1/2° S., 134° E.
15:22:33.
Near coast of New Guinea.
h about 100 km.

Table 5.--Distant earthquakes--Continued

Apr. 12

M	Z	eP	21:01:30.3
O	Z	eP	21:01:29.8
D	Z	eP	21:01:29.9
U	Z	iP	21:01:30.7
U	PEZ	eS	21:07:27
U	PEZ	iR	21:11:09
Hi	Z	iP	21:01:35.1

15-1/2° S., 173° W.
20:54:00.
Samoa Is. region. Felt at Apia.
Magnitude 6 to 6-1/4.

Apr. 14

U	PEZ	eR	03:12:07

24° N., 109-1/2° W.
02:53:04.
Gulf of California.
Magnitude 5-1/4 to 5-1/2.

Apr. 14

M	Z	iP	07:27:48.1
O	Z	iP	07:27:48.7
D	Z	iP	07:27:49.3
U	Z	iP	07:27:48.0
Hi	Z	iP	07:27:45.6

57-1/2° N., 155° W.
07:20:28.
Alaska Peninsula.
h about 60 km.

Apr. 15

U	PEZ	eR	00:40:52

41-1/2° N., 143° E.
00:15:21.
Near south coast of Hokkaido, Japan.

Apr. 16

M	Z	iP	07:35:36.1	d
O	Z	iP	07:35:35.8	d
D	Z	e	07:35:35.1	
U	Z	iP	07:35:35.9	d
Hi	Z	iP	07:35:38.4	d

23-1/2° S., 179° E.
07:27:27.
South of Fiji Is.
h about 550 km.

Apr. 16

M	Z	iP	16:23:53.9
O	Z	iP	16:23:54.2
D	Z	e	16:23:53.3
U	Z	eP	16:23:53.7
U	PEZ	eR	16:40:31
Hi	PEZ	eP	16:23:54.8

12-1/2° N., 143° E.
15:13:56.
Mariana Is. region.
h about 100 km.
Magnitude 6-1/2.

Table 5.--Distant earthquakes--Continued

Apr. 18

Hi	Z	iP	06:27:37.1

4-1/2° S., 153-1/2° E.
06:18:00.
New Ireland region. Felt at Londolovit and Rabaul.
h about 100 km.

Apr. 19

U	PEZ	eR	08:09:30

45° S., 82° W.
07:26:15.
Pacific Ocean.
Magnitude 6.

Apr. 19

M	Z	iP	15:10:52.8
O	Z	iP	15:10:52.9
D	Z	iP	15:10:53.7
U	Z	eP	15:10:52.3
U	PEZ	eR	15:20:59

58° N., 152-1/2° W.
15:03:26.
Near Kodiak Is., Alaska.
Magnitude 6-1/4.

Apr. 20

Hi		eP	03:28:02.4
U	PEE	eS	03:46:15
U	PEZ	eSS	03:50:25
U	PEN	eG	03:50:01
U	PEZ	eR	03:55:37

Apr. 20--Continued

6° S., 149-1/2° E.
03:27:52.
New Britain. Felt at Kandrian and Walindi.
h about 100 km.
Magnitude 6.

Apr. 21

M	Z	iP	12:50:00.8
D	Z	iP	12:50:02.0

56° N., 162-1/2° W.
12:42:50.
Bristol Bay.

Apr. 22

M	Z	iPn	11:03:21.1
O	Z	iPn	11:03:22.7
D	Z	iPn	11:03:23.1
U	Z	eP	11:02:06.3
U	Z	iPn	11:03:21.5
U	Z	Tmax	11:39:22
Hi	Z	e	11:02:19
Hi	Z	iPn	11:03:19.8
Hi	Z	Tmax	11:39:13
Ha	Z	iPn	11:03:02.2
Ha	Z	Tmax	11:37:29

54° N., 167° W.
10:55:05.
Fox Is., Aleutian Is.
Magnitude 6.

Table 5.--Distant earthquakes--Continued

Apr. 22

U	PEZ	eR	21:02:38	

36-1/2° S., 97-1/2° W.
20:26:46.
Pacific Ocean.
Magnitude 5-3/4 to 6.

Apr. 24

U	PEZ	eR	10:02:21	

11-1/2° N., 86-1/2° W.
09:31:33.
Near coast of Nicaragua.
Magnitude 6-1/4 to 6-1/2.

Apr. 24

M	Z	iP	18:07:39.3	d
O	Z	iP	18:07:38.6	d
D	Z	iP	18:07:37.5	d
U	Z	iP	18:07:38.2	c
U	PEZ	iP	18:07:38.5	c
U	PEN	iS	18:15:24.2	
U	PEZ	eSS	18:19:03	
U	PEZ	iR	18:29:05	
Hi	Z	eP	18:07:40.2	c
Ha	Z	eP	18:07:44.5	c

31° S., 178° W.
17:57:58.
Kermadec Is.
Magnitude 6-3/4 to 7.

Apr. 26

O	Z	iP	20:52:09.9	c
D	Z	iP	20:52:09.4	c
U	Z	iP	20:52:09.5	d
U	PEZ	iP	20:52:09.3	c
U	PEZ	ipP	20:52:37	
U	PEZ	isP	20:52:46	
U	PEZ	ePP	20:54:44	
U	PEZ	iS	21:01:44	
U	PEZ	iPS	21:02:22	
U	PEZ	eSS	21:06:02	
U	PEN	iG	21:09:40	
U	PEZ	iR	21:14:50	
Hi	Z	iP	20:52:09.8	c
Hi	N	eS	21:01:40	
Ha	Z	iP	20:52:03.0	c
Ha	N	eS	21:01:31	

25° N., 122-1/2° E.
20:40:38.
Near northeast coast of Formosa.
Two killed and minor damage at Taipei.
h about 150 km.
Magnitude 7-1/2 to 7-3/4.

Apr. 27

M	Z	eP	10:00:17.0	
O	Z	eP	10:00:17.5	

Table 5.--Distant earthquakes--Continued

Apr. 27--Continued

D	Z	eP	10:00:14.7	
U	Z	eP	10:00:17.4	
Hi	Z	eP	10:00:19.2	

7° S., 129° E.
09:48:09.
Banda Sea.

Apr. 27

M	Z	iP	12:59:29.7	
O	Z	iP	12:59:29.7	
U	Z	eP	12:59:26.9	

1/2° S., 124° E.
12:47:27.
Celebes region.
h about 200 km.

Apr. 28

M	Z	iP	11:19:39.0	d
O	Z	iP	11:19:38.1	d
D	Z	iP	11:19:38.7	d
U	Z	iP	11:19:38.3	d
U	PEZ	iP	11:19:37.5	c
U	PEZ	iS	11:27:52.0	
U	PEZ	eSS	11:31:46	
U	PEN	eG	11:34:24	
U	PEZ	iR	11:36:49	
Hi	Z	iP	11:19:36.8	d
Ha	Z	iP	11:19:47.9	d

Apr. 28--Continued

15° N., 93° W.
11:09:30.
Mexico-Guatemala border.
Magnitude 6-1/2 to 6-3/4.

May 1

Hi	Z	iP	15:06:57.4	

5° S., 154° E.
14:56:57.
Solomon Is. region. Felt at Londolovit and Rabaul.
h about 60 km.

May 3

U	PEZ	eR	05:11:33	

12-1/2° N., 87-1/2° W.
04:41:24.
Near coast of Nicaragua. Felt at San Vicente, El Salvador.
h about 100 km.

May 4

M	Z	iP	07:24:21.6	d
O	Z	iP	07:24:22.5	d
D	Z	iP	07:24:22.9	d
U	Z	iP	07:24:22.4	d
U	PEZ	iP	07:24:22.4	d
U	Z	ePn	07:27:01.1	
U	PEN	iS	07:31:15	
U	PEN	eSS	07:34:00	
U	PEZ	iSSS	07:34:56	
U	PEE	iQ	07:35:00	

Table 5.--Distant earthquakes--Continued

May 4--Continued

U	PEZ	iR	07:36:49	
U	Z	Tmax	08:17:24	
Hi	Z	iP	07:24:21.0	d
Hi	Z	ePn	07:27:07	
Hi	E	eS	07:31:26	
Hi	E	eQ	07:35:40	
Hi	N	iR	07:37:36	
Hi	Z	Tmax	08:16:42	
Ha	Z	iP	07:24:10.2	d
Ha	Z	iPP	07:26:09.6	
Ha	Z	ePn	07:26:43	
Ha	Z	ePPP	07:26:47	
Ha	N	eS	07:31:05	
Ha	E	eQ	07:35:12	
Ha	N	iR	07:36:51	
Ha	Z	Tmax	08:22:02	

52-1/2° N., 159-1/2° E.
07:15:42.
Near east coast of Kamchatka;
1 killed and 13 injured.
h about 60 km.
Magnitude 8.

May 5

M	Z	eP	19:13:04.4	
D	Z	eP	19:13:05.0	

May 5--Continued

U	Z	eP	19:13:07.2	
U	PEZ	eS	19:20:23	
U	PEZ	eR	19:26:14	

53° N., 159° E.
19:04:16.
Kamchatka aftershock.
Magnitude 6.

May 5

M	Z	iP	17:36:45.3	
O	Z	iP	17:36:44.7	
Hi	Z	iP	17:36:48.8	

18° S., 179° W.
17:29:26
Fiji Is.
h about 600 km.

May 7

U	PEZ	eS	00:21:50	
U	PEZ	iR	00:30:27	

3-1/2° S. 148-1/2° E.
00:03:24.
Bismarck Sea.
Magnitude 6 to 6-1/4.

May 7

U	PEZ	eR	11:44:15	

3-1/2° S., 150° E.
11:17:16.
Bismarck Sea.

Table 5.--Distant earthquakes--Continued

May 7

M	Z	iP	20:35:18.1

8-1/2° S., 123-1/2° E.
20:22:41.
Flores Is.

May 8

M	Z	eP	11:43:30.8
O	Z	eP	11:43:30.0
D	Z	eP	11:43:31.6
U	PEZ	eS	11:50:35
U	PEZ	iR	11:56:37

53-1/2° N., 160-1/2° E.
11:34:50.
Near east coast of Kamchatka.
h about 60 km.
Magnitude 6.

May 10

U	PEZ	eR	00:24:35

45° N., 149° E.
23:57:09 (May 9).
Kurile Is.

May 12

M	Z	eP	05:05:55.4
O	Z	eP	05:05:54.9
D	Z	eP	05:05:53.7
U	PEZ	eP	05:05:49
U	PEN	iS	05:12:36
U	PEE	iQ	05:15:51
U	PEZ	iR	05:17:56

May 12--Continued

Hi	N	eR	05:17:42

54-1/2° N., 168° E.
04:57:35.
Komandorskie Is.
Magnitude 6-1/2.

May 12

U	PEZ	eS	21:53:05
U	PEZ	iR	21:56:34
Ha	Z	Tmax	22:24:15

51-1/2° N., 177° W.
21:40:22.
Andreanof Is., Aleutian Is.

May 12

M	Z	eP	22:07:10.7
O	Z	eP	22:07:10.9
D	Z	eP	22:07:11.8
U	PEZ	iS	22:12:36
U	PEZ	iR	22:16:12
Ha	Z	Tmax	22:43:45

51-1/2° N., 177° W.
21:59:56.
Andreanof Is., Aleutian Is.
Magnitude 6.

May 14

U	PEZ	eR	07:39:06

35-1/2° N., 24-1/2° E.
06:36:57.
Crete.
Magnitude 6-1/2.

Table 5.--Distant earthquakes--Continued

May 14

U	PEZ	eS	09:49:52
U	PEZ	iR	09:56:46

19° S., 170° E.
09:33:22.
New Hebrides Is.

May 14

U	PEZ	eS	12:05:45
U	PEZ	iR	12:12:37

19° S., 170° E.
11:49:20.
New Hebrides Is.

May 14

U	PEZ	eS	13:35:51
U	PEZ	iR	13:42:47

19° S., 170° E.
13:19:32.
New Hebrides Is.

May 16

M	Z	eP	06:26:01.0
O	Z	eP	06:26:01.3
D	Z	eP	06:26:0018
U	PEZ	eP	06:25:58
U	PEE	iS	06:33:50
U	PEZ	eSS	06:37:11
U	PEN	iQ	06:39:46
U	PEZ	iSSS	06:40:11

May 16--Continued

U	PEZ	iR	06:41:35
U	Z	Tmax	07:25:37
Hi	Z	iP	06:26:01.5
Ha	Z	eP	06:26:00
Ha	Z	Tmax	07:25:26

4-1/2° S., 153-1/2° E.
06:16:23.
New Britain. Felt at Karoola, Taliligap and Rabaul.
h about 60 km.
Magnitude 6-3/4.

May 20

M	Z	eP	01:00:05.1
O	Z	eP	01:00:03.6

23° S., 114° W.
00:50:03.
South Pacific Ocean.

May 20

M	Z	iP	11:36:05.0	
O	Z	eP	11:36:05.8	
D	Z	iP	11:36:05.4	

32-1/2° N., 136-1/2° E.
11:26:28.
South of Honshu, Japan.
h about 450 km.

May 20

M	Z	iP	19:44:32.5	c
O	Z	iP	19:44:33.1	c

Table 5.--Distant earthquakes--Continued

May 20--Continued

D	Z	iP	19:44:32.7	c
U	Z	eP	19:44:33.0	c
U	PEZ	eR	19:59:07	
Hi	Z	iP	19:44:32.7	c

44-1/2° N., 149° E.
19:35:03.
Kurile Is.

May 21

U	PEZ	eR	07:07:42	

52-1/2° N., 170-1/2° W.
06:51:40.
Fox Is., Aleutian Is.

May 21

Hi	Z	eP	11:47:47.1	
U	PEZ	ePS	12:00:11	
U	PEZ	eSS	12:05:17	
U	PEZ	eR	12:17:23	

28° S., 69° W.
11:34:23.
Northern Chile - Argentina border.
h about 60 km.
Magnitude 6.

May 24

M	Z	iP	19:27:06.9	d
O	Z	iP	19:27:06.2	d
D	Z	iP	19:27:06.9	d

May 24--Continued

U	Z	iP	19:27:06.2	d
U	PEZ	iP	19:27:07	d
U	PEZ	ipP	19:27:35	
U	PEN	iS	19:34:48	
U	PEN	isS	19:35:24	
U	PEZ	eSS	19:38:28	
U	PEN	iG	19:40:35	
U	PEZ	iSSS	19:40:48	
U	PEZ	iR	19:42:57	
Hi	Z	iP	19:27:04.4	d
Ha	Z	eP	19:27:13.2	c

17-1/2° N., 97° W.
19:17:40.
Oaxaca, Mexico; 5 killed, 10 injured, and minor property damage. Felt also in Mexico City.
h about 100 km.
Magnitude 6-3/4 to 7.

May 26

U	Z	eP	04:24:10.2
U	PEZ	eR	04:44:48
Hi	Z	eP	04:24:09.9
Ha	Z	eP	04:24:01.7

27-1/2° N., 126-1/2° E.
04:13:01.
Ryukyu Is. region.
h about 100 km.
Magnitude 6-1/2 to 6-3/4.

Table 5.--Distant earthquakes--Continued

May 29

M	Z	iP	10:51:53.6	c
O	Z	iP	10:51:53.2	c
D	Z	eP	10:51:52.4	c
U	Z	iP	10:51:53.3	c
U	PEZ	iP	10:51:54.3	c
U	PEZ	ipP	10:52:16.8	
U	PEZ	iS	10:59:42	
U	PEN	eQ	11:03:26	
U	PEZ	iSSS	11:05:01	
U	PEZ	iR	11:07:40	
Hi	Z	iP	10:51:56.3	c
Ha	Z	iP	10:51:55.9	c
Ha	Z	epP	10:52:22	

19° S., 169-1/2° E.
10:42:48.
New Hebrides Is.
h about 60 km.
Magnitude 6-1/2.

May 31

O	Z	eP	09:37:39.7	
D	Z	eP	09:37:38.9	
U	PEZ	iP	09:37:41	
U	PEZ	iS	09:45:16	
U	PEZ	eSS	09:49:06	
U	PEZ	iR	09:52:37	
U	PEE	eQ	09:54:37	

May 31--Continued

6-1/2° S., 155° E.
09:28:09.
Solomon Is.
Magnitude 6-1/2.

June 1

U	PEZ	eP	17:16:45
U	PEZ	eS	17:24:25
U	PEZ	eSS	17:28:09
U	PEZ	iR	17:31:39

6-1/2° S., 155-1/2° E.
17:07:23.
Solomon Is.
h about 100 km.

June 2

U	PEZ	eR	01:17

31-1/2° N., 131-1/2° E.
00:47:17.
Near coast of Kyushu, Japan.

June 2

U	PEZ	eR	03:44:49

25° S., 176° W.
03:23:12.
Tongo Is. region.

June 2

U	PEZ	eR	05:19:29

21° N., 121-1/2° E.
04:57:18.
Baton Is. region.

Table 5.--Distant earthquakes--Continued

June 3

U	PEZ	eR	05:59:09	

52-1/2° N., 170° W.
05:43:28.
Fox Is., Aleutian Is.

June 5

U	PEZ	eR	21:07:35	

12° N., 86-1/2° W.
20:37:15.
Near coast of Nicaragua.
h about 100 km.

June 14

M	Z	iP	00:25:09.8	c
O	Z	iP	00:25:09.1	c
D	Z	iP	00:25:09.4	c
U	Z	iP	00:25:10.0	c
U	PEZ	iP	00:25:10	d
U	PEZ	ipP	00:25:38	
U	PEZ	iPP	00:28:34	
U	PEZ	iPPP	00:29:34	
U	PEE	iS	00:35:38	
U	PEE	isS	00:36:40	
U	PEZ	eSP	00:42:29	
U	PEN	eQ	00:48:59	
U	PEZ	iSSS	00:49:41	
U	PEZ	iR	00:54:36	

June 14--Continued

Hi	Z	iP	00:25:06.5	c
Hi	Z	ipP	00:25:38.4	
Hi	Z	Tmax	02:08:00	
Ha	Z	iP	00:25:17.4	d
Ha	Z	epP	00:25:49.9	
Ha	Z	Tmax	02:09:29	

20-1/2° S., 68° W.
00:11:57.
Southwestern Bolivia; 1 killed and minor property damage in northern Chile.
h about 100 km.
Magnitude 7-1/4 to 7-1/2.

June 14

M	Z	eP	21:10:57.1
O	Z	eP	21:10:56.6

23-1/2° S., 179-1/2° W.
21:02:32.
Tonga Is. region.
h about 300 km.

June 15

M	Z	iP	02:50:34.7
O	Z	iP	02:50:35.0
D	Z	iP	02:50:34.6

25° N., 122-1/2° E.
02:38:48.
Near northeast coast of Formosa.

Table 5.--Distant earthquakes--Continued

June 18

U PEZ eR 07:26:09

55° S., 129° W.
06:50:45.
Pacific Ocean.

June 18

M Z iP 15:40:10.9

O Z iP 15:40:11.8

D Z iP 15:40:11.7

U Z eP 15:40:11.0

U PEZ eP 15:40:12.5

U PEN ePcS 15:46:49

U PEZ iS 15:47:18

U PEE iQ 15:51:29

U PEZ iR 15:53:23

Hi Z iP 15:40:10.3

54° N., 161° E.
15:31:25.
Near east coast of Kamchatka.
Magnitude 6-1/4 to 6-1/2 (sic).

June 18

M Z iP 16:07:23.8

O Z iP 16:07:24.9

D Z iP 16:07:24.8

U PEZ iR 16:20:09

Hi Z eP 16:07:20.9

June 18--Continued

54° N., 161° E.
15:58:38.
Near east coast of Kamchatka.
Magnitude 6-1/2 to 6-3/4 (sic).

June 19

Hi Z eP 20:42:20.6

U PEZ eR 20:52:53

27-1/2° N., 111° W.
20:34:40.
Gulf of California.

June 21

U PEZ eR 22:34:08

11-1/2° S., 167° E.
22:11:51.
Santa Cruz Is.

June 22

Hi Z eP 14:15:04.1

17° S., 177° W.
14:06:50.
Fiji Is.

June 23

U PEN eQ 14:50:53

39° N., 119° W.
14:35:02.
Western Nevada. Felt in
Nevada and eastern California.
Magnitude 6-1/4.

Table 5.--Distant earthquakes--Continued

June 25

U	PEZ	eR	07:31:48	

62° N., 27-1/2° W.
06:46:55.
South of Iceland.

June 27

M	Z	iP	19:14:15.0	d
O	Z	iP	19:14:14.6	d
D	Z	iP	19:14:13.8	d
U	Z	iP	19:14:14.7	d
U	PEZ	iP	19:14:14.7	d
U	PEZ	epP	19:14:49	
U	PEZ	esP	19:15:11	
U	PEN	iS	19:22:04	
U	PEN	isS	19:23:04	
U	PEZ	eSS	19:25:52	
U	PEN	eQ	19:27:48	
U	PEZ	eR	19:30:48	
Hi	Z	iP	19:14:17.4	c
Ha	Z	iP	19:14:20.8	c

33° S., 179° W.
19:04:27.
South of Kermadec Is.
h about 100 km.
Magnitude 6-3/4.

June 28

M	Z	iP	19:56:07.4	
O	Z	iP	19:56:07.8	
D	Z	iP	19:56:07.2	
U	Z	iP	19:56:08.4	
U	PEZ	iS	20:06:27	
U	PEZ	eR	20:23:34	
Hi	Z	iP	19:56:09.3	
Ha	Z	iP	19:56:05.5	

9-1/2° S., 122-1/2° E.
19:43:22.
Sawoe Sea.

June 29

U	PEZ	eP	07:25:44	
U	PEE	eS	07:33:41	
U	PEZ	eR	07:41:20	

7° S., 155-1/2° E.
07:16:07.
Solomon Is.
Magnitude 6 to 6-1/4.

June 29

M	Z	iP	13:31:31.5	d
O	Z	iP	13:31:31.6	d
D	Z	iP	13:31:30.6	d
U	Z	iP	13:31:31.7	d

Table 5.--Distant earthquakes--Continued

June 29--Continued	June 30
6° N. 126-1/2° E. 13:19:47. Near south coast of Mindanao. Philippine Is. h about 150 km.	M Z eP 10:33:12.1 O Z iP 10:33:11.5 34° S., 179° W. 10:23:17 South of Kermadec Is.

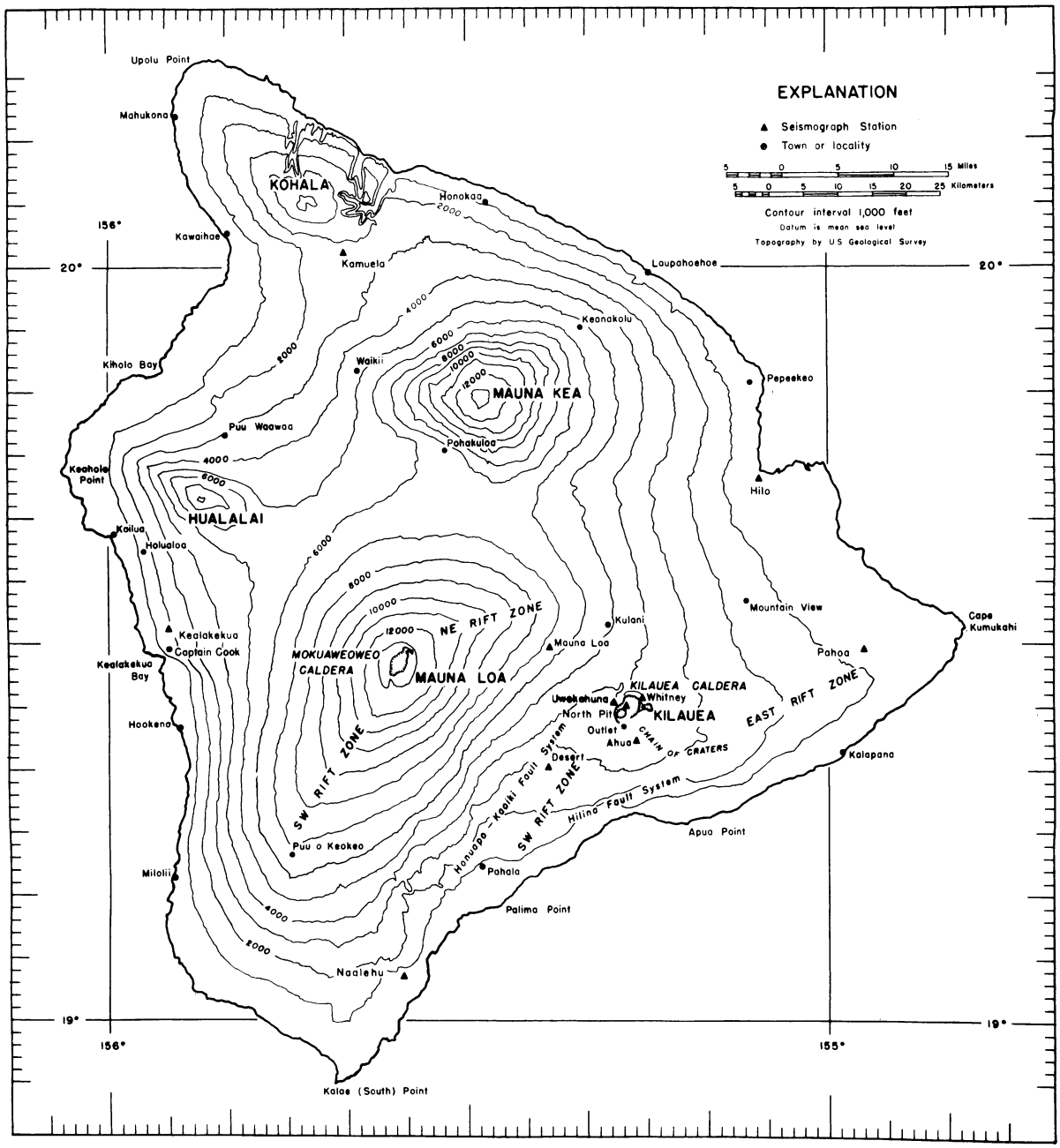

Figure 2.--Map of the Island of Hawaii showing seismograph stations operated by the Geological Survey and localities mentioned in the text. Epicenters of local earthquakes are given in terms of geographic coordinates, which are indicated at the edges of the map.

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

HAWAIIAN VOLCANO OBSERVATORY

SUMMARY 15

July-September 1959

by

J. P. Eaton and H. L. Krivoy

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July 1963

HAWAIIAN VOLCANO OBSERVATORY SUMMARY 15

By J. P. Eaton and H. L. Krivoy

Chronological summary

Tilt bases around the Kilauea summit tilted generally inward toward the south rim of Kilauea caldera between early May and mid-August. Rates of tilting were quite small at all stations, averaging slightly less than 1 microradian per month, with a maximum of 1.4 microradians per month at Sand Spit and Kamokukolau and a minimum of 0.5 microradian per month at Kalihipaa. Comparison of the present pattern of tilting (fig. 1) with that from October 1958 to February 1959 (Summary 13) reveals a striking contrast. The present tilt vectors are almost exactly reversed with respect to corresponding vectors of the earlier epoch; and present tilting rates average only about 1/3 those of the earlier epoch. Even Sand Spit, which appeared to be anomalous during the October to February epoch because it tilted toward the caldera while other stations tilted away, reversed. From May to August it tilted outward from the caldera while other stations tilted toward the caldera.

Gentle subsidence of the summit of Kilauea in response to a slow escape of magma from a reservoir beneath the south rim of the caldera is suggested by the present tilt pattern. Keamoku, a new tilt base, failed to conform to the pattern set by the rest of the stations and tilted northward away from the southwest rift zone adjacent to the caldera. Possibly, magma moving from the sub-summit reservoir into the southwest rift zone is responsible for this apparent anomaly.

Of the 107 earthquakes recorded at Uwekahuna during July, 3 were reported felt. The first of these occurred near Kealakekua at 02^h19^m on July 10 and was felt in Capt. Cook. Its magnitude was only 2.0. The second was somewhat larger, with a magnitude of 3.0, and it was also felt in Capt. Cook. It originated at a shallow depth near Hookena at 15^h27^m on July 29. The magnitude 3.5 earthquake which was felt at Kilauea caldera on July 31 at 18^h44^m was the largest Hawaiian earthquake of the month. It originated at a focus 5 km south of Mokuaweoweo caldera and 30 km deep.

An interesting group of moderately deep earthquakes with magnitudes of 2.6 to 3.5 occurred at scattered points on a broad ring around Kilauea volcano at an average distance of about 35 km from Kilauea caldera. In order of occurrence these earthquakes were:

July 7, $15^h41^m21^s$, 8 km south of Hilo and 40 km deep;
July 13, $09^h52^m01^s$, 27 km south of Cape Kumukahi and 15 km deep;
July 13, $22^h21^m00^s$, 22 km east of Naalehu and 25 km deep;
July 28, $16^h51^m01^s$, 10 km southeast of Kalapana and 10 km deep;
July 31, $18^h43^m55^s$, 5 km south of Mokuaweoweo and 30 km deep.

On June 30, 1959, D. H. Richter arrived from Denver to join the Observatory staff as Geologist to replace G. D. Fraser, who returned to Denver on July 26, 1959.

From August 14 to August 20 a great swarm of small earthquakes and many hours of accompanying spasmodic tremor emanated from a zone a few kilometers north of Kilauea caldera and about 52 km beneath the surface of the earth. About 2,400 distinct earthquakes were recorded on the Desert seismograph, which obtained the clearest record of the swarm. Spasmodic tremor was strong enough during the first day to mask many earthquakes. After about 40 hours tremor diminished markedly, and it died out altogether during the last half of the swarm.

Earthquakes of the swarm were divided into two families: (1) those for which the first arrival at Hilo followed that at Uwekahuna by less than 1.6 seconds and (2) those for which it followed by 1.6 seconds or more. An analysis of 26 of the largest earthquakes of the first family disclosed that the P wave reached Uwekahuna first, 7.5 seconds after the earthquake occurred. Arrival times of P at other stations minus its arrival time at Uwekahuna were as follows: Outlet, +0.1 sec.; Desert, +0.4 sec.; Mauna Loa, +0.4 sec.; Hilo, +1.3 sec.; Haleakala, +16.4 sec. These data fixed the focus of this group of quakes at 19°29' N., 155°18' W., at a depth of 54 km. A similar analysis of 28 earthquakes of the second family indicated that P reached Uwekahuna 6.9 seconds after the origin time. Additional times required for P to reach other stations were: Outlet, +0.1 sec.; Mauna Loa, +0.4 sec.; Desert, +0.5 sec.; Hilo, +1.8 sec.; Haleakala, +16.7 sec. These data placed the focus of the second family of earthquakes at 19°28' N., 155°19' W. at a depth of 49 km, about 5 km above and 2 km southwest of the focus of the first family of quakes.

In the computation of both foci the Mauna Loa arrival times were corrected by -0.3 sec. to allow for a delay at that station revealed by a study of distant earthquake P phases.

Actually, the two families graded into one another; and the two foci should serve only to indicate the apparent dimensions of the region from which they emanated. This region is clearly distinct from that which produced a similar swarm of deep earthquakes and spasmodic tremor in January 1959, however (Summary 13). It lies about 10 km above and 10 km west of the source of the January disturbance.

As a result of the swarm of deep earthquakes the number of earthquakes recorded at Uwekahuna during August rose to 2,314; but only three were felt. The first, which had a magnitude of 3.4 and was felt in Capt. Cook and Kealakekua, originated 20 km west of Keahole Point at 16^h13^m on August 12. The second, with a magnitude of 4.0 was the largest earthquake in Hawaii during August. It occurred 8 km south of Kalapana at a depth of about 45 km at 13^h55^m on August 18 and was felt at Kilauea caldera and Hilo. The third was reported felt

only in Hilo. It originated 4 km north of Keanakolu at 03^h06^m on August 25 and had a magnitude of 3.5.

During August, seven earthquakes with magnitudes of 1.8 to 2.8 occurred at depths ranging from 20 to 32 km beneath the summit of Kilauea; none of these was felt.

The number of earthquakes recorded at Uwekahuna during September fell to 146. The magnitude 4.0 earthquake from a shallow focus 3 km west of Kalalua Crater at 14^h50^m on September 18, which was felt at Kilauea caldera and Hilo, was both the largest earthquake and the only earthquake felt in Hawaii during the month.

Two magnitude 2.0 earthquakes originated at depths of about 30 km beneath the summit region of Kilauea in early September.

One earthquake in August and four in September augmented the group of moderately deep earthquakes which occurred around Kilauea during July at a distance of about 35 km from the caldera. These earthquakes were:

Aug. 18, $13^h54^m55^s$, 8 km south of Kalapana and 45 km deep;
Sept. 1, $21^h22^m16^s$, 15 km north of Hilo and 50 km deep;
Sept. 12, $07^h44^m21^s$, 14 km south of Hilo and 25 km deep;
Sept. 13, $18^h31^m25^s$, 10 km southeast of Naalehu and 35 km deep;
Sept. 18, $11^h05^m54^s$, 10 km west-southwest of Hilo and 40 km deep.

In mid-September the North Pit seismograph began to record a swarm of tiny, shallow earthquakes originating very near the northeast rim of Halemaumau. From its commencement about September 17 until September 24, the swarm averaged about 60 earthquakes per day. From September 24 until the end of the month it averaged about 85 earthquakes per day. Earthquakes of the swarm were so small and originated so near the North Pit seismograph that no more than one earthquake in 10 recorded at that station could be detected on the Outlet seismograph less than 3 km away. For the largest quakes, amplitudes recorded at Outlet were only about 1/100th of those recorded at North Pit.

Tilting of the ground around Kilauea caldera

Tilting of the ground around the summit of Kilauea is monitored daily by a short-base water-tube tiltmeter in Uwekahuna vault, and at irregular intervals it is measured on a regional scale by means of a network of field tilt bases and a portable water-tube tiltmeter (tables 1 and 2). The attitude of the ground surface at each tilt base is reported in terms of north-south and east-west tilt coordinates. Both coordinates at each station were arbitrarily set equal to 500 when measurements at that station were begun. Increasing tilt coordinates correspond to northward and eastward tilting of the earth's surface,

Table 1.--Tilt coordinates at Uwekahuna vault, July-September 1959

Date	N-S	E-W	Date	N-S	E-W
July 5	518	469	Aug. 23	519	466
12	518	469	30	520	471
19	518	471	Sept. 6	521	467
26	518	472	13	521	467
Aug. 2	519	474	20	521	469
9	520	464	27	521	467
16	519	465			

Table 2.--Tilt coordinates and changes at tilt bases around Kilauea caldera (see fig. 1)

Tilt base (location)	Date (1959)	Tilt coordinates		Rate and direction of tilting since last reading (10^{-6} rad/mo)		Date of last reading (1959)
		N-S	E-W			
Uwekahuna (19°25.5' N., 155°17.4' W.)	Aug. 13	543.3	471.0	0.4	S. 54° E.	Apr. 27
Tree Molds (19°26.3' N., 155°17.3' W.)	Aug. 14	499.7	498.5	0.7	S. 5° W.	Apr. 28
Summer Camp (19°24.6' N., 155°15.6' W.)	Aug. 15	517.7	525.2	0.8	W.	May 4
Sand Spit (19°24.1' N., 155°16.8' W.)	Aug. 15	527.4	485.8	1.4	S. 38° E.	May 4
Kalihipaa (19°21.4' N., 155°15.3' W.)	Aug. 14	488.6	501.0	0.5	N. 44° W.	Apr. 28
Keamoku (19°25.1' N., 155°19.0' W.)	Aug. 17	516.1	497.5	1.1	N. 17° W.	May 12
Kamokukolau (19°22.7' N., 155°16.6' W.)	Aug. 16	493.9	506.1	1.4	N. 5° W.	May 12

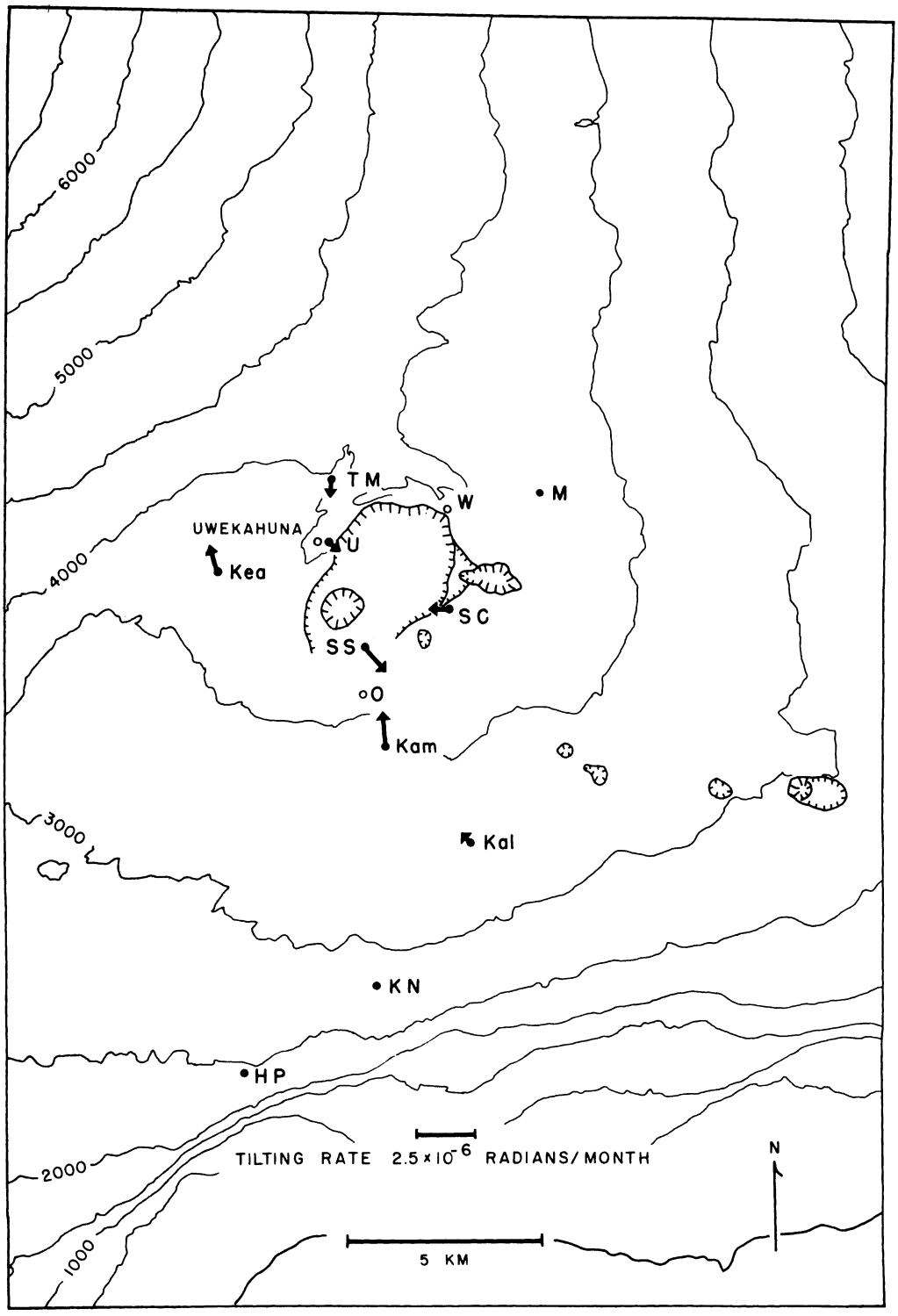

Figure 1.--Tilting of the ground around Kilauea caldera, May 5, 1959, to Aug. 15, 1959. The vector depicting tilting at a given tilt base points in the direction of maximum relative subsidence and has a length proportional to the rate of tilting during the measurement interval. Closed circles represent field tilt bases; open circles, short-base water-tube tiltmeters.

that is, to a relative subsidence toward the north and east. A 1-unit change in coordinate corresponds to a 1-microradian (1 mm per km) tilt in the direction indicated.

Seismic summary

Events recorded by the U.S. Geological Survey seismograph network in Hawaii fall into two categories: local earthquakes and tremor originating in the region of the Hawaiian Islands, usually within 100 km of at least one seismograph, and distant earthquakes originating farther than 3,000 km from Hawaii. As an index of seismic activity at Hawaiian volcanoes, weekly totals of earthquakes with magnitudes of 2.5 or greater, earthquakes with magnitudes less than 2.5, and minutes of continuous tremor, all recorded on the HVO-1 seismograph at Uwekahuna, are reported in table 3. Earthquakes of magnitude 2.5 or greater are generally sufficiently well recorded to be located; they are listed individually in table 4. Data on identifiable phases from distant earthquakes are listed in table 5.

Locations of the seismograph stations are shown on figure 2; and essential data on the stations were given in Summary 13, table 6.

Table 3.--Local earthquakes and tremor recorded by the HVO-1 seismograph at Uwekahuna, July-September 1959

Week beginning	Number of earthquakes		Minutes of continuous tremor
	Magnitude ≥2.5	Magnitude <2.5	
July 5	3	29	56
12	3	21	8
19	1	20	0
26	3	24	29
Aug. 2	0	20	0
9	35	1,345	1,815
16	13	852	555
23	1	36	4
30	3	22	0
Sept. 6	2	29	0
13	5	37	0
20	1	35	0
27	1	35	34

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, July-September 1959

[Except for smaller earthquakes of special interest, only earthquakes with magnitudes of 2.5 or greater are listed. Time is Hawaiian standard]

Date		Time			Magnitude	Epicenter			Remarks
		h	m	s		Lat. N.	Long. W.	Description	
July	7	15	41	21	2.6	19°39'	155°04'	8 km S. of Hilo----------	40 km deep.
	8	12	40	55	2.5	19°22'	155°26'	7 km NW. of Desert seismograph.	Depth about 5 km.
	8	14	56	36	2.7	19°27'	155°24'	5 km S. of Mauna Loa seismograph.	Depth about 5 km.
	10	02	19	17	2.0			Near Kealakekua. Felt in Capt. Cook.	At shallow depth.
	12	11	37	16	2.9	19°15'	155°33'	10 km NW. of Pahala-------	Depth about 5 km.
	13	09	52	01	2.6	19°17'	154°47'	27 km S. of Cape Kumukahi-	Depth about 15 km.
	13	22	21	00	3.0	19°03'	155°23'	22 km E. of Naalehu-------	Depth about 25 km.
	19	21	00	49	2.5	20°03'	155°50'	Kawaihae----------	Depth about 15 km.
	28	16	51	01	3.0	19°17'	155°03'	10 km SW. of Kalapana-----	Depth about 10 km.
	29	15	27	29	3.0			West coast of Hawaii near Hookena. Felt in Capt. Cook.	At shallow depth.
	31	18	43	54	3.5	19°25'	155°36'	5 km S. of Mokuaweoweo caldera. Felt at Kilauea caldera.	Depth about 30 km.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, July-September 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Aug. 9	04	08	30	2.5	19°21'	155°18'	5 km S. of Outlet seismograph.	32 km deep.
11	01	45	42	2.8	19°31'	155°29'	10 km NNE. of Mauna Loa seismograph.	Depth about 5 km.
12	16	12	51	3.4	19°44'	156°16'	20 km W. of Keahole Point. Felt in Capt. Cook and Kealakekua.	Depth about 15 km.
14	07	07	41	2.5	19°26'	155°17'	30 km deep beneath N. rim of Kilauea caldera.	
14	23	44	54	2.5	19°29'	155°18'	7 km N. of Uwekahuna. (This focus will be designated by KM 54 in rest of this list.)	54 km deep.
14	23	51	54	2.5			KM 54.	
15	00	55	00	3.1			KM 54.	
15	01	30	38	3.4	19°28'	155°19'	5 km NNW. of Uwekahuna. (This focus will be designated by KM 49 in rest of this list.)	Depth about 49 km.
15	01	49	55	2.8			KM 54.	

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, July-September 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Aug. 15	02	04	14	2.9			KM 54.	
15	02	05	50	2.8			KM 54.	
15	03	18	10	2.7			KM 49.	
15	03	44	31	2.7			KM 49.	
15	05	09	38	2.7			KM 49.	
15	05	48	21	3.4			KM 54.	
15	06	05	56	3.0			KM 49.	
15	06	08	59	3.1			KM 54.	
15	06	11	11	3.1			KM 54.	
15	06	29	27	3.4			KM 49.	
15	06	42	17	2.5			KM 49.	
15	08	05	22	2.5			KM 49.	
15	08	38	36	2.7			KM 49	
15	08	41	52	2.7			KM 49.	

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, July-September 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Aug. 15	09	08	39	2.5			KM 49.	
15	09	19	06	2.8			KM 54.	
15	17	01	56	2.5			KM 49.	
15	17	22	16	2.8			KM 49.	
15	19	31	52	3.0			KM 49.	
15	19	35	59	2.9			KM 54.	
15	19	58	14	2.8			KM 54.	
15	20	42	09	3.2			KM 49.	
15	20	48	56	2.8			KM 49.	
15	21	39	11	2.5			KM 49.	
15	22	25	38	2.5			KM 49.	
15	23	52	39	2.5			KM 49.	
16	01	34	31	2.8			KM 54.	
16	01	56	19	2.5			KM 54.	
16	03	34	41	2.5			KM 54.	

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, July-September 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Aug. 16	07	05	42	2.5			KM 54.	
16	08	29	30	2.5			KM 49.	
16	10	47	46	2.6	19°22'	155°16'	5 km SE. of Outlet seismograph.	20 km deep.
17	00	46	39	2.5			KM 54.	
17	02	02	34	2.5			KM 54.	
17	02	13	56	2.7			KM 54.	
17	02	33	48	2.8			KM 54.	
17	22	04	45	2.9			KM 54.	
18	04	34	38	2.5			KM 49.	
18	13	54	50	4.0	19°17'	154°57'	8 km S. of Kalapana. Felt at Kilauea caldera and Hilo.	Depth about 45 km.
25	03	06	16	3.5	19°57'	155°21'	4 km N. of Keanakolu. Felt in Hilo.	Depth about 10 km.
Sept. 1	21	22	16	2.8	19°51'	155°04'	15 km N. of Hilo----------	50 km deep.
2	06	08	48	2.5	19°00'	155°41'	10 km N. of South Point on the Kahuku fault.	Depth about 5 km.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, July-September 1959--Continued

Date	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Sept. 5	23	33	51	2.5	19°18'	155°53'	10 km S. of Hookena-------	Depth about 10 km.
11	22	55	01	3.0	18°57'	156°43'	100 km W. of South Point--	Depth about 15 km.
12	07	44	21	2.5	19°36'	155°03'	14 km S. of Hilo----------	Depth about 25 km.
13	18	31	25	2.4	18°59'	155°32'	10 km SE. of Naalehu------	Depth about 35 km.
14	07	01	27	2.6	20°06'	155°50'	7 km N. of Kawaihae-------	Depth about 15 km.
14	23	57	15	3.3	19°45'	157°59'	170 km S. of Honolulu-----	Depth about 15 km.
16	10	50	22	2.9	19°49'	155°55'	5 km S. of Kiholo Bay-----	Depth about 10 km.
18	11	05	54	3.1	19°41'	155°10'	10 km WSW. of Hilo--------	Depth about 40 km.
18	14	50	04	4.0	19°24'	155°06'	3 km W. of Kalalua Crater. Felt at Kilauea caldera and Hilo.	At shallow depth.
20	16	11	07	2.5	19°28'	155°53'	5 km SW. of Capt. Cook on Kealakekua fault.	Depth about 10 km.

Table 5.--Distant earthquakes

[Times are reported in Greenwich civil time, which is 10 hours faster than Hawaiian standard time. A "c" following the time of P indicates that the first motion was a compression; a "d," that it was a dilatation. Station symbols, locations, and instrumentation were presented in Summary 13, table 6. Locations of epicenters, origin times, focal depths, and magnitudes are from the notices of Preliminary Determination of Epicenters published by the U.S. Coast and Geodetic Survey]

July 2

M	Z	iP	11:41:50.7	c
O	Z	iP	11:41:49.8	c
U	Z	iP	11:41:49.7	d
Hi	Z	iP	11:41:52.5	c

20° S., 178-1/2° W.
11:34:20.
Fiji Islands.
h about 650 km.

July 3

U	PEZ	iP	18:03:51.4
U	PEZ	iS	18:10:47

16° S., 173° E.
17:55:10.
New Hebrides Islands region.
Magnitude 6-1/2.

July 3

M	Z	eP	18:04:30.6	d
O	Z	eP	18:04:29.6	d
U	Z	eP	18:04:31	
U	PEZ	iP	18:04:31.1	d
U	PEZ	iS	18:11:27	
U	PEZ	iSS	18:14:54	

July 3--Continued

U	PEE	iQ	18:15:38
U	PEZ	iR	18:16:44

16° S., 173° E.
17:55:53.
New Hebrides Islands region.
Magnitude 6-1/2.

July 6

U	PEZ	e	09:22:52
M	Z	epPP	09:29:27
U	PEZ	esPP	09:30:24
U	PEZ	eSP	09:35:24
U	PEZ	esSP	09:39:26
U	PEZ	esSS	09:44:28
Hi	Z	e	09:23:09

26-1/2° S., 61° W.
09:10:17.
Chuco Province, Argentina.
h about 600 km.
Magnitude 6-3/4.

July 6

U	PEE	ePS	09:48:38
U	PEE	esSP	09:52:30
U	PEZ	esSS	09:57:38

Table 5.--Distant earthquakes--Continued

July 6--Continued

26-1/2° S., 61-1/2° W.
09:23:21.
Chuco Province, Argentina.
h about 600 km.
Magnitude 6-3/4 to 7.

July 9

M	Z	eP	16:18:29.0	
M	Z	epP	16:19:05.0	
M	Z	esP	19:19:14.5	
O	Z	eP	16:18:29.5	
O	Z	esP	16:19:15.3	
D	Z	eP	16:18:29.7	
D	Z	esP	16:19:15.7	
U	Z	eP	16:18:30.6	
U	PEZ	eP	16:18:31	
U	PEZ	isP	16:19:11	
U	PEZ	esPP	16:22:50	
U	PEZ	eS	16:29:54	
U	PEZ	esPS	16:31:18	
U	PEZ	eSS	16:35:50	
U	PEZ	iR	16:48:20	
Hi	Z	eP	16:18:28.0	
Ha	Z	eP	16:18:38.0	

20-1/2° S., 68° W.
16:05:18.
Chile-Bolivia border.
h about 100 km.
Magnitude 6-3/4.

July 11

U	PEZ	eR	05:15:29	

July 11

U	PEZ	eR	13:02:19	

37° S., 79° E.
12:01:39.
Indian Ocean.
Magnitude 6-1/4 to 6-1/2.

July 12

M	Z	eP	00:32:04.5	
O	Z	eP	00:32:02.9	
Hi	Z	iP	00:32:05.7	

19-1/2° S., 177-1/2° W.
00:24:22.
Fiji Islands region.
h about 400 km.
Magnitude 6-1/4.

July 13

M	Z	iP	12:35:39.2	c
M	Z	ipP	12:35:49.5	
O	Z	iP	12:35:39.7	c
O	Z	ipP	12:35:50.4	
D	Z	iP	12:35:40.9	
D	Z	ipP	12:35:50.8	
U	Z	iP	12:35:39.0	c
U	Z	ipP	12:35:49.5	
U	Z	ePn	12:36:54.6	
U	Z	Tmax	13:13:12	
U	PEZ	eP	12:35:39.1	d

Table 5.--Distant earthquakes--Continued

July 13--Continued

U	PEZ	ePP	12:37:00	
U	PEZ	iS	12:41:12	
U	PEE	iQ	12:42:57	
U	PEZ	iR	12:44:30	
Hi	Z	eP	12:35:37.6	c
Hi	Z	ipP	12:35:48.3	
Hi	Z	ePn	12:36:52.8	
Ha	Z	eP	12:35:25.1	c
Ha	Z	ipP	12:35:34.1	
Ha	Z	Tmax	13:11:23	

52° N., 172-1/2° W.
12:28:45.
Andreanof Islands, Aleutian Islands.
Magnitude 6-1/2.

July 14

U	PEZ	eR	08:56:31	

51-1/2° N., 172° W.
08:40:48.
Fox Islands, Aleutian Islands.

July 14

U	PEZ	eS	13:15:53	
U	PEZ	eR	13:21:25	

16-1/2° S., 173° E.
13:00:24.
New Hebrides Islands region.
h about 100 km.

July 18

U	PEN	eL	12:35	

50-1/2° N., 130° W.

July 18--Continued

12:18:35.
Off coast of Vancouver, British Columbia.

July 18

M	Z	iP	19:37:38.9	c
O	Z	iP	19:37:38.4	c
U	Z	iP	19:37:38.1	d
Hi	Z	iP	19:37:40.9	c
Ha	Z	iP	19:37:42.8	c

19:29:22.
Fiji Islands region.

July 18

M	Z	iP	20:06:54.0	d
M	Z	ipP	20:07:33.7	
M	Z	isP	20:07:47.2	
O	Z	iP	20:06:54.8	d
O	Z	ipP	20:07:33.8	
O	Z	isP	20:07:47.7	
D	Z	iP	20:06:54.9	
D	Z	ipP	20:07:34.8	
D	Z	isP	20:07:47.0	
U	Z	iP	20:06:56.6	c
U	Z	ipP	20:07:33.5	
U	PEZ	iP	20:06:55.6	d
U	PEZ	ipP	20:07:31.6	
U	PEZ	iS	20:16:48	
U	PEN	isS	20:17:49	
U	PEZ	iSS	20:21:09	

Table 5.--Distant earthquakes--Continued

July 18--Continued

U	PEN	iSSS	20:25:14	
U	PEZ	iR	20:31:27	
Hi	Z	iP	20:06:56.6	d
Hi	Z	ipP	20:07:34.2	
Ha	Z	iP	20:06:49.5	d
Ha	Z	ipP	20:07:27.8	

15-1/2° N., 120-1/2° E.
19:54:45.
Luzon, Philippine Islands. Felt.
h about 150 km.
Magnitude 6-1/2 to 6-3/4.

July 19

U	Z	eP	15:18:51	
U	PEZ	iP	15:18:52.0	
U	PEZ	epP	15:19:54	
U	PEZ	esP	15:20:07	
U	PEZ	ePP	15:22:26	
U	PEZ	epPP	15:23:17	
U	PEN	iS	15:29:30	
U	PEN	isS	15:31:04	
U	PEN	eSS	15:35:28	
U	PEN	esSS	15:36:56	
U	PEN	iG	15:42:09	
U	PEZ	iR	15:49:09	
Hi	Z	iP	15:18:54.2	
Hi	Z	epP	15:19:47.5	

July 19--Continued

Ha	Z	iP	15:19:01.9	

15° S., 70-1/2° W.
15:06:10.
Peru. Felt in Northern Chile.
h about 200 km.
Magnitude 7.

July 20

M	Z	iP	17:01:41.6	
O	Z	iP	17:01:41.2	
D	Z	iP	17:01:40.1	
U	Z	iP	17:01:40.7	
Hi	Z	iP	17:01:43.9	
Ha	Z	eP	17:01:45.8	

23-1/2° S., 179° E.
16:53:38.
Fiji Islands region.
h about 600 km.

July 21

M	Z	iP	07:52:05.7	
O	Z	eP	07:52:05.5	
U	PEZ	eP	07:52:12	
U	PEZ	iS	07:59:26	
U	PEZ	iR	08:05:32	

14-1/2° S., 167-1/2° E.
07:43:13.
New Hebrides Islands.
Magnitude 6-1/4.

Table 5.--Distant earthquakes--Continued

July 22

M	Z	iP	11:27:39.0	
O	Z	iP	11:27:39.1	
U	Z	eP	11:27:39.3	

2° N., 126-1/2° E.
11:15:33.
Molucca Passage.

July 22

M	Z	iP	19:32:31.3	c
O	Z	iP	19:32:32.0	c
D	Z	iP	19:32:31.9	c
U	Z	iP	19:32:31.7	c
U	PEZ	iP	19:32:32.1	c
U	PEN	eS	19:39:12	
Hi	Z	iP	19:32:31.6	c
Ha	Z	iP	19:32:21.0	c

53° N., 153° E.
19:24:17.
Sea of Okhotsk.
h about 650 km.
Magnitude 6-1/4.

July 22

M	Z	eP	23:12:12.6
O	Z	eP	23:12:11.8
D	Z	iP	23:12:12.2
U	Z	eP	23:12:11.8
U	PEZ	iP	23:12:11.3

July 22--Continued

U	PEZ	iS	23:20:04
U	PEZ	eSS	23:24:09
U	PEN	eG	23:25:49
U	PEZ	eR	23:29:49
Hi	Z	eP	23:12:14.0
Ha	Z	eP	23:12:08.9

5° S., 152-1/2° E.
23:02:27.
New Britain. Felt.
h about 60 km.

July 23

M	Z	eP	15:05:28.6
D	Z	eP	15:05:28.3
U	Z	eP	15:05:27.1
U	PEZ	eP	15:05:26.8
U	PEZ	eS	15:12:27
U	PEZ	eR	15:18:44
Hi	Z	eP	15:05:19.5
Ha	Z	eP	15:05:32.9

24-1/2 S., 176° W.
14:56:45.
Tonga Islands region.
h about 60 km.
Magnitude 5-3/4.

July 24

U	Z	eP	01:29:51.7
U	PEZ	eP	01:29:52.8

Table 5.--Distant earthquakes--Continued

July 24--Continued

U	PEN	eS	01:35:13	
U	PEN	iQ	01:36:54	
U	PEZ	eR	01:38:09	
U	Z	Tmax	02:04	
Hi	Z	eP	01:29:48.2	
Hi	Z	eQ	01:37:06	
Hi	Z	Tmax	02:05:25	
Ha	Z	eP	01:29:51.7	
Ha	Z	eQ	01:36:59	
Ha	Z	Tmax	02:03:49	

41° N., 125-1/2° W.
01:23:09.
Off coast of Northern California.
Felt at Humboldt County.
Magnitude 5-3/4.

Aug. 4

M	Z	eP	08:09:52.1	
O	Z	eP	08:09:51.5	
U	Z	eP	08:09:51.1	

20-1/2° S., 178° W.
08:02:17.
Fiji Islands region.
h about 600 km.

Aug. 7

U	PEZ	eS	21:08:47	
U	PEZ	eR	22:02:31	
U	Z	Tmax	22:31:20	

Aug. 7--Continued

Hi	Z	Tmax	22:31:30	
Ha	Z	Tmax	22:30:15	

56-1/2° N., 154° W.
21:45:26.
Kodiak Island.
Magnitude 5.

Aug. 8

M	Z	iP	00:56:19.5	c
M	Z	ipP	00:56:29.4	
O	Z	eP	00:56:19.9	
O	Z	ipP	00:56:29.9	
D	Z	iP	00:56:20.0	c
D	Z	ipP	00:56:29.8	
U	Z	epP	00:56:29.5	
U	PEN	eS	01:03:07	
U	PEN	eQ	01:07:11	
U	PEZ	eR	01:08:41	
Hi	Z	iP	00:56:19.9	c
Ha	Z	eP	00:56:07.9	c

55° N., 162-1/2° E.
00:47:38.
Near east coast of Kamchatka.
Magnitude 6-1/2.

Aug. 8

U	PEZ	eS	09:56:47	
U	PEZ	eR	10:00:37	

Table 5.--Distant earthquakes--Continued

Aug. 9

M	Z	iP	20:38:36.2	
O	Z	iP	20:38:36.0	
D	Z	iP	20:38:35.1	
U	Z	eP	20:38:35.1	
U	PEZ	iS	20:46:15	
U	PEZ	eR	20:52:39	
Hi	Z	iP	20:38:38.9	

10° S., 161° E.
20:29:28.
Solomon Islands.
h about 100 km.

Aug. 12

U	Z	eP	10:06:22.2	
U	PEZ	eP	10:06:16	
U	PEN	iS	10:12:39.0	
U	PEE	eQ	10:15:11	
U	PEZ	eSS	10:15:56	
U	PEZ	iR	10:17:11	
Hi	Z	eP	10:06:16.8	
Ha	Z	eP	10:06:27.8	

16-1/2° S., 177-1/2° W.
09:58:22.
Fiji Islands region.
Magnitude 6-1/2.

Aug. 14

M	Z	iP	04:51:24.2	
O	Z	eP	04:51:24.4	

Aug. 14--Continued

0°, 125-1/2° E.
04:39:07.
Molucca Passage.

Aug. 15

M	Z	eP	09:09:00.4	c
O	Z	eP	09:09:00.6	c
D	Z	eP	09:09:00.0	c
U	Z	eP	09:09:00.2	d
U	PEZ	iP	09:08:59.5	c
U	PEE	iS	09:18:52	
U	PEE	iPPS	09:19:45	
U	PEN	iSS	09:23:25	
U	PEN	iQ	09:28:11	
U	PEZ	eR	09:32:31	
Hi	Z	iP	09:09:01.6	c
Ha	Z	iP	09:09:06.4	c

23° N., 121° E.
08:57:04.
Formosa; 16 killed, many injured and extensive property damage.
Magnitude 6-3/4 to 7.

Aug. 16

U	PEZ	eP	01:01:03.5	
U	PEZ	eS	01:08:44	
U	PEZ	eR	01:15:51	

21° S., 169° E.
00:51:40.
Loyalty Islands region.
Magnitude 6.

Table 5.--Distant earthquakes--Continued

Aug. 16

Hi	Z	iP	10:01:11.7	

18° S., 178° W.
09:53:52.
Fiji Islands.
h about 350 km.

Aug. 17

M	Z	eP	21:14:17.3	c
O	Z	eP	21:14:17.2	c
D	Z	eP	21:14:16.6	c
U	Z	iP	21:14:18.4	d
U	PEZ	iP	21:14:18.7	d
U	PEN	e	21:21:11	
U	PEE	iS	21:22:02	
U	PEZ	iSS	21:25:49	
U	PEN	iQ	21:26:58	
U	PEZ	iR	21:29:19	
Hi	Z	eP	21:14:19.1	c
Ha	Z	iP	21:14:16.1	c

7-1/2° S., 156° E.
21:04:40.
Solomon Islands.
Magnitude 7 to 7-1/4.

Aug. 18

M	Z	eP	00:45:33.8	
O	Z	eP	00:45:34.3	
D	Z	eP	00:45:33.8	

Aug. 18--Continued

22-1/2° N., 122° E.
00:34:03.
Near east coast of Formosa.
h about 200 km.

Aug. 18

M	Z	eP	06:45:31.3	
O	Z	iP	06:45:30.2	d
D	Z	iP	06:45:31.2	d
U	Z	iP	06:45:31.5	d
U	PEZ	iP	06:45:31.5	c (d)
U	PEZ	iS	06:52:13	
U	PEZ	iSS	06:55:43	
U	PEN	iG	06:56:11	
U	PEZ	iR	06:57:45	
Hi	Z	iP	06:45:29.8	d
Hi	E	eS	06:52:10	
Hi	N	eQ	06:55:16	
Ha	Z	iP	06:45:28.3	c
Ha	E	eS	06:52:06	
Ha	N	eQ	06:55:53	
Ha	N	eR	06:58:13	

44°55' N., 111°05' W.
06:37:15.0.
Hebgen Lake, Montana; many killed and injured; major property damage.
Magnitude 7.1.

Table 5.--Distant earthquakes--Continued

Aug. 18

M	Z	iP	15:34:23.0	c
O	Z	iP	15:34:23.0	c
D	Z	iP	15:34:24.1	c
U	Z	eP	15:34:22.2	d
U	PEZ	iP	15:34:22.8	d
U	PEN	iS	15:41:06	
U	PEN	iSS	15:44:21	
U	PEN	eQ	15:45:58	
U	PEZ	iR	15:46:58	
Hi	Z	eP	15:34:19.4	d
Ha	Z	iP	15:34:20.4	d

44°53' N., 110°44' W.
15:26:06.5.
Hebgen Lake aftershock.
Magnitude 6-1/2.

Aug. 19

U	PEZ	eR	04:23:51

44°54' N., 111°38' W.
04:04:03.0.
Hebgen Lake aftershock.
Magnitude 6.

Aug. 20

M	Z	eP	07:30:13.7
O	Z	eP	07:30:12.7
D	Z	eP	07:30:14.2
U	Z	eP	07:30:13.4

Aug. 20--Continued

7° S., 85° W.
07:18:34.
Off coast of Peru.

Aug. 21

U	PEN	ePPS	08:28:26
U	PEZ	eR	08:44:33

50-1/2° S., 139-1/2° E.
08:03:15.
Indian Ocean south of Australia.
Magnitude 5-3/4 to 6.

Aug. 21

U	PEZ	eR	10:19:18

50-1/2° S., 140° E.
09:37:49.
Indian Ocean south of Australia.

Aug. 24

M	Z	iP	15:50:54.8	d
O	Z	iP	15:50:54.6	d
D	Z	iP	15:50:53.8	d
U	Z	eP	15:50:54.0	c
U	PEZ	iP	15:50:54.0	c
U	PEZ	eS	15:58:29	
U	PEZ	eR	16:05:57	
Hi	Z	iP	15:50:57.2	c
Ha	Z	iP	15:50:54.6	c

10-1/2° S., 161-1/2° E.
15:41:40.
Solomon Islands foreshock.

Table 5.--Distant earthquakes--Continued

Aug. 24

M	Z	iP	21:40:01.0	c
O	Z	iP	21:40:00.7	c
D	Z	iP	21:39:59.2	
U	Z	eP	21:39:59.5	c
U	PEZ	eP	21:39:58	c
U	PEN	e	21:47:01	
U	PEN	iS	21:47:39	
U	PEZ	eSS	21:51:06	
U	PEZ	iR	21:53:59	
Hi	Z	iP	21:40:02.2	d
Ha	Z	iP	21:40:00.5	d

10-1/2° S., 161° E.
21:30:46.
Solomon Islands.
Magnitude 7.

Aug. 24

U	PEZ	eS	23:49:13	
U	PEZ	eR	23:55:19	

10-1/2° S., 161° E.
23:32:23.
Solomon Islands aftershock.

Aug. 26

M	Z	iP	08:35:23.9	c
M	Z	ipP	08:35:36.0	
O	Z	iP	08:35:23.3	c
O	Z	ipP	08:35:35.1	

Aug. 26--Continued

D	Z	iP	08:35:24.1	c
D	Z	ipP	08:35:35.1	
U	Z	iP	08:35:23.3	
U	Z	ipP	08:35:34.9	
U	PEZ	iP	08:35:23.7	c
U	PEZ	iS	08:43:23	
U	PEN	iG	08:50:00	
U	PEZ	iR	08:52:15	
Hi	Z	iP	08:35:21.5	c
Hi	Z	ipP	08:35:33.1	
Ha	Z	iP	08:35:28.4	d
Ha	Z	ipP	08:35:39.2	

18° N., 94-1/2° W.
08:25:30.
Vera Cruz, Mexico; 14 killed, many injured, and extensive property damage throughout Tehuantepec Isthmus.
Magnitude 6-3/4.

Aug. 26

U	PEZ	eP	10:34:45
U	PEZ	iS	10:40:43
U	PEN	iQ	10:42:41
U	PEZ	eR	10:44:18
U	Z	Tmax	11:13:31
Hi	Z	iQ	10:42:48
Hi	Z	Tmax	11:13:15

Table 5.--Distant earthquakes--Continued

Aug. 26--Continued

Ha	Z	eQ	10:42:38	
Ha	Z	Tmax	11:12:55	

51° N., 132° W.,
10:27:41.
Queen Charlotte Islands region.

Aug. 27

U	PEZ	eR	14:20:21	

45° S., 80-1/2° W.
13:36:50.
Off coast of southern Chile.

Aug. 28

U	PEZ	eR	03:01:41	

9° S., 158° E.
02:37:00
Solomon Islands.
h about 150 km.

Aug. 28

U	Z	iP	12:15:51.7	
Hi	Z	iP	12:15:49.4	

63-1/2° N., 149° W.
12:07:44.
Central Alaska. Felt at College and Fairbanks.

Aug. 28

U	Z	eP	16:01:44.3	
U	PEZ	eP	16:01:43	
U	PEZ	eS	16:09:01	
U	PEZ	eR	16:15:41	

Aug. 28--Continued

17° S., 167° E.
15:52:10.
New Hebrides Islands.

Aug. 29

U	PEZ	eR	03:45:11	

03:21:07.
Solomon Islands region.

Aug. 29

M	Z	iP	17:15:20.8	d
O	Z	iP	17:15:21.3	d
D	Z	iP	17:15:21.3	d
U	Z	iP	17:15:20.5	d
U	PEZ	iP	17:15:21.6	d
U	PEZ	iS	17:25:27	
U	PEZ	eSS	17:30:47	
U	PEN	eG	17:36:41	
U	PEZ	eR	17:40:11	
Hi	Z	iP	17:15:20.7	d
Ha	Z	iP	17:15:12.6	d

52° N., 106-1/2° E.
17:03:10.
Lake Baikal, USSR.
Magnitude 6-1/2 to 6-3/4.

Aug. 30

U	PEZ	eR	22:45:30	

36-1/2° S., 78-1/2° E.
21:45:07.
Indian Ocean.

Table 5.--Distant earthquakes--Continued

Sept. 3			
M	Z	iP	06:40:06.5
O	Z	iP	06:40:06.4
D	Z	eP	06:40:06.3
U	Z	eP	06:40:06.5
U	PEZ	iP	06:40:06.3
U	PEN	eS	06:50:37
U	PEZ	eSS	06:56:03
U	PEN	eG	07:01:35
U	PEZ	eR	07:05:31
4-1/2° S., 123° E. 06:27:30. Celebes Islands.			
Sept. 3			
U	PEZ	eSS	22:06:47
15° S., 175-1/2° W. 21:48:56. Fiji Islands region.			
Sept. 5			
M	Z	eP	06:19:34.3
O	Z	eP	06:19:34.7
U	PEN	ePPS	06:30:03
U	PEN	eQ	06:39:05
U	PEZ	eR	06:41:36
1° N., 129° E. 06:07:38. Halmahera Island region.			
Sept. 5			
U	PEZ	eR	16:08:43
1° N., 129° E. 15:34:44. Halmahera aftershock.			
Sept. 5			
U	PEZ	eR	21:45:45
Sept. 5			
M	Z	iP	23:12:22.7
O	Z	iP	23:12:21.7
D	Z	eP	23:12:20.8
U	Z	iP	23:12:21.4
Hi	Z	iP	23:12:24.6
Ha	Z	iP	23:12:26.7
18° S., 178-1/2° W. 23:04:00. Fiji Islands.			
Sept. 6			
M	Z	iP	00:39:57.3
O	Z	eP	00:39:57.2
U	Z	eP	00:39:57.2
5-1/2° N., 126-1/2° E. 00:27:59. Near south coast of Mindanao, Phillippine Islands.			
Sept. 8			
U	PEZ	eR	14:25:27

Table 5.--Distant earthquakes--Continued

Sept. 8--Continued

13:12:04.
South Atlantic Ocean about 700 miles east of Bouvet Island.

Sept. 8

U	PEZ	eR	19:44:39	

42-1/2° N., 142-1/2° E.
19:19:39.
Hokkaido, Japan; felt at Hiroo, Obihiro, Kushiro, and Urakawa.

Sept. 10

M	Z	iP	05:44:41.9	d
O	Z	iP	05:44:41.8	d
D	Z	iP	05:44:41.0	d
U	Z	eP	05:44:42.8	
U	PEZ	eS	05:52:56	
U	PEZ	eSSS	05:58:41	
U	PEZ	eR	06:00:21	
Hi	Z	iP	05:44:44.1	c
Ha	Z	iP	05:44:40.7	c

6-1/2° S., 154-1/2° E.
05:35:04.
Solomon Islands.

Sept. 10

M	Z	eP	23:05:42.0	
D	Z	eP	23:05:42.5	

47° N., 152° E.
22:56:34.
Kurile Islands.

Sept. 12

U	PEZ	eSKS	02:04:15	
U	PEZ	eSS	02:12:25	
U	PEZ	isSS	02:12:46	
U	PEZ	eSSS	02:16:11	
U	PEN	eQ	02:18:51	
U	PEZ	iR	02:21:51	

20° S., 68° W.
01:41:03.
Southern Bolivia.
h about 150 km.

Sept. 12

U	PEZ	eR	07:29:31	

3° S. 146-1/2° E.
07:01:45.
Bismarck Sea.

Sept. 12

U	PEE	iS	11:42:00	
U	PEZ	iR	11:49:39	

9-1/2° S., 156° E.
11:24:27.
Solomon Islands region.

Sept. 14

U	Z	eP	13:24:40.3	
U	PEZ	eS	13:31:35	
U	PEZ	eR	13:38:01	
Hi	Z	eP	13:24:36.7	

Table 5.--Distant earthquakes--Continued

Sept. 14--Continued

24° S., 176-1/2° W.
13:15:49.
Tonga Islands region.
Magnitude 5-3/4 to 6.

Sept. 14

M	Z	iP	14:18:56.7	d
M	Z	ipP	14:19:16.4	
O	Z	iP	14:18:56.1	d
O	Z	ipP	14:19:15.8	
D	Z	eP	14:18:55.1	d
D	Z	ipP	14:19:14.9	
U	Z	iP	14:18:56.0	d
U	Z	ipP	14:19:14.4	
U	PEZ	iP	14:18:52.9	d
U	PEZ	i	14:18:56.2	
U	PEZ	ipP	14:19:07	
U	PEN	iS	14:26:28	
U	PEE	eScS	14:28:47	
U	PEE	iG	14:30:41	
U	PEZ	iR	14:33:11	
Hi	Z	iP	14:18:58.2	c
Hi	Z	ipP	14:19:16.8	
Hi	N	eS	14:26:31	
Hi	E	eQ	14:31:35	
Hi	N	eR	14:38:45	

Sept. 14--Continued

Ha	Z	iP	14:19:02.0	c
Ha	Z	ipP	14:19:20.3	
Ha	N	eS	14:26:14	
Ha	E	eR	14:34:03	

28-1/2° S., 177° W.
14:09:39.
Kermadec Islands. Felt on Raoul.
Magnitude 7-3/4.

Sept. 14

M	Z	eP	17:15:29.8
O	Z	eP	17:15:29.4
D	Z	e	17:15:24.7
U	Z	eP	17:15:31.3
U	PEN	iS	17:23:00
U	PEZ	eR	17:30:01
Hi	Z	iP	17:15:32.9
Ha	Z	e	17:15:49.2

29° S., 176-1/2° W.
17:06:15.
Kermadec aftershock. Felt on Raoul.

Sept. 14

M	Z	eP	22:33:17.7
O	Z	eP	22:33:16.5
U	PEZ	eP	22:33:18
U	PEN	iS	22:40:39

Table 5.--Distant earthquakes--Continued

Sept. 14--Continued

U	PEZ	eR	22:47:27	

29° S., 177° W.
22:23:53.
Kermadec aftershock. Felt on Raoul.
Magnitude 6-1/2.

Sept. 15

M	Z	iP	06:08:58.3	
O	Z	iP	06:08:57.1	
U	Z	eP	06:08:53.4	
U	PEZ	iP	06:08:54.4	
U	PEE	iS	06:16:22	
U	PEE	iScS	06:18:53	
U	PEZ	iSS	06:19:55	
U	PEE	eQ	06:20:11	
U	PEZ	iR	06:23:45	
Hi	Z	eP	06:08:59.2	
Hi	E	eS	06:16:20	
Hi	E	eQ	06:24:39	
Hi	N	eR	06:28:03	
Ha	Z	iP	06:08:59.8	
Ha	N	eS	06:16:29	
Ha	N	eQ	06:22:35	

28-1/2° S., 177° W.
05:59:42.
Kermadec aftershock. Felt on Raoul.
Magnitude 6-1/2 to 6-3/4.

Sept. 15

M	Z	iP	11:13:20.2	c
M	Z	iScP	11:17:38.3	
O	Z	iP	11:13:19.6	c
O	Z	iScP	11:17:37.7	
D	Z	eP	11:13:20.1	c
U	Z	iP	11:13:19.1	c
U	PEE	iS	11:19:33	
U	PEE	iScS	11:22:18	
Hi	Z	iP	11:13:21.8	c
Ha	Z	iP	11:13:25.1	c

21-1/2° S., 179-1/2° W.
11:05:33.
Fiji Islands region.
h about 600 km.
Magnitude 6-1/2.

Sept. 16

U	PEN	iS	16:13:45	
U	PEZ	eR	16:21:11	

28-1/2° S., 176° W.
15:57:03.
Kermadec aftershock.
Magnitude 5-3/4 to 6.

Sept. 17

U	PEN	eS	14:52:47	
U	PEZ	eR	15:00:31	

28-1/2° S., 176° W.
14:36:11.
Kermadec aftershock.
Magnitude 5-3/4 to 6.

Table 5.--Distant earthquakes--Continued

Sept. 17

U	PEZ	eR	22:32:11	

30-1/2° S., 114° W.
22:14:40.
Gulf of California.
Magnitude 5-1/4.

Sept. 18

U	PEZ	eR	13:00:31	

57-1/2° S., 24° W.
12:01:11.
Sandwich Islands.

Sept. 20

U	PEZ	eS	06:25:15	
U	PEN	eQ	06:30:27	
U	PEZ	eR	06:32:35	
U	Z	Tmax	07:16:16	
Hi	E	eQ	06:32:49	

13-1/2° S., 11-1/2° W.
06:07:59.
Pacific Ocean north of Easter Island.

Sept. 21

U	PEZ	eR	02:37:11	

9-1/2° S., 149° E.,
02:08:28.
Near coast of New Guinea. Felt on Wanigella.

Sept. 25

M	Z	eP	02:48:45.6	d
O	Z	iP	02:48:46.1	d
D	Z	iP	02:48:45.1	d
U	Z	eP	02:48:45.3	d
U	PEZ	iP	02:48:45	c
U	PEE	eS	02:58:38	
U	PEZ	eSS	03:02:51	
U	PEZ	eR	03:11:28	

22° N., 122-1/2° E.
02:36:48.
Near east coast of Formosa.

Sept. 26

M	Z	eP	08:27:42.4	
M	Z	Tmax	09:02:35	
O	Z	iP	08:27:40.6	
O	Z	Tmax	09:02:31	
D	Z	Tmax	09:02:30	
U	PEN	eS	08:32:50	
U	PEN	eQ	08:34:30	
U	PEZ	iR	08:35:40	
U	Z	Tmax	09:02:45	
Hi	Z	eP	08:27:34.4	
Hi	N	eQ	08:35:35	
Hi	Z	Tmax	09:02:11	

Table 5.--Distant earthquakes--Continued

Sept. 26--Continued				
Ha	Z	iP	08:27:37.7	
Ha	Z	Tmax	09:02:08	
43-1/2° N., 128-1/2° W. 08:20:51. Off coast of Oregon.				
Sept. 29				
U	Z	eP	15:41:18.0	
U	PEZ	eP	15:41:16.0	
U	PEN	iS	15:48:44	
U	PEZ	eR	15:54:50	
29° S., 176-1/2° W. 15:31:57. Kermadec Islands. Magnitude 6-1/2 to 6-3/4.				
Sept. 30				
M	Z	iP	20:35:15.3	d
O	Z	iP	20:35:15.1	d
D	Z	iP	20:35:13.9	d
U	Z	iP	20:35:14.7	c
U	PEZ	eS	20:43:55	
U	PEZ	eR	20:50:30	
Hi	Z	eP	20:35:17.4	d
Ha	Z	eP	20:35:16.6	d
18° S., 168° E. 20:25:58. New Hebrides Islands. Felt at Port Vila and Vate. Magnitude 6-1/2.				

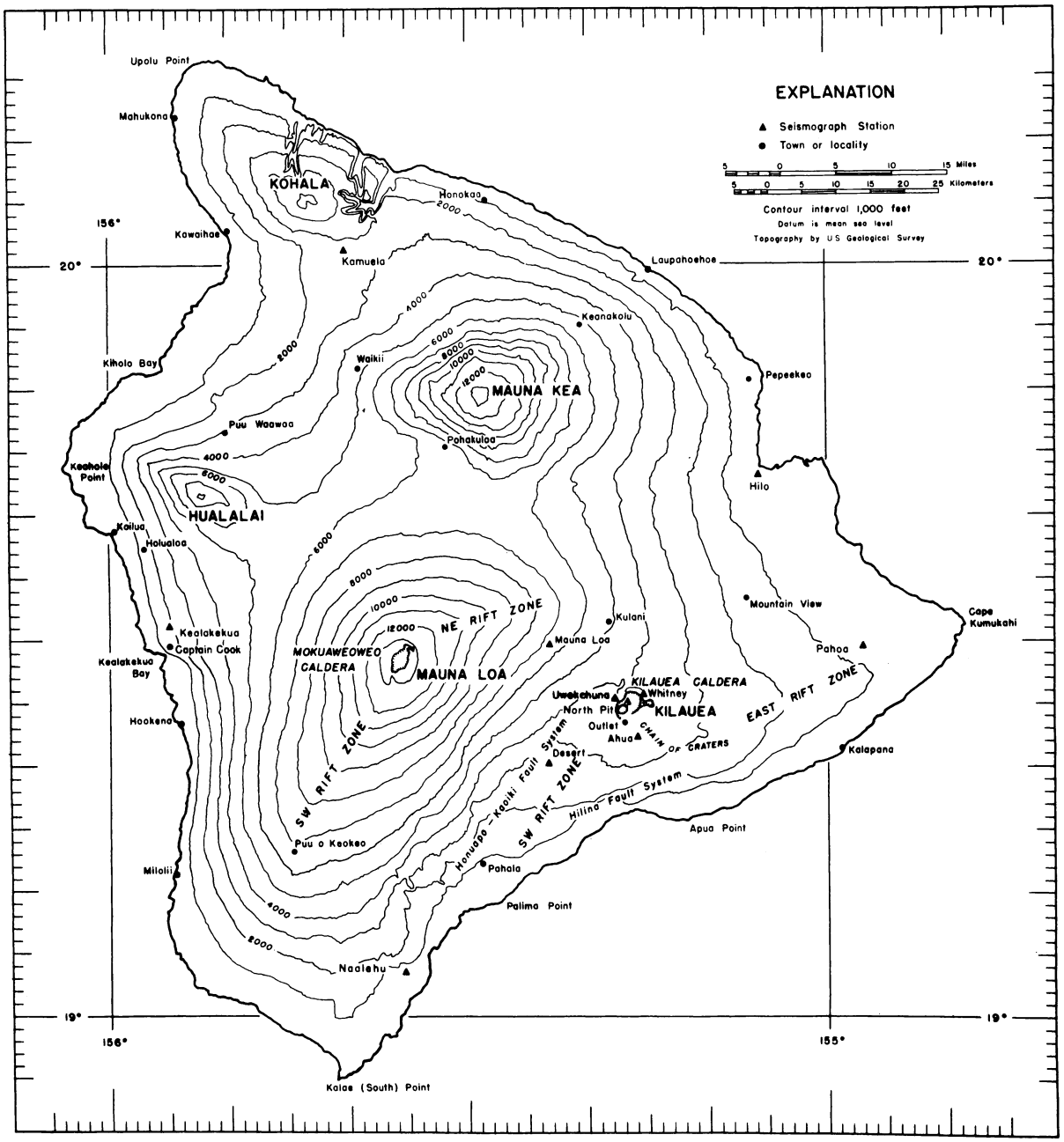

Figure 2.--Map of the Island of Hawaii showing seismograph stations operated by the Geological Survey and localities mentioned in the text. Epicenters of local earthquakes are given in terms of geographic coordinates, which are indicated at the edges of the map.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HAWAIIAN VOLCANO SUMMARY

SUMMARY 16

October, November and December, 1959

by

Harold L. Krivoy, Michael P. Lane and Jerry P. Eaton

Issued ~~August~~, 1965

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#16 APV draft June missing pages

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#16 Kilauea summit

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PRELIMINARY

Preface

It is important for the reader to notice that this Summary 16, for October, November and December of 1959, is actually being issued in 1965. All modern summaries, starting with 24, have been circulated or are in press; the gap between 16 and 24 is being filled now.

The gap in chronological sequence of this series was caused largely by the extreme activity of Hawaiian volcanoes which began in November, 1959 with the eruption of Kilauea-Iki. And there have been surface lava flows from Kilauea every year (excepting 1964) since then, as well as varied seismic storms and crises.

~~During~~ the seismic and volcanic events between 1959 and 1965, the staff of the Hawaiian Volcano Observatory grew in experience as well as in numbers. Also many changes and improvements in instrumentation took place in that period. It would be foolish to blind ourselves to this broader understanding and general amelioration. And so this Summary 16, and the others up to Summary 24, will certainly reflect this "armed" vision." It should, however, not be confused with prevision; in writing Summaries 16 through 23 we will be guided by our knowledge of eruptions and earthquakes "yet to come." But in mentioning these events in a context of earlier chronology, we mean to avoid giving any manifestation of a prescience we neither have, nor claim to possess.

In the present Summary we have attempted an hybrid reportage --- using formats, tables, etc. which were used in Summary 15 --- but also consciously starting a transition toward the style, format and content in vogue by the time of Summary 34. To complicate this attempt at evolution, we are confronted by the unique events of 1959/60 and by the need to utilize entirely new graphical and tabular methods for their complete and orderly representation.

If there is any confusion, therefore, in the continuity or interpretation of Summaries 16 through 23, the reader is urged to consult both Summaries 15 and 24; or he is invited to write for information to:

Hawaiian Volcano Observatory
Hawaii Volcanoes National Park
Hawaii

It would be possible to omit this "note." But there have been enough queries regarding the back-log, that we could easily justify such a statement.

Hawaiian Volcano Observatory

Summary 16

PREFATORY NOTE

It is important for the reader to notice that this Summary 16, for October, November and December of 1959, is actually being issued in 1966. All modern summaries, starting with 24, have been circulated or are in press; the gap between 16 and 24 is being filled now.

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Hawaiian Volcano Observatory

Hawaii Volcanoes National Park

Hawaii

Ratté has gone over this (re-written) page. I am sure he is still not happy with it, and I am not happy with his guide lines.

Chronological Summary

During this quarter workers at Hawaiian Volcano Observatory had the opportunity to study and to sample a very remarkable eruption in Kilauea-Iki, a collapse feature near the summit of Kilauea. Many useful accounts of the Kilauea-Iki eruption have already been published although the most definitive report is still being finalized. Thus we shall attempt to give a brief review of major events in a style and sequence which will not be too repetitive of earlier publications and also which will not detract from the forthcoming Professional Paper.

A partial list of references is as follows:

1. Ault, W. U., 1960, Geochemical research during the 1959-60 activity of Kilauea Volcano: Geochemical News, p. 1-5.

2. Eaton, J. P., 1962, Crustal structure and volcanism in Hawaii in Crust of the Pacific Basin: Geophys. Mon. 6, p. 13-29.

3. Eaton, J. P., and Murata, K. J., 1960, How volcanoes grow: Science, v. 132, no. 3432, p. 925-938.

4. Eaton, J. P., and Wentworth, C. K., 1962, The Hawaiian Volcano Observatory in Thrum's Annual "All About Hawaii" (1961 ed.): p. 35-44.

5. Macdonald, G. A., 1961, Volcanology: Science, v. 133, no. 3454, p. 673-679.

6. Richter, D. H., 1963, Volcano observations: Am. Geophys. Union Trans., v. 44, no. 2, p. 505-507.

7. Richter, Donald H., and Eaton, Jerry P., The 1959-60 eruption of Kilauea volcano: The New Scientist, v. 7, p. 994-997.

In the third quarter of 1959 (Summary 15) small, inward tilting was measured at Kilauea tilt bases. Thus measurements around October 16, 1959 (Fig. 2a) revealed a radical change in the pattern; gentle collapse was replaced by gentle re-inflation. Tilt measurements made before the eruption of 14 November (Fig. 26) showed about five times the previous rate of inflation-tilt. In the short article for The New Scientist* (reference 7, above) Richter and Eaton illustrate this tilt trend in their Figure 2. That illustration shows the same results depicted by Figures 2c and 2d in the following text. Figure 2c shows the collapse coincident with the Kilauea-Iki eruption; 2d shows the re-inflation of the summit storage zone which actually began early in the Kilauea Iki eruption.

* On Page 7 of Summary 24 are plotted 7-day averages of tilt recorded East-West and North-South by the short base, liquid-level tiltmeter in Uwekahuna Vault. This illustrates the history of tilt measurements at Uwekahuna; it starts in July of 1956 and is plotted till August, 1962. The deformation described above is shown and also its relationship to tilt cycles before and after Kilauea-Iki.

The daily tilt readings in Table I, if plotted, reveal a curve similar to that shown in the New Scientist article and one which might be more indicative of day-by-day deformation.

Thus, Kilauea before the eruption in Kilauea-Iki displayed an increasing rate of shallow lava storage. Seismically there was little of note except for a greater and greater number of events recorded at the North Pit seismometer. In Table 3 these events are counted under the heading "Kilauea caldera, shallow." It can be seen in Table 3 that this count reached a high of 800 quakes on October 24 and then the count decreased to reach 90 on November 1, 1959. Thereafter the count rose sharply; by November 8 the number could only be estimated, by November 12 it exceeded 2000 events in a 24-hour period.

This activity had not been previously observed in Hawaii -- probably because there had never been such a sensitive instrument so fortuitously located. In the present case it is noteworthy that similar instruments at Uwekahuna and Outlet -- within 3 km of North Pit failed to show more than 1% of the thousands of small, shallow events. These therefore are assumed to come from failure of the inflating floor of Kilauea caldera, from Halemaumau itself, and from the nearby 1954 rupture zone which lies at the head of the east rift and which leads to Kilauea-Iki and the "chain-of-craters."

The largest quake recorded in October was magnitude 4.4 on October 4, 1959. It was located beneath the offshore portion of Haleakala's east rift and was felt by residents of east Maui.

Three other quakes of magnitude 3.4 were recorded during the month but were not reported felt. Of these, the quake of 03-10-03.5 on 21 October was interesting in that it took place only 30 km south of Honolulu and seemed relatively deep.

Other unusual quakes in October were as follows:

A. 3 Oct., 15-36-08.0 M = 3.2 h = 50
This deeper event was located 25 km east of Pahoa in a region where shallow, east-rift quakes are more common.

B. 16 Oct., 03-37-37.0 M = 3.0 h ca 30
This event was located 35 km N. of the Haleakala seismograph.

C. 25 Oct., 01-43-14.2 M = 2.9 h ca 8
This quake was similar in location to the "felt" event of October 3 described above. Earthquakes from this offshore source are remote from the Kilauea seismic network and so their location is tentative. But the general region -- north of Kohala and east of Haleakala has produced many quakes since 1956.

During the first 13 days of November, 1959, the following large, unusual and/or felt quakes took place:

A. 6 Nov., 11-14-33.4 M = 3.1 h = 5
This event 4 km N. of the Desert station was in the Kaoiki Fault system which separates Mauna Loa and Kilauea.

B. 11 Nov., 07-22-52.3 M = 4.0 h = 13
This is an unusual quake from an offshore epicenter 200 km south of Oahu and 300 west of Mauna Loa station.

C. 12 Nov., 00-21-12.2 M = 3.2 h = 15
12 Nov., 00-31-22.5 M = 3.2 h = 15
These two events from an epicenter 11 km SE of Naalehu were almost replicas of each other; the exception lay in a reversal of first-motion direction at the Hilo seismometer.

D. 12 Nov., 18-04-36.7 M = 2.3 h = 3
13 Nov., 01-00-46.6 M = 1.4 h = 8
Both of these smaller quakes originated at shallow depth beneath Kilauea's summit and they were felt in the summit area.

It should be observed that many small events are listed in Table 4; magnitude 2.5 has hitherto been regarded as a cutoff point for use in this listing. Because of the Kilauea-Iki eruption, however, we have tried to locate and list all readable events which preceed 14 November. There seemed to be no seismic indication during October that an eruption was near except for the thousands of events recording at North Pit. These circumstances, together with tilt results, kept the staff of HVO and the interested public in a high state of expectation during October.

The state of public and official alert continued into November heightened by increased tilt and shallow seismic activity. The felt quakes during the afternoon of November 14 added to the general excitement, and by the time of the outbreak that evening, the Hawaiian Volcano Observatory and the Uwekahuna overlook were already crowded with U.S.G.S. staff members, National Park personnel and tourists -- all scanning and searching the dark vista.

Chronological Summary

Introduction

During this quarter, workers at Hawaiian Volcano Observatory had the unique opportunity to study and to sample a very remarkable eruption in Kilauea-Iki, a collapse feature near the summit of Kilauea. Many useful accounts of the Kilauea-Iki eruption have already been published, although the most definitive report is still being finalized. In this summary, therefore, major events will be reviewed in a style and sequence which will not be too repetitive of earlier publications, and also which will not detract from the forthcoming Professional Paper.

In the course of the seismic and volcanic events between 1959 and 1966, the staff of the Hawaiian Volcano Observatory grew in experience as well as in numbers. Also many changes and improvements in instrumentation took place in that period. And so this Summary 16 and the others up to Summary 24, will reflect a sort of "armed vision." It should, however, not be confused with prevision; in writing Summaries 16 through 23 we will be guided by our knowledge of eruptions and earthquakes "yet to come." But in mentioning these events in a context of earlier chronology, we mean to avoid giving any manifestation of a prescience we neither have, nor claim to possess.

This paragraph has been re-written often, without (I admit) changing the essential "arty" qualities. I think this page is important but perhaps not vital

Pre-eruption events

In the third quarter of 1959 (Summary 15), small inward tilting (collapse) was measured at Kilauea tilt bases. Thus, measurements around October 16, 1959 (fig. 2a, table 2a) revealed a change in the pattern; gentle collapse was replaced by gentle inflation. Tilt measurements made just prior to the eruption of November 14, 1959 (fig. 2b, table 2b) showed about five times the previous rate of inflationary tilt. Richter and Eaton (1960, fig.2) illustrated this tilt trend and showed the same results depicted by figures 2c and 2d of this Summary. The collapse coincident with the Kilauea-Iki eruption is shown on figure 2c, and the reinflation of the summit storage zone (which actually began early in the Kilauea-Iki eruption) is shown on figure 2d.

"The history of tilt measurements at Uwekahuna,"in HVO Summary 24 (Krivoy and others, 1961, p.7, fig.2) illustrated the deformation described above, and also its relationship to tilt cycles before and after Kilauea-Iki. The daily tilt readings in table 1, if plotted, reveal a curve similar to that shown by Richter and Eaton (1960), and one which is more indicative of day-by-day deformation.

In general, therefore, there was evidence to show an increasing rate of shallow lava storage beneath Kilauea prior to the eruption in Kilauea-Iki.

this page might benefit from simplification. Too many references to other publications and Summaries, But I'm too lazy to insert a tilt curve.

There was little to note seismically in this period except for an increasing number of events recorded at the North Pit seismometer. These events are recorded (table 3) under the heading "Kilauea Caldera, shallow." This count reached a high of 800 quakes on October 24 but decreased to 90 by November 1, 1959 (table 3). The count rose sharply thereafter: by November 8 the number could only be estimated, and by November 12 it exceeded 2,000 events per 24-hour period.

Such micro-earthquake activity had not been previously observed in Hawaii -- probably because there had never been such a sensitive instrument so fortuitously located. Seismometers located at Uwekahuna and Outlet, within 3 km of North Pit, failed to show more than 1 percent of the thousands of small shallow events. Therefore these events are assumed to come from failure of the inflating floor of Kilauea caldera, from Halemaumau itself, and from the nearby 1954 eruption fissure zone which lies at the head of the east rift leading to Kilauea-Iki and the "chain-of-craters."

The thousands of events recorded at North Pit and the tilt findings kept the staff of the Hawaiian Volcano Observatory and the interested public in a high state of expectation during October.

An earthquake of magnitude 4.4 occurred on October 4, 1959, beneath the offshore portion of Haleakala's east rift and was felt by residents of east Maui. This was the largest quake recorded for the month. Three events of magnitude 3.4 were also recorded but were not reported felt. Of these, the quake of 03:10:~~XX~~ 03.5 on October 21 was interesting in that it took place only 30 km south of Honolulu and seemed relatively deep.

nothing too controversial here

An unusually deep quake (h=50) was recorded at 15:36 on October 3 from an epicenter 25 km east of Pahoa. This magnitude 3.2 event came, therefore, from an epicentral location where shallow quakes are more common. On 16 October at 03:37, a magnitude 3.0 earthquake occured at a depth of about 30 km and a location about 35 km north of the station at Haleakala, Maui. At 01:43 on October 25, an earthquake of 8 km depth and 2.9 magnitude was located close to the felt event of 4 October described above. Earthquakes from this offshore source are remote from the Kilauea seismic network and so their location is tentative. But the general region --- north of Kohala and east of Haleakala --- has produced many quakes since 1956.

The above large and/or unusual earthquakes in October 1959 are not very different in either number or distribution from such seismic content of other quarters or months. They can certainly not be said to presage (in a regional sense) the eruptive activity in the months to come. Left to be interpreted! I agree to omit.

During the first 13 days of November, 1959, the following large, unusual and/or felt quakes took place; At 11:14:33.4 on November 6 a magnitude 3.1 quake occurred at a depth of 5 km about 4 km north of the Desert seismometer in the Kaoiki Fault system which separates Mauna Loa and Kilauea. At 01:22:52.3 on November 11, an unusual quake of magnitude 4.0 originated from an offshore epicenter 200 km south of Oahu and 300 km west of Mauna Loa station. A depth of 13 km is assumed for this event.

On November 12 at 00:21:12.2 and 00:31:22.5 two almost identical quakes originated at 15 km depth and 11 km southeast of Naalehu. Both quakes were measured as 3.2 magnitude: they were replicas of each other with the sole expeption of a reversal of first-motion direction at the Hilo seismometer. other at nothing otherwise

At 18:04:36.7 on November 12 and at 01:00:46.6 on the 13th. shallow earthquakes of magnitudes 2.3 and 1.4 respectively, originated beneath Kilauea's summit. These were remarkable because they were reported felt despite their small size. In this regard it should be observed that Table 4 --- once restricted to earthquakes of magnitude 2.5 or greater --- has been expanded in scope so as to list and describe all interpretable events regardless of size.

What was true of October, 1959 can also be said of the first 13 days of November --- there seemed to be no seismic indication that an eruption was near, except for the thousands of events recording at North Pit. [illegible]

These circumstances, however, caused the state of public and official alert to continue into November. The felt quakes during the afternoon of November 14 added to the general excitement, and by the time of the outbreak that evening, the Hawaiian Volcano Observatory and the Uwekahuna Overlook were already crowded with U.S.G._S. staff members, National Park personnel and tourists --- all scanning and searching the dark vista.

I don't think Rittè likes this hot climax. But I claim "Laissez faire" "dont de segueur" or one of those French dreams. Otherwise no hu-hu ??

Seismological tracking of the eruptive process

A three-component set of Press-Ewing seismometers (15-second seismometers and 90-second galvanometers) recording optically at 15 mm per minute, has been used continuously and with no change in physical characteristics since January 1958. These instruments have been vital to the study of distant earthquakes, and also have responded usefully to some local events and to barometric pressure changes.

The present evaluation of the 1959-60 records shows a correlation between certain features of volcanism and instability of the Press-Ewing traces. The author first observed a similar phenomenon during the eruptive events of 1961 -- and it was correctly interpreted as tilt-induced. This same sort of tilt "storm" has been recognized as a premonitory feature of lava movements both surficial and sub-surface for all such volcanic events since that time. In fact, the Press-Ewing "departures" would serve to give several hours of warning in the case of incipient volcanism. Such use of the data would require electronic development so that a visible recording was always available, and so that a warning signal might be generated to alert the Observatory staff outside of duty hours.

Many related events are listed in chronological order in Table A --- in general keyed to a qualitative appraisal of Press-Ewing behavior. Table A starts with November 14, 1959; but instability was first noted in the records of November 8. This instability took the form of wandering of the spot at periods of about 20 minutes. Most obvious on the east-west component, it continued through November 9, 10, 11 and 12 but was either small or else not present on the records of 13 November, 1959.

I think that this page contains useful info and is non-confidential.

By January of 1958 a three-component set of Press-Ewing seismometers ~~were~~ operational. ~~These have~~ been used continuously since then with no change in ~~their~~ physical characteristics; 90-second galvanometers and 15-second seismometers, recording optically at 15 mm/minute. These instruments have been vital to our study of distant earthquakes and have given useful responses to some local events and to barametric pressure charges.

During the eruptive events of 1961, the author observed important correlations between certain features of volcanism and instability of the Press-Ewing ~~spots~~ traces. These were correctly interpreted as tilt-induced departures and all Kilauea eruptive events (as well as some apparent sub-surface lava movements) have been indexed by the recorded long-period response of the Press-Ewings in the Uwekahuna vault. When the evaluation of the old 1959/60 records was resumed (in 1964) the same phenomena were noted. The following schedule, therefore, lists many related events in chronological order -- in general, keyed to a qualitative appraisal of Press-Ewing behaviour. Other sources of information were the original logs of the Hawaiian Volcano Observatory, a National Park report -- "Report of Eruption in Kilauea-Iki", the text of the forthcoming professional paper, "The 1959-60 eruption of Kilauea, and the ~~results of~~ author's personal notes, recollections and record-analyses.

The following review commences with 14 November, 1959. It should be noted in Table III, however, that Press-Ewing instability was first noted on November 8, 1959. This wandering of about 20-minute period was ~~not~~ MOST active on the east-west component; it continued through the 9th, 10th, 11th, and 12th of November; but was reduced in amplitude on 13 November 1959.

Table A.--Schedule of tilt-induced departures of the Press-Ewing horizontals at Uwekahuna Vault, and their correlation with other observations during the Kilauea-Iki eruption of 1959-60

Date (1959)	Time From	Time To	Press Ewing	Other sources[1/]
Nov. 14	14:15	14:20	Strong ~~southwest~~ SW. tilt records on horizontals. Summit collapse indicated.	
14	14:48	-----	----------	First of about ~~one~~ 1 dozen felt, Kilauea-Iki premonitory events.
14	20:02	-----	----------	Tremor increase indicates actual start of eruption.

This is the format developed by Tricia into which the following data need be inserted. You should check the following and feel free to change terminology, concepts etc. to conform better with your recent (quantitative) paper on the subject.

1/ Other sources include the original logs of the Hawaiian Volcano Observatory; a report by the Hawaii National Park, "Report of the Eruption in Kilauea-Iki;" the text of the forthcoming professional paper on the 1959-60 eruption of Kilauea-Iki; and the author's personal notes, recollections, and record analyses.

format suggested format

Jackie A. Jaca

Schedule of tilt-induced departures of the Press-Ewing horizontals at Uwekahuna Vault, and their correlation with other observations during the Kilauea-Iki eruption of 1959/60.

Date / Time	Press-Ewing Evidence	Other Sources
Nov. 14, 1959 14:15 to 14:20	Strong south-west tilt records on horizontals. Summit collapse indicated.	
14:48		first of about one dozen felt, Kilauea-Iki premonitory events.
20:02		tremor increase indicates actual start of eruption.
20:08		Kilauea-Iki eruption sighted.
Nov. 21, 1959 19:25	Moderate NNW tilt takes place.	End of tremor and also observed time for end of Phase I.
Nov. 26, 1959		
16:34	Strong WNW tilt on horizontal P-E	
16:35		Reported by observers as "instant" end of fountain with immediate back-flow. End of II.
16:47		Tremor ends on most short-period instruments.
Nov. 29, 1959		
21:47		Official end of Phase III
21:48	Strong WNW tilt (inflation) similar to II.	
Dec. 4, 1959 (start of Phase IV)		
01:00		Given as starting time in HVO reports.
02:57		Occasional spurts to 100' reported by Rangers.

Schedule of tilt-induced departures of the Press-Ewing horizontals at Uwekahuna Vault, and their correlation with other observations during the Kilauea-Iki eruption of 1959/60 (cont.)

	Press-Ewing Evidence	Other Sources
"all morning"	- -	50-100' reported by Rangers
(no special action near 9:00 a.m.)		
09:10	- - - Good indication of modest SE tilt (collapse of summit) on Press Ewings	
09:45 to 11:20	- -	"increased outpouring" reported by Rangers.
Dec. 5, 1959 09:26	- - - Slight N-tilt and large W-tilt. Seems gradual but persists for 2 hours of overwriting. Thus strong inflation indicated beneath north-central portion of Kilauea Caldera.	
09:27	- -	Official report -- "Dead calm settled over the vent" end of Phase IV.
Dec. 6, 1959	- - - Gratuitous tilt between phases IV and V.	Tremor on UZ 0613 ± → 06:50
06:14	- - - Start of two large north-tilts (on PE-N) lasting 1/2 hour. Important inflation beneath Halemaumau implied.	UZ - 1 to 2 MM O - 3/2 MM N - over-write (D, ML, not seen)
06:05	- - - Start of same process on the E-W; west-tilt in two distinct surges which lasts 1/2 hour.	NO VISIBLE SURFACE PHENOMENON AT THE TIME OF THIS TILT AND TREMOR.
Dec. 6, 1959	- - - Phase V start, indicated on PE-E/W by subtle, gradual east-tilt (collapse) shown as slight widening between adjacent lines.	
Dec. 7, 1959	- - - Strong west-tilt begins at 00:21 and persists (slightly north). Showing inflation of center of Kilauea Caldera	End of Phase V.

Schedule of tilt-induced departures of the Press-Ewing horizontals at Uwekahuna Vault, and their correlation with other observations during the Kilauea-Iki eruption of 1959/60 (cont.)

	Press-Ewing Evidence	Other Sources
00:24 00:32	- -	Listed on "official table" in Professional Paper ms. Probably in error.
Dec. 8, 1959 02:45	- - - Another big W-tilt starts at exactly 02:45, crosses over and covers the next hour-line.	
02:45	- -	Official end of Phase VI.
03:00, 04:00 05:00, 06:00	- - - Widening PE lines to indicate east tilt or deflation - - -	Tremor on Z and NP -- possible charge very clear on "O" starts at 05:03.
8 Dec. 1959 around 13:00	- -	Phase VII start reported.
16:53	- -	"Suddenly at 16:53 the fountain roared to 850 ft." (From P.P.)
16:53	- - - On E/W Press Ewing only, gentle but persistent E-tilt which widens spaces between lines for one hour.	
20:12	- - - Immediate demonstration of strong west-tilt (slightly north) i.e.: supposed inflation beneath north-central caldera.	
20:12	- -	End of Phase VII.
21:05 to 23:00	- - - PE-E/W wide spaces = east tilt - - - - - - - - - - - - - - -	"Fountain stopped abruptly" good "band" of tremor U, D, M, etc. 21:05→ 23:00 ±
Dec. 10, 1959	- - - Power outage in Uwe Vault 12:20 to 21:11	

Schedule of tilt-induced departures of the Press-Ewing horizontals at Uwekahuna Vault, and their correlation with other observations during the Kilauea-Iki eruption of 1959/60 (cont.)

	Press-Ewing Evidence	Other Sources
15:15	- -	Subtle start of VIII.
Dec. 11, 1959		
02:00	- -	Activity picks up - HNP
02:10 ±	- - - Widening of spaces begins and implies east-tilt and increased eruptivity.	
02:40	- -	Ftns. to 700 & 1000 ft. do.
03:30	- -	Spatter Ridge shower.
(Dec. 10, '59)	Starting around 21:20 only on PE-Z about one hour of ca.280-second waves (13 cycles in one hour)). Probably a barometric phenomenon due to testing?	
Dec. 11, 1959 10:48	- - - Strong west-tilt (slightly north) in the usual manner. Takes one hour to recover or "catch up."	
08:14 to 10:48	- -	"Official" slow death of Phase VIII.
Dec. 13, 1959		
05:08	- - - (No PE change) -	Feeble start of IX.
06:25	- -	Rolling boil of lava.
ca. 06:30	- - - Spacing increases in a direction to imply east-tilt, caldera collapse and increased outpouring. - - -	
by 07:00	- -	Ft. betw. 100 & 700 ft.
13:40	- - - Typical west-tilt deflection of Press-Ewing E/W - - - - - -	Official end of Phase IX.
Dec. 14, 1959		
07:45 to 10:40	- -	Slow start of X.
11:00	- -	"Ftn. roared to life" (to 1100 ft. in 8 minutes).
11:01	- - - Strong east-tilt starts with spaces wider than ever at the "starts" so-far studied. - -	

Schedult of tilt-induced departures of the Press-Ewing horizontals at Uwekahuna Vault, and their correlation with other observations during the Kilauea-Iki eruption of 1959/60 (cont.)

	Press-Ewing Evidence	Other Sources
15:36	- - - Strong west-tilt in the usual manner for end of phase - - -	Also "official" end of Phase X.
Dec. 15, 1959		
06:11	- -	Gentle start of XI; but at 1000 ft. in minutes.
ca. 06:25	- - - Very strong east-tilt begins and seems to last 1/2 hour. Also around 07:00, south-tilt becomes apparent on the N-S instrument.	
10:25	- -	Official end of XI.
10:27 to 10:28	- - - Usual WNW tilt shows strongly. (Wide spacing in E-W immediately after 10:28 inflation shows collapse on the heels of the usual west-tilt). (This might be the start of storage in the east-rift).	
Dec. 15, 1959		
19:30	- -	First sighted & "within 30 min. jetting to 1000 ft."
(20:00)		
19:55	- - - Strong east-tilt on E/W pinpoints start of strong action. At the same time (roughly) there is subtle south tilting shown on N/S.	
21:28	- - - Start of strong west-tilt (north, too subtle to copy).	
21:30	- -	Official end of XII.
22:35	- - - Slight "bobble" on E/W, P-E coincides with end of noise and rapid backflow whirlpool.	
Dec. 16, 1959 (During phase XIII)		
13:35	- -	"Rapidly hit a peak outflow in a few minutes"
13:45	- - - Indicates east-tilt at ca. 13:45 which persists 1/2 hour. Also compression of lines shows slight south-tilt.	

Schedule of tilt-induced departures of the Press-Ewing horizontals at Uwekahuna Vault, and their correlation with other observations during the Kilauea-Iki eruption of 1959/60 (cont.)

	Press-Ewing Evidence	Other Sources
16:35	- - -	Fountain choked.
17:19	- - -	XIII appeared stopped by backflow.
17:19	Good, strong cross-over on E/W to show west-tilt.	
17:20	Weak indication of north-tilt.	
Dec. 17, 1959		
02:15	- - -	Approximate "official" start of Phase XIV.
02:32	Collapse shown on PE-E, only.	
04:01	Start of west-tilt on PE-E.	
04:02	- - -	Official end of Phase XIV
11:10	- - -	Spatter observed and small outflow for two hours.
13:53	- - -	Sudden pickup in output.
13:55	Large east tilt.	
14:05	(No special change)	1900 ft. fountain.
14:41	- - -	Surges begin.
15:18	Small west tilt.	
15:29	Start of large west tilt which persists 1/2 hour.	
15:32	- - -	Official end of Phase XV.
Dec. 19, 1959		
02:40	- - -	Gentle start of XVI which reached 1500 ft. during next 25 minutes (03:25?).
03:13	East tilt readily apparent on EW P-E, and faint south tilt implied on N/S.	
06:14 to 06:15	Strong west tilt on EW, P-E small, but visible on N-S.	
06:16	- - -	Abrupt end observed.

Schedule of tilt-induced departures of the Press-Ewing horizontals at Uwekahuna Vault, and their correlation with other observations during the Kilauea-Iki eruption of 1959/60 (cont.)

Phase XVII. Has no tilt ramifications on the Press-Ewings, although the record changed about 07:58 on 12/20 --- roughly the time of phase ending. Also no Z tremor seen during this Phase.

Up to, and including Jan. 8, Press-Ewing E/W has no overt or sudden departures. As of the records of Jan. 9, 10, 11, 12, and 13, as many as 10 departures daily showed east- or collapse-tilt. At this time N and Z did nothing observable.

Jan. 14, 1960. Either no suspicious tilt on P-E or too much earthquake noise to read it.

Jan. 30, 1960. West-stop reached on Press Ewing E/W...i.e., east-tilt has taken its toll.

Scientific Investigations during the Kilauea-Iki Eruption

As one outcome of international attention to active volcanism, there have been many attempts to codify and to regulate human behaviour under such circumstances. The interest is dual --- protection of the civilian populace, and conduct of the necessary scientific investigations. It seems valid, therefore, to add to this growing literature --- if only for the guidance and information of future workers at the Hawaiian Volcano Observatory.

A telegram sent by the HVO scientist-in-charge, K.J.Murata to our Branch Chief (Field Geochemistry and Petrology) in Washington D.C., William T. Pecora, will introduce the theme. "An eruption of Kilauea volcano started Saturday night, Nov. 14, in Kilauea-Iki, a pit crater immediately adjacent to the summit caldera. After first breaking out on a wide front, the lava is now issuing from a single large vent in a fiery fountain 700 feet high. It is an awesome sight, especially at night. We are so occupied that we must beg off giving a detailed account at this time."

The foregoing only vaguely suggests the great activity undertaken by workers at the U.S.G.S. Hawaiian Volcano Observatory and by the employees of the National Park Service; this was an activity scheduled completely by nature so that after a few weeks of dramatic eruption punctuated by equally dramatic quiet, life on the summit of Kilauea became a beautiful, sleepless blur of unreality.

A primary consideration was for the well-being and convenience of the thousands of visitors who came from Hawaii, from other islands of the State and from the mainland to witness this breath-taking natural wonder. During the first phase of the outbreak it became difficult to use the Crater-Rim Road where it passed behind the main Kilauea-Iki vent. For the early phases of the eruption the Hawaii National Park crew was able to free the road of ash once the phases subsided. But the job soon got to be too great for available road equipment (a small

road grader had to be rescued itself) and the fall-out hill now known as Puu Pauai was allowed to grow. It now covers parts of the old Crater Rim road with over 100 feet of ash and fire-fountain aglutinate. Also eventually covered was a pleasant picnic area called "Summer Camp." This area, which includes the water-tube tilt base listed by the same Name, now lies under twenty or thirty feet of ash and is part of the Devastation Trail area where a wooden cat-walk permits tourists to inspect tree-molds and other features of Kilauea-Iki volcanism.

Thus, the Kilauea-Iki eruption provided a serious traffic problem for the Park Service Ranger staff. Eventually this was handled by setting up a convoy pattern of traffic in which visiting vehicles were turned at Thurston Lava Tube (just west of BM 3918 at the eastern extremity of Kilaue Iki crater. See Figure C.) On the return trip (westward) toward Park Headquarters, they were permitted to park and to view the eruption from a railed overlook near BM 3874. This ~~latter~~, therefore, became the main viewing point for the thousands of tourists who visited the Park during the eruption. It was just about one kilometer from the main fountain; and thus it offered the visitors an un-blocked view of the fountains which at times soared to 2,000 feet; with the growing lava lake of Kilauea ~~And in the foreground rose the growing lava lake of Kilauea-Iki.~~ Pit in the foreground

At this main overlook, therefore, one of the National Park Naturalists was almost always on ~~continuous~~ duty. Their notes of fountain heights and their color film footage and still photography were to prove vital links in piecing together the complete story of the eruption.. As soon as the Kilauea-Iki fountain began to demonstrate a proclivity for unheard of heights, Park Service and Geological Survey officials consulted to set safety standards. It was decided to evacuate tourists from the main overlook whenever the measured fountain height exceeded 1000 ft. This was later raised to 1,200 feet when

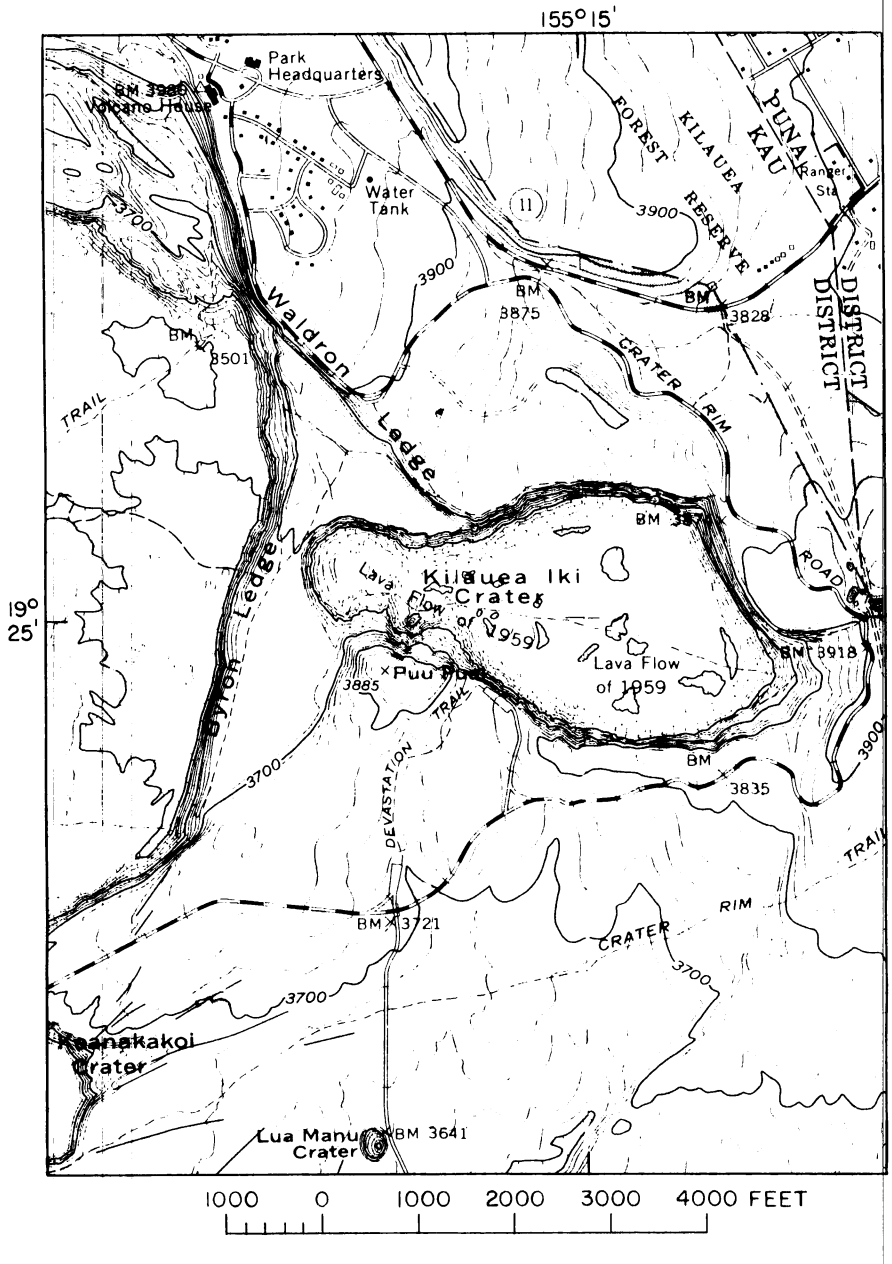

155°15'
19°
25'
Park Headquarters
BM 3987
Volcano House
Water Tank
11
FOREST
KILAUEA
PUNA
KAU
RESERVE
Ranger Sta.
DISTRICT
DISTRICT
3900
3700
BM 3875
BM 3828
BM 3501
Waldron Ledge
CRATER RIM
TRAIL
Byron Ledge
BM 3711
ROAD
Kilauea Iki Crater
Lava Flow of 1959
Puu Puai
3885
Lava Flow of 1959
BM 3918
TRAIL
DEVASTATION
BM 3835
BM 3721
CRATER RIM
Kaanakakoi Crater
Lua Manu Crater
BM 3641
1000 0 1000 2000 3000 4000 FEET

Fig C...?

we began to get more blase. Probably because trade widds persisted throughout the eruption ~~which~~ carried the bulk of the eruption debris over the Kau Desert to the south and southwest of the main vent, only minor ash fallout was ever experienced at the main visitor overlook. Nevertheless visitors ~~they~~ were evacuated at times according to the criteria of fountain height and also when the adjacent trees and shrubs were dried and ignited by the deepening lava lake.

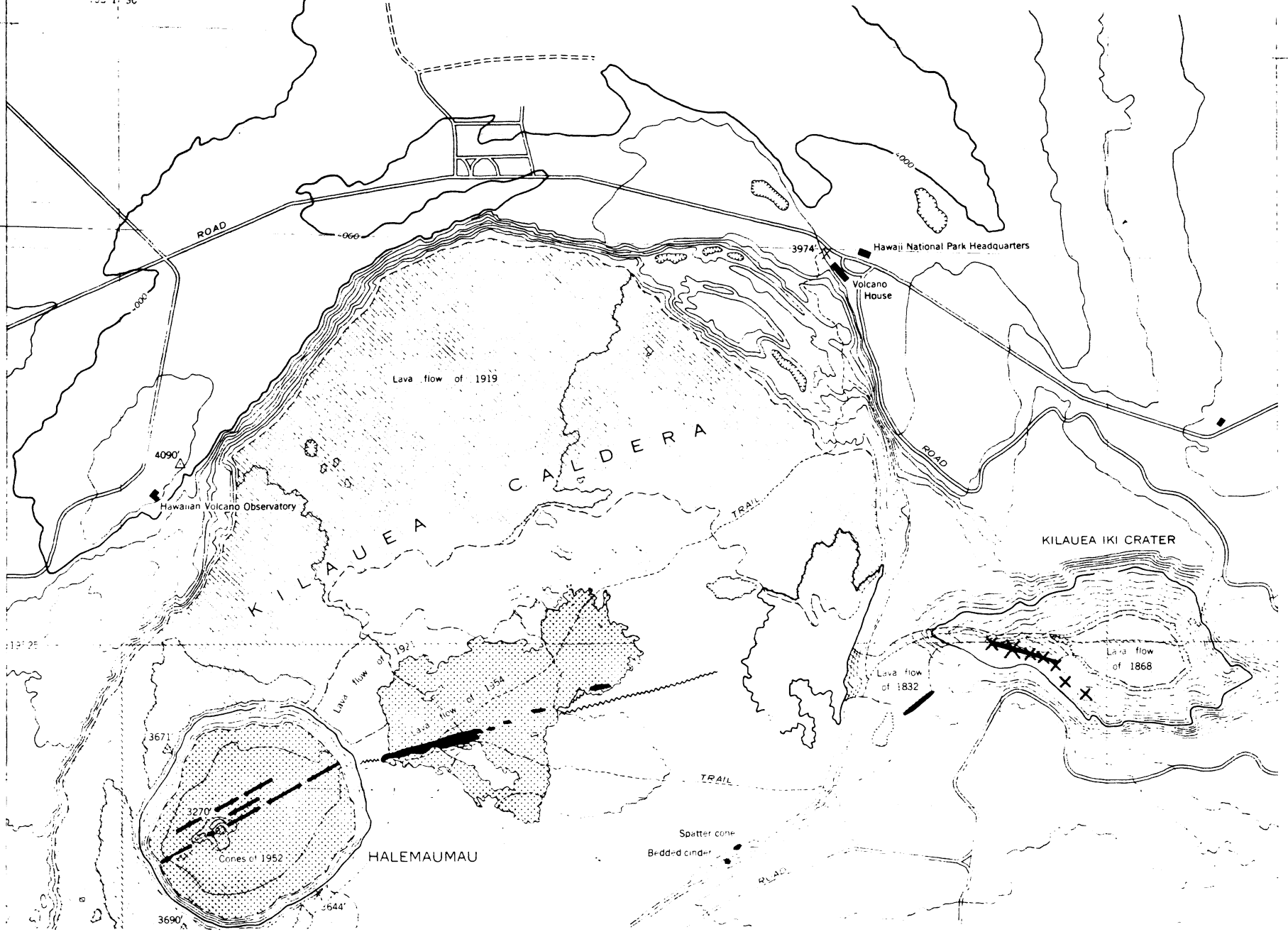
Just north of the main Kilauea-Iki vent, on the north rim of Kilauea-Iki crater, were other trails and possible overlooks. These were within 1,500 feet of the main vent. And it is a tribute to the vigilance of Park Rangers that no visitors were injured on the several occasions when the fountain deflected and plastered large areas of that north rim with ~~MMMM~~ bombs *and* molten spray. It is a tribute to some goddess of chance that no scientist ~~or~~ park official or official press observer ever suffered more than slight damage. Although we all had to run more than once, ~~away, on many occasions~~ from wind changes or from increased fountains.

A ~~Another~~ psychological hazard early in the eruption was caused by low-flying aircraft which flocked in from Oahu. ~~to view the eruption.~~ To those of us working within the crater, the noise of their engines suggested imminent, new volcanism right under our feet. To flight passengers the trip might have given a sensation of flying through the field of fire of an artillery piece. At any rate, such overflights were discontinued by FAA order after several instances of windshield breakage and other damage to participating aircraft.

The foregoing should suffice to show, in a brief and general way, the rather hectic and carnival atmosphere of a typical Hawaiian eruption. It is important to strees that many of the international guides to evacuation and protection of the populace simply do not apply in Hawaii where the problem is the reverse --- the inflow of large numbers of tourists.

From Tables 2a, 2b, 2c and 2d it can be reckoned that 24 bases were occupied using the water tube tiltmeter during the quarter. These are done after dark and require a team of four men. Each single occupation takes an average of two hours. Thus it can be seen that a great deal of time needed to be devoted to the basic material of this summary by people already working double shifts at both routine and emergency duties. The tilt crew always consisted of Eaton and Krivoy as readers. As notekeeper and valve-man, duty was rotated among other members of the staff. J.C.Forbes, Akira Yamamoto, W.H.Francis and B.J.Loucks were the most frequently tapped for this duty. ~~Although~~ D.H.Richter, W.U.Ault, K.J.Murata, G.Kojima and R.T.Okamura either joined the tilt party on occasions, or else took on some other task which freed some other staff member for the function.

The first task seriously undertaken after the outbreak in Kilauea-Iki was the attempt to colledt gases and vapours. Most of the people at HVO had a hand in that and we worked onder the direction of geochemist W.U.Ault. Figure B will give some idea of the number and location of the original outbreak vents. Where these lay paraldel to the Crater Rim Road, thick clouds of ~~gas and smoke~~ rose up the slopes of Kilauea-Iki Crater and swirled over the road. Most of the staff, therefore, spent considerable time going back and forth to this location with a variety of evacuated flasks supplied by Wayne Ault and George Kojima. The most obvious constituent of these gas clouds was SO_2 with some slight admixture


ROAD
Hawaii National Park Headquarters
3974'
Volcano House
Lava flow of 1919
4090'
Hawaiian Volcano Observatory
KILAUEA CALDERA
TRAIL
ROAD
KILAUEA IKI CRATER
Lava flow of 1868
Lava flow of 1832
Lava flow of 1954
Lava flow of 192
3671'
3270'
Cones of 1952
HALEMAUMAU
TRAIL
Spatter cone
Bedded cinder
ROAD
3690'

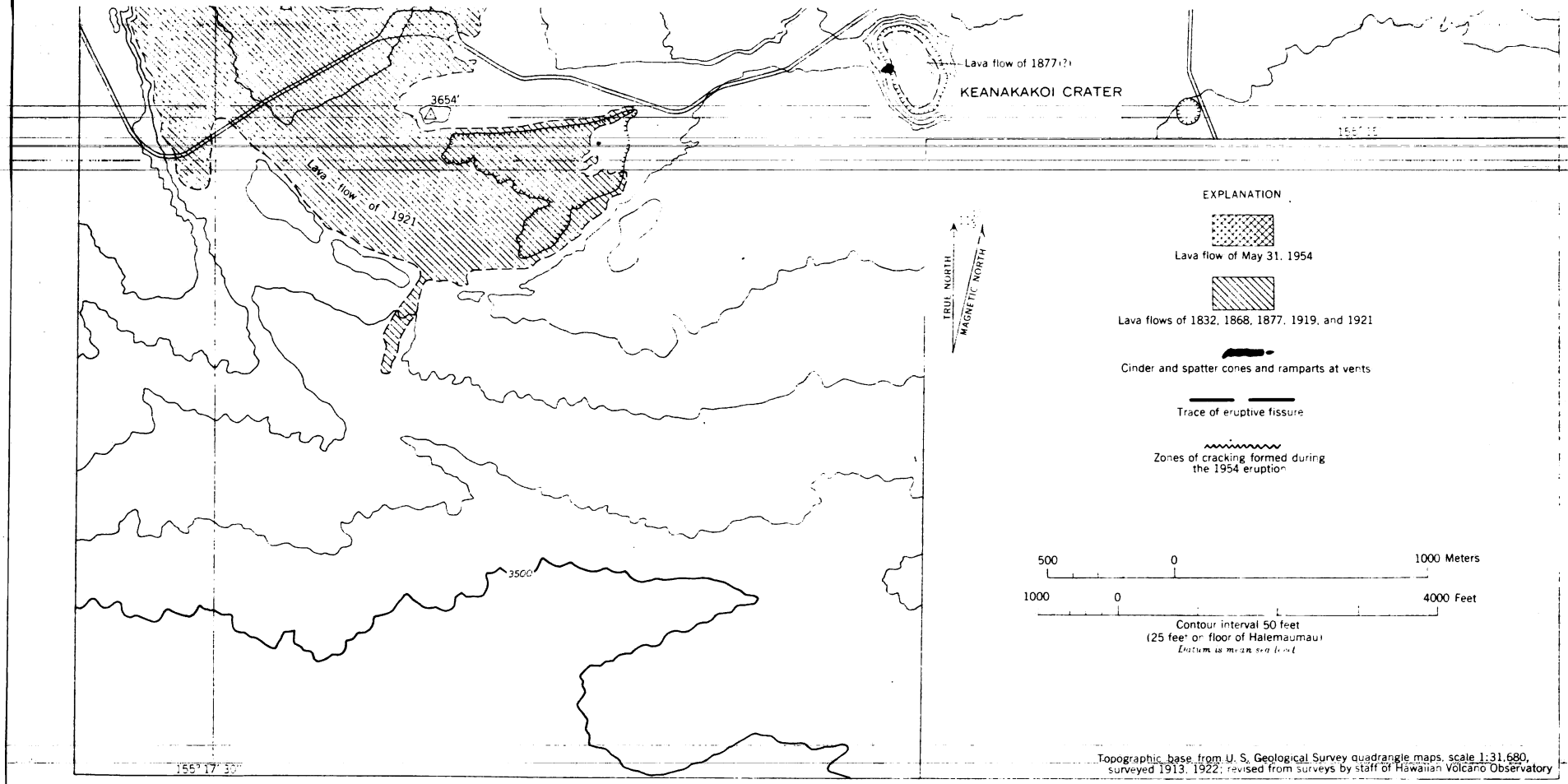

Lava flow of 1877(?)
KEANAKAKOI CRATER
3654'
Lava flow of 1921
3500
155° 17' 30"
TRUE NORTH
MAGNETIC NORTH
EXPLANATION
Lava flow of May 31, 1954
Lava flows of 1832, 1868, 1877, 1919, and 1921
Cinder and spatter cones and ramparts at vents
Trace of eruptive fissure
Zones of cracking formed during the 1954 eruption
500 0 1000 Meters
1000 0 4000 Feet
Contour interval 50 feet
(25 feet on floor of Halemaumau)
Datum is mean sea level
Topographic base from U. S. Geological Survey quadrangle maps, scale 1:31,680, surveyed 1913, 1922; revised from surveys by staff of Hawaiian Volcano Observatory

Fig B . . . ?

of H_2S. It was found to be too clumsy to use gas masks; wet handkerchiefs were preferred. The investigators were usually able to park on the side of the road away from the crater where they could work without protection and with only moderate discomfort. The practise then was to cover nose and mouth with a wet cloth and to dash over to the edge of the road which was also the edge of the crater, to plunge the collecting flask *into* the most obvious gas and vapour cloud, to break the vacuum seal and finally go re-seal the vessel and retreat for another flask.

Results of these studies of the gas phase will be discussed in the forthcoming Professional Paper. The techniques described above could be used only during the earliest hours and days of the eruption; once Kilauea-Iki settled down to a single roaring vent it imposed such a strong pattern of air circulation that no sampling was possible except over the orifice. In the course of the eruption a few gas samples were attempted by the expedient of flights through the rising vapour column. Some gas collections were made from the vent and from the growing cinder cone between phases of the eruption. Thought was given to the possibility of erecting a collecting tram although this was not carried out during the Kilauea-Iki eruption. Such a device was completed for sampling gasses in Halemaumau during 1960, and another was operated in 1961 which ran on wires above the main Halemaumau vent.

Jack Murata organized the laboratory facilities which permitted him to run rapid silica determinations. And during the Kilauea-Iki and Kapoho eruptions, the staff supplied him with freshly collected, timed and dated samples which represented what was probably the most complete chemical and mineralogical record of an eruption anywhere in the world. The persistence of single vents --- both at Kilauea-Iki and at Kapoho

made such samples more meaningful and easier to obtain. At Kilauea-Iki we were all armed with sample bags and could easily drive along Crater Rim Road, observe fresh samples falling on the road, and make collections with reasonable impunity. At night, freshness could be attested by glowing interiors; at times fingers were burned and sample bags were charred. To supplement this hourly sample suite, the fall-out cone and the lake surface were sampled whenever possible.

As often as was possible, temperature measurements were made using two Leeds and Northrup optical pyrometers. These were used by groups of two or three people who passed the pyrometers from man to man in order to get as much confirmation as possible of the lava temperature in any particular fountain and at any particular time. Other measurements involved the lava production of each phase. These data were obtained by Don Richter who made level and transit runs into Kilauea-Iki crater leaving monuments at known elevations and then recording the time it took for the rising lake to overcome these monuments.

Other eruption duties included dealings with the public, the press and with officials of both local and federal governments. Once the eruption broke out, the Observatory went on a 24-hour basis; one person was needed to change the smoked-paper seismograms which often became filled in three or four hours; another person was needed to answer the phones and keep a log of the activities and whereabouts of the staff. Many of these functions were ably handled by volunteers, Mrs.Chester Wentworth and Mrs. Burt Loucks. Observatory workers were very appreciative of emergency snacks which turned up out in the field thanks to some unknown Park Service, USGS or Volcano Community wife.

Thousands of feet of color 16mm. movie film were expended with most everyone taking a turn with the 1946 model Bell and Howell. Hundreds of 4x5 black and white photos were made of every conceivable scene and from every possible angle.

A portable tape-recorder was used to record eruption sounds: fountains roaring, a hornito hissing, splatter and ash falling, etc. Although we did not have synchronous recording of sound and film, the magnetic tapes were used with considerable effect by the film laboratories where actual recordings were dubbed into eruption footing for the movie 1959-60 Eruption of Kilauea.

We went through the motions of using a vertical Askania magnetometer soon after the eruption broke out. Although there was a magnetic traverse which crossed Kilauea and part of Mauna Loa, it was far from Kilauea Iki. Furthermore no one on the staff had had sufficient preparation in work on Kilauea to permit the establishment of a better traverse. As is typical in other igneous settings, slight changes in tripod level or location can cause excursions of thousands of gammas in the reading. Thus care, patience and experience are vital in any study of the absolute field or of transients in such an environment. It was found to be very hard to read the magnetometer near the vent due to mechanical agitation of the balance caused by earth tremor. After a few trials the magnetometer was put aside. In the six years since the Kilauea Iki eruption some scant use of magnetometers has been made --- usually to study the terrain effect of steep banks and/or the cooling and thickening of hot lava lakes such as Kilauea-Iki. The Hawaii Institute of Geophysics has flown crude preliminary magnetic traverses over the Hawaiian volcanoes. But no one has tried to use the magnetometer as an aid in outlining sub-surface lava pockets. Nor have they used magnetic transients as a clue to underground lava motion such as is hinted at by tremor, tilt and deformation in general.

Before the end of 1959, a portable World-Wide gravimeter was in use to compile a gravity map of Kilauea (Krivoy and Eaton, 1961). In

the intervening years, gravity maps have been completed for Hawaii, as well as for other major islands of the state. Some attempt has been made to repeat traverses using the drift-free LaCoste-Romberg. But it seems likely that in gravity, as well as in geo-magnetism, sensitive, low-drift, continuous-recording devices might prove the most instructive regarding volcano-dynamism in Hawaii.

Tilting of the ground around Kilauea caldera.--Tilting of the ground around the summit of Kilauea is monitored daily by a short-base water-tube tiltmeter in Uwekahuna Vault, and at irregular intervals it is measured on a regional scale by means of a network of field tilt bases and a portable water-tube tiltmeter. The attitude of the ground surface a each tilt base is reported in terms of north-south and east-west tilt coordinates. Both coordinates at each station were arbitrarily set equal to 500 when measurements at that station were begun. Increasing tilt coordinates correspond to northward and eastward tilting of the earth's surface, i.e., to a relative subsidence toward the north and east. A one-unit change in coordinate corresponds to a tilting of 1 microradian (1 mm per km) in the direction indicated.

Table 1.--Tilt coordinates at Uwekahuna Vault October, November, and December, 1959

[These data are usually reported on a basis of 7-day averages. Dates and coordinates in parentheses reflect added detail introduced because of rapid changes during this eruption period.]

Date	N-S	E-W	Date	N-S	E-W
Oct. (1)	(522)	(462)	Nov. 15	513	445
4	523	460	(18)	(511)	(449)
(7)	(523)	(461)	22	506	484
11	523	459	(25)	(506)	(480)
(14)	(522)	(461)	29	509	461
18	523	460	Dec. (2)	(510)	(453)
(21)	(524)	(459)	6	514	441
25	523	455	(9)	(517)	(432)
(28)	(524)	(454)	13	523	428
Nov. 1	523	451	(16)	(531)	(425)
(4)	(523)	(453)	20	538	428
8	520	449	(23)	(540)	(428)
(11)	(518)	(448)	27	542	430
			(30)	(546)	(432)

Table 2a.--Tilt coordinates and changes at bases around Kilauea caldera (See tilt diagram, fig. 2a).

Tilt base	Date	Tilt coordinates		Rate (10^{-6} rad/mo) and direction of tilting since last reading		Date of last reading (1959)
		N-S	E-W			
Uwekahuna (19°25.5'N, 155°17.4'W)	Oct. 12	546.9	468.2	2.3	N38°W	Aug. 13
Tree Molds (19°26.3'N, 155°17.3'W)	13	501.5	498.1	0.9	N13°W	14
Summer Camp (19°24.6'N, 155°15.6'W)	16	519.8	529.5	2.3	N64°E	15
Sand Spit (19°24.1'N, 155°16.8'W)	16	525.3	483.7	1.4	S46°W	15
Kalihipaa (19°21.4'N, 155°15.3'W)	13	488.6	500.7	0.15	W	14
Keamoku (19°25.1'N, 155°19.0'W)	20	515.4	493.3	1.9	S81°W	17
Kamokukolau (19°22.7'N, 155°16.6'W)	19	488.6	505.8	2.5	S3°W	16

Table 2b.--Tilt coordinates and changes at bases around Kilauea caldera (See tilt diagram, fig. 2b).

Uwekahuna	Nov. 10	552.8	464.9	7.0	N29°W	Oct. 12
Tree Molds	12	509.5	496.4	8.2	N12°W	13
Summer Camp	13	531.0	538.6	15.5	N38°E	16
Sand Spit	13	527.5	473.9	11.8	N78°W	16
Kalihipaa	12	487.1	501.7	1.8	S34°E	13

Table 2c.--Tilt coordinates and changes at bases around Kilauea caldera (See tilt diagram, fig. 2c).

Tilt base	Date	Tilt coordinates		Rate (10^{-6} rad/mo) and direction of tilting since last reading		Date of last reading (1959)
		N-S	E-W			
Uwekahuna	Dec. 1	535.7	464.1	23.3	S3°W	Nov. 10
Tree Molds	2	504.7	490.1	11.9	S53°W	12
Sand Spit	4	545.0	469.9	25.7	N13°W	13
Kalihipaa	2	486.7	501.8	0.5	S10°E	12
Keamoku	4	504.9	496.7	7.4	S17°E	Oct. 20
(AHUA) Kamokukolau	3	479.2	500.9	7.1	S28°W	19

Table 2d.--Tilt coordinates and changes at bases around Kilauea caldera (See tilt diagram, fig. 2d).

Uwekahuna	Dec. 28	570.5	447.1	42.7	N25°W	Dec. 1
Tree Molds	28	516.2	488.2	13.4	N9°W	2
Sand Spit	31	605.8	467.7	67.7	N2°W	4
Kalihipaa	29	471.3	509.0	19.0	S25°E	2
Keamoku	31	543.8	469.8	44.7	N42°W	4
(AHUA) Kamokukolau	30	414.1	535.6	81.9	S27°E	3

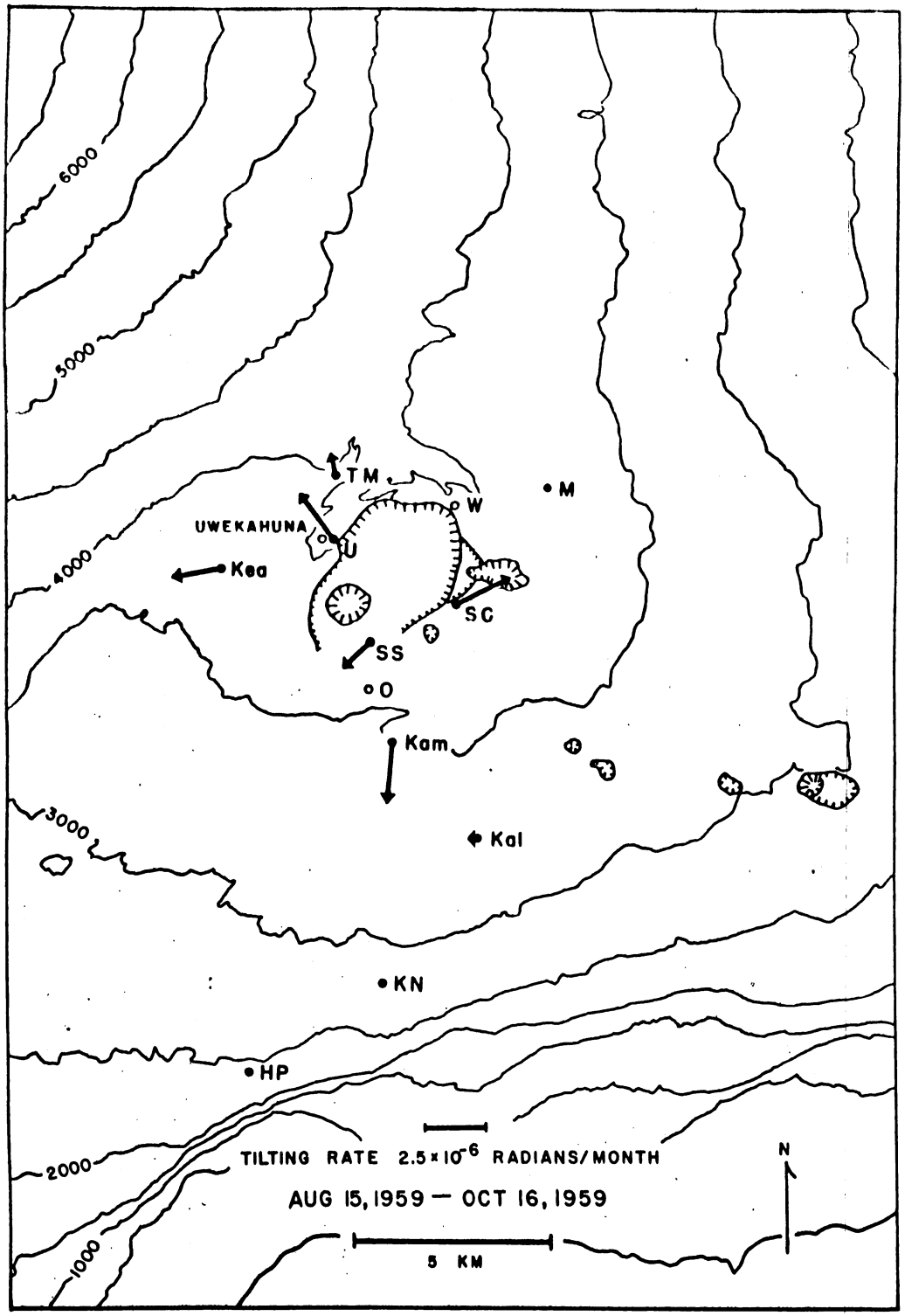


Figure 2a.-- Tilting of the ground around Kilauea caldera, August 15 to October 16, 1959. The vector depicting tilting at a given tilt base points in the direction of maximum relative subsidence and has a length proportional to the rate of tilting during the measurement interval. Closed circles represent field tilt bases; open circles, short-base water-tube tiltmeters.

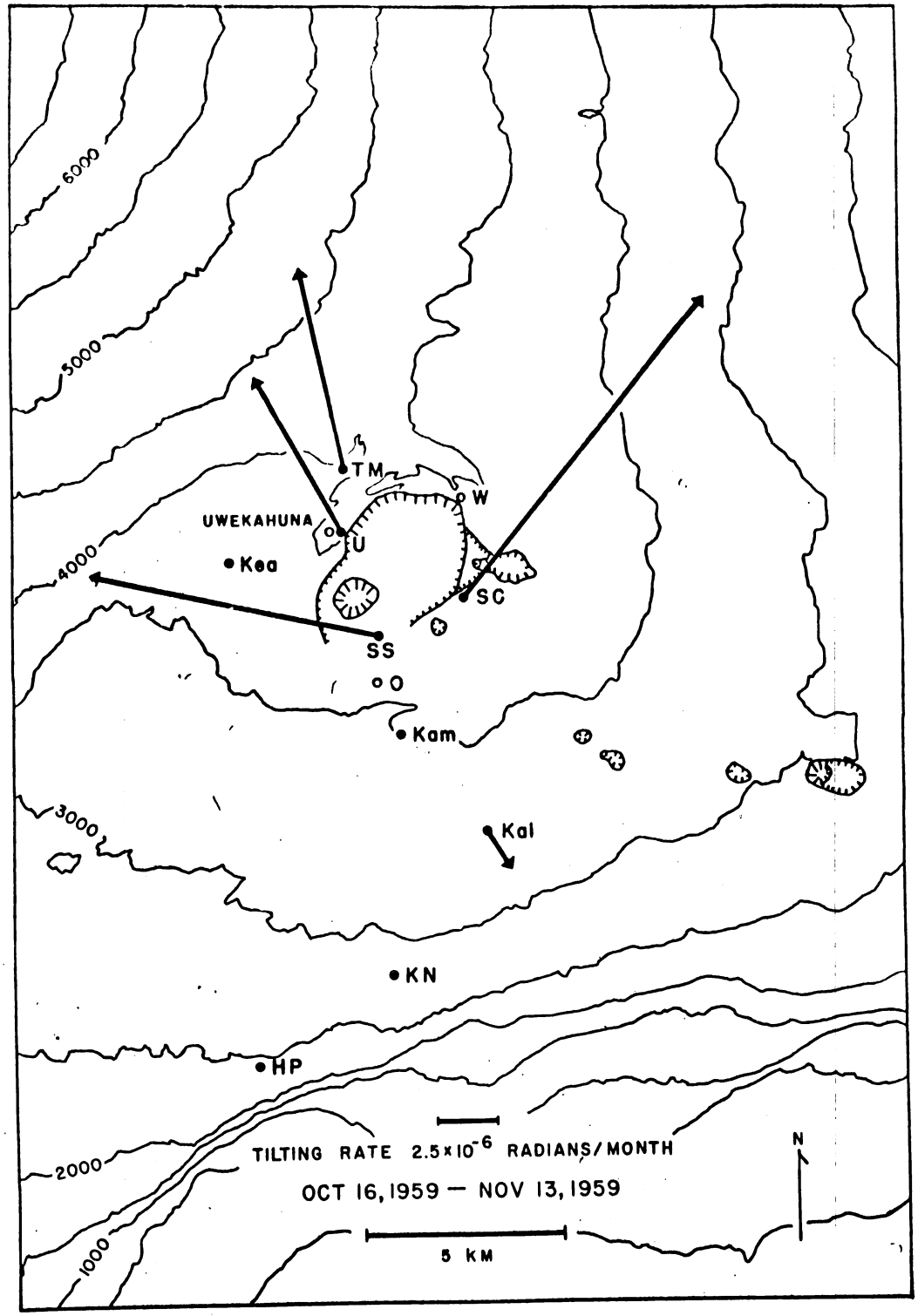


Figure 2b.-- Tilting of the ground around Kilauea caldera, October 16 to November 13, 1959. The vector depicting tilting at a given tilt base points in the direction of maximum relative subsidence and has a length proportional to the rate of tilting during the measurement interval. Closed circles represent field tilt bases; open circles, short-base water-tube tiltmeters. All field bases were not occupied because of the start of the 1959 eruption in Kilauea-Iki the evening of November 14, 1959.

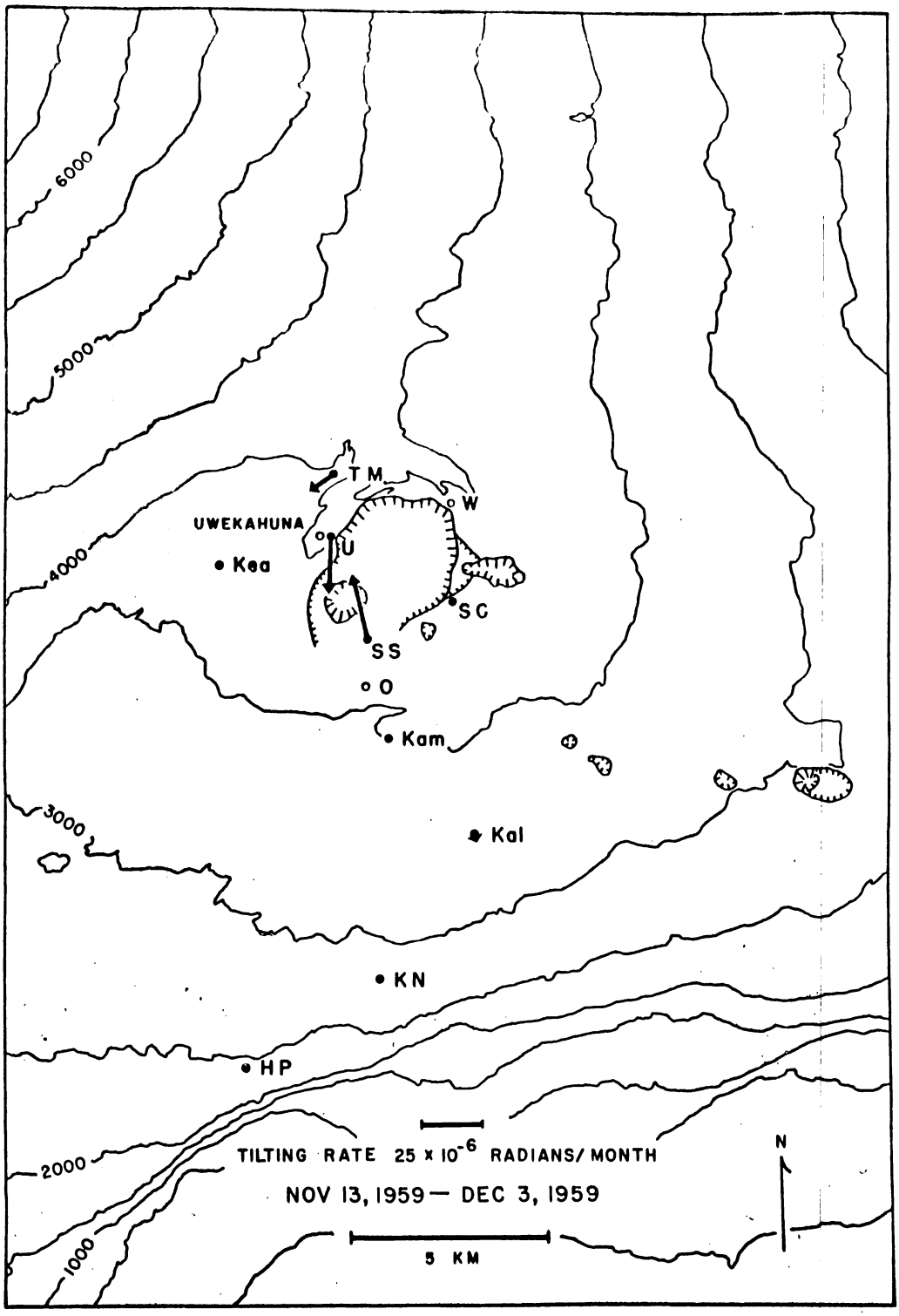


Figure 2c.-- Tilting of the ground around Kilauea caldera, November 13 to December 3, 1959. The vector depicting tilting at a given tilt base points in the direction of maximum relative subsidence and has a length proportional to the rate of tilting during the measurement interval. Closed circles represent field tilt bases; open circles, short-base water-tube tiltmeters. The tilt base at Summer Camp (SC) was occupied for the last time on October 16, 1959; in the course of the Kilauea-Iki eruption it was covered by about thirty feet of ash.

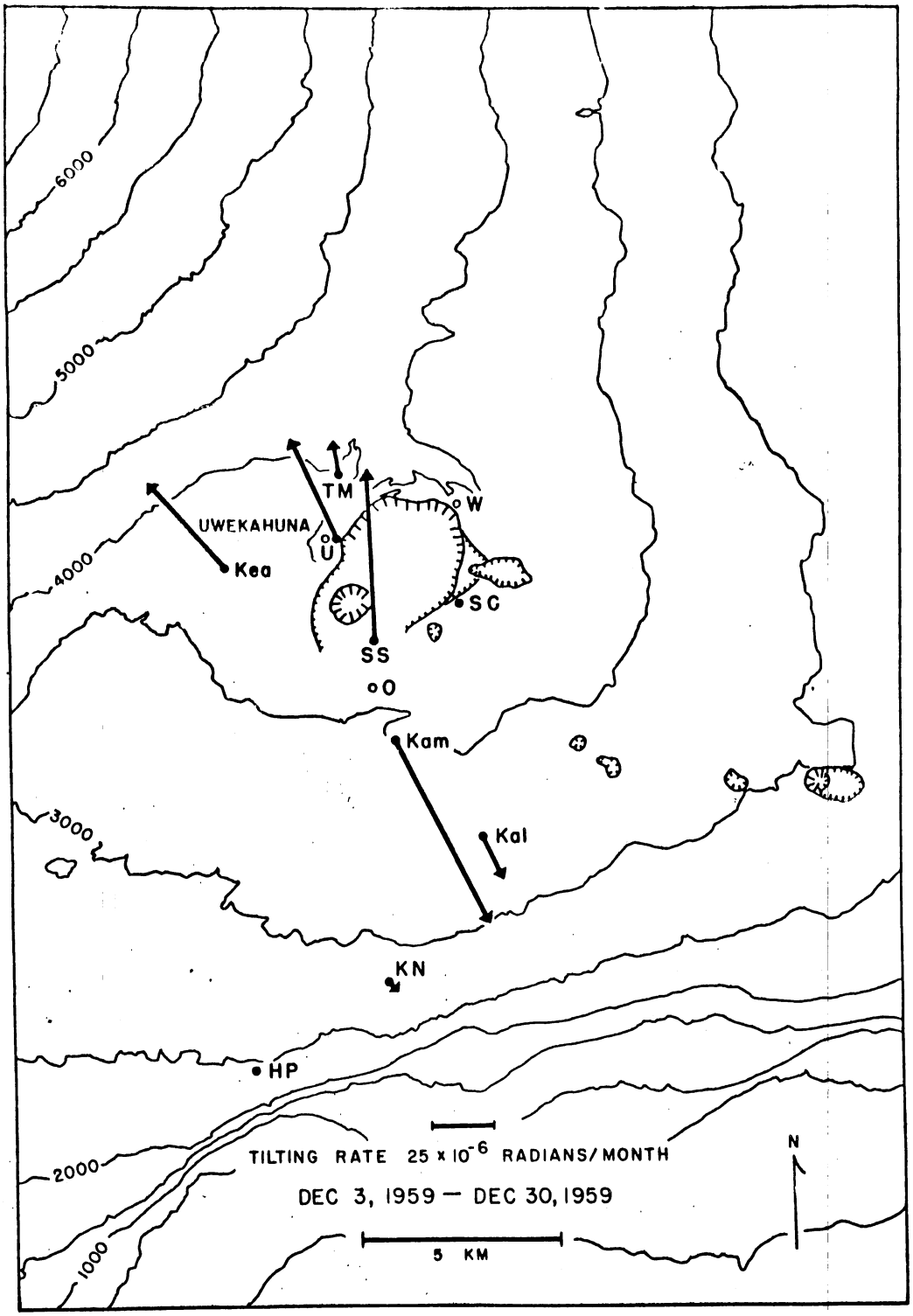


Figure 2d.-- Tilting of the ground around Kilauea caldera, December 3 to December 30, 1959. The vector depicting tilting at a given tilt base points in the direction of maximum relative subsidence and has a length proportional to the rate of tilting during the measurement interval. Closed circles represent field tilt bases; open circles, short-base water-tube tiltmeters.

Jerry

This paragraph has been worked on a little. It is not integrative but some of the textual matter is repeated in Table C which follows.

Table B is all factual and should be a good guide in other such cases --- where tremor obscures part of the data, and a generalization becomes necessary.

For the sake of brevity, we might combine the 3 paragraphs which deal with deep quakes;

The present dreams, history of,
and philosophy of.

Deep seismic storm. (SWARM)

A very large swarm of deep quakes with associated tremor began during the afternoon of December 11, 1959. This swarm ceased during the night of December 14 after a total of 4,500 separate events had been counted (or estimated conservatively,) on the Desert seismograms.

During the swarm, eruptive phases IX and X took place in Kilauea-Iki. And Thus, many events could only be counted and could not be timed, because of excess background "noise." Such noise was in the form of eruption tremor, deep tremor (with the first 2,000 recorded quakes) and/or confusion caused by quakes recording two or three per minute and interfering with each other and with events on adjacent traces.

In the Chronological Summary of HVO Summary 13 on page 2, there is a brief description of a deep swarm from a source 10 km northeast of Kilauea caldera at a depth of about 60 km. That swarm continued for two days (January 5 and 6, 1959) and added up to some 600 separate events. Of these, 29 were magnitude 2.5 or greater, although none was felt. The largest was magnitude 3.2.

Between August 14th and August 20, 1959, another deep swarm recorded on the USGS Kilauea summit network. This swarm consisted of about 2,400 individual events; 45 were greater than magnitude 2.5; none was felt although the largest was magnitude 3.4.

This seismic storm of August, 1959 seemed to represent two deep families which graded into one another and were recorded in no special order. One of these families best fits a depth of 54 km and an epicenter 7 km north of Uwekahuna; the second family fitted a location 5 km NNW of Uwekahuna and a depth of 49 km. The deep August swarm is reported in Summary 15 .

The first deep quake which could be timed on summit seismograms took place at 10h06m on 12 December, 1959. The following schedule is an attempt to oomplete the record by describing a chronology of deep ev ents which could not be read and/or timed.

TABLE B

ABSTRACTS FROM ORIGINAL READING SHEETS FOR THE DEEP SWARM BETWEEN December 11 and December 14

	DESERT (4,500 total)	MAUNA LOA (4,300 total)
Dec.11	Ca 14:00 = start of tremor and deep quakes P-travel-time (when discernible) 8.4 to 8.6 seconds.	Ca 16:00 faint tremor is seen Ca 17:00 1,700 quakes appear in tremor of increasing amplitude.
	Ca 21:00, p-travel-time decreases to 7.9 sec	P-travel time varies from 7.5 (7.5) to 6.7 sec; the smaller value at 22:00 record change.
	Ca 22:50, p-travel-time decreases to 7.5 sec or less.	22:50 to 06:45, where visible, first motion is down and p-travel-time is between 6.4 and 7.3 seconds.
	22:39 to 04:20 (2nd.record) p-travel-time 7.0 to 7.5 sec.	
Dec.12	some events of magnitude 3 & 4 Instances of both UP and DOWN first-motion	06:50 to 13:02, p-travel-time between 6.4 and 7.0 seconds.
	04:26 to 10:02, 6.7 to 7.0 sec Both UP and DOWN first-motion.	
	10:06 = first readable quake	
	10:08 to 13:32, 6.9 to 7.0 sec	13:07 to 18:49, 6.4 to 6.7 seconds
	13:36 to 18:52, 6.8 to 7.1 sec Both UP and DOWN first-motion.	
	18:58 to 03:55, 6.8 to 7.3 sec	18:54 to 04:07, 6.3 to 6.8 seconds
Dec.13	04:06 to 13:20, fewer deep events + eruption tremor.	04:17 to 15:06, 6.4 to 6.7 seconds, first-motion mixed, UP and DOWN.
	13:25 to 00:46, 6.6 to 7.0 sec	15:10 to 03:45, 6.4 to 6.7 seconds
Dec.14	p-travel-time. First-motion not easily seen.	and mixed UP and DOWN first-motion.
	00:51 to 12:52 deep quakes in eruption tremor noise. 6.8 to 7.1 sec. p-travel-time.	03:52 to 17:00, fewer deep events
	12:55 to 02:47, fewer deep	17:05 to 06:07, deep quakes decrease
Dec.15	events of 6.7 to 7.1 sec p-travel-time.	sharply in number.

ABSTRACTS FROM ORIGINAL READING SHEETS FOR
THE DEEP SWARM BETWEEN December 11 and 14th.

OUTLET

Dec.11 17:10 to 06:51 (12/12) ca 130 events counted. In the few cases where first-motion is seen, it is always UP. P travel-times are between 6.2 and 7.0 sec

Dec.12 06:57 to 21:32, first-motion UP, when readable. P-travel-time between 6.4 and 6.8 seconds.

21:45 to 07:07, deep events confused by eruption of phase IX

Dec.13 Tremor of Phase IX blocks all earthquake readings

Dec.14 Tremor from Phase IX, Phase X and bursts of tremor between these two phases + fewer deep events --- all factors reduce the value of Outlet record for this study.

UWEKAHUNA, etc.

Tremor and deep quakes begin ca 16:00 but spot is too active and faint to be read after 18:30

Maui: *Z becomes "active" after 20:00 but no time marks on record. However, S-P is measureable on 3 events and all are UP first-motion. 18.1 and 18.2 seconds S-P is about 24.8 or 24.9 seconds p-travel-time.

HMO (Oahu) does not show either deep quakes or tremor.

Uwekahuna: readings on deep events blocked by tremor of Phase IX.

Maui: *by the morning of December 13, NO further deep events seen on Maui record.

* a total of 21 deep events were large enough to record on the MAUI records; of these only three were clear enough to use for some idea of S-P time and for p-first-motion.

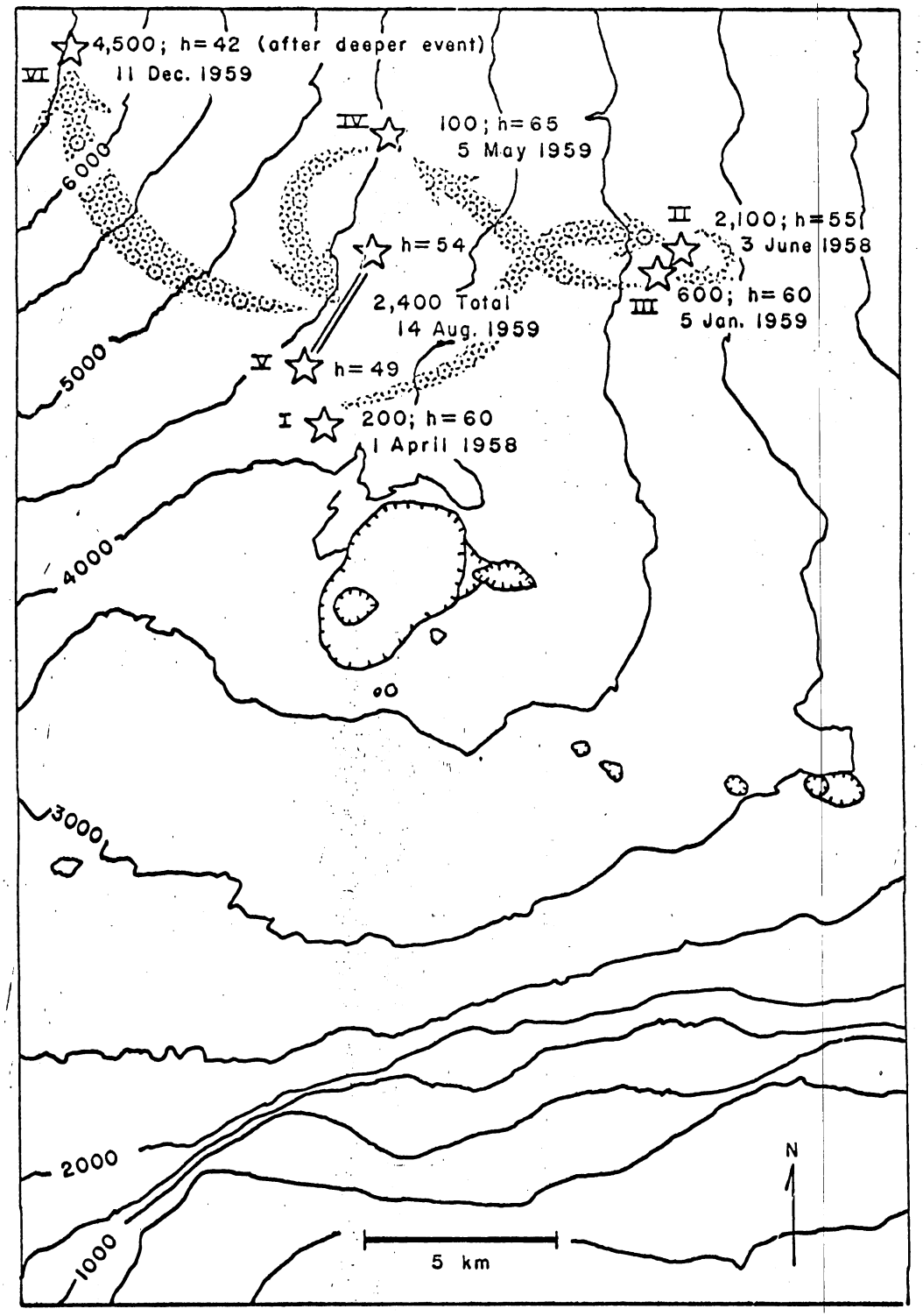


Figure A. -- Epicentral locations of six separate deep seismic swarms from 1958 to 1960. Arrows lead from one epicentral region to the next in chronological order. Data given are: number of events, depth and date. Base map used is standard Kilauea tilt plat as per Figure 2.

Instrumentation and earthquake-reporting

In the seven days from the 4th. of October, 1959 to the 11th. a number of earthquakes took place in Hawaii and were recorded with varying acuity at different sites and by different instruments of the Hawaiian Volcano Observatory network. This period of time is selected for convenience; also it represents "normal" background seismicity in that only a single seismic anomaly contributes to the background. The following schedule will list the features which we wish to illustrate.

Instrument Name	Number of Events Counted	Type of Installation
Uwekahuna - Z	60	hi-gain vertical
Mauna Loa - Z	57	hi-gain vertical
Outlet - - Z	61	hi-gain vertical
Desert - - Z	54	hi-gain vertical
North Pit - Z	2,680	hi-gain vertical
Naalehu, E & N	1	lo-gain mechanical horizontal pendulae
Kealakekua, E & N	2	" " "
Waimea, E & N	1	" " "
Pahoa, E & N	1	" " "
Hilo - - Z	10	hi-gain vertical

In the week reviewed above, 17 local earthquakes were chosen for study, location and analysis; these were judged to be well-enough recorded so as to permit accurate location. It can be seen that mechanical seismographs contributed little during this particular week. Perhaps a period could be found which portrayed mechanical recording in a more favourable light. But the opposite has usually been found to be true; the mechanical instruments provide poorly-timed and poorly-recorded data on about 10% of quakes large enough for location. And in extreme cases - by comparison with local swarms such as recorded on North Pit above, they record less than 1% of events countable on the records of more sensitive instruments located at more fortuitous sites.

Specifically, the low gain (magnification about 10x) drastically limited the amount of information contributed by mechanical horizontals. Low-gain, combined with horizontal polarization made first-motion "p" questionable in all but the largest quakes; a general rule-of-thumb was that "the mechanicals would not record quakes unless they were felt in the immediate town where the instrument was located; and if the quakes were felt near the instrument site, the instrument would perforce be dismantled." All of these problems were vastly more complicated at stations such as Konawaena, Waimea and Pahoa. The first two requires half a day for travel time alone. Thus periodic visits for care and cleaning were not frequent enough, and special trips at times of emergency were out of the question.

Early in the 1950's -- when experimental short-period, high-gain

vertical seismometers proved their practicality and acuity, the slow transition to electromagnetic dynamic recording was begun. Hilo and Maui were the first non-Kilauea station so converted. In December of this present quarter Konawaena was completely abandoned; the ancient mechanicals there had deteriorated beyond repair. Unfortunately, it was not till 1964 that a more modern system was installed at Kona.

Eventually all mechanical, horizontal pendulaa were replaced with high-gain instruments; such changes will be described in the appropriate summaries. In some cases (Pahoa and Naalehu) it was sufficient to block off windows, erect partitions, re-build piers and essentially to use the same building for electro-dynamic/optical-recording installations. In Waimea it was discovered that the low-gain side was adjacent to a heavily travelled vehicular roadway. This did not disturb the original seismograph, but it ruled out any simple conversion; the new instrument at Waimea was moved several miles away.

This is the painful and happy story of modernization at HVO. We hope it will always be in progress but wish to point out that it was most radical in the decades 1950 and 1960.

U. S. Geological Survey seismograph stations in Hawaii

Station	Symbol	Location		Altitude (m) above sea level	Equipment (Z, vertical; N, north-south; E, east-west)
		Latitude N.	Longitude W.		
Uwekahuna	U	19°25.4'	155°17.6'	1,240	Long-period Press-Ewing; N, E, Z. (seismometer and galvanometer periods are 15 and 90 sec. respectively) Short-period Sprengnether; E,Z. HVO-1: Z 1/
Mauna Loa	M	19°29.8'	155°23.3'	2,010	Remote recording HVO-2: Z 2/.
Ahua	A	19°22.4	155°15.9'	1,070	Remote recording HVO-2:
Desert	D	19°20.2'	155°23.3'	835	Do.
North Pit	N	19°24.9'	155°17.0'	1,115	Do. 1.0 sec EV-17 transistorized
West Pit	WP	19°24.7'	155°17.5'	1,115	Do. 1.0 sec EV-17
Makaopuhi	MP	19°21.8'	155°10.7'	885	1.0 sec. Benioff all transistorized; Z. (Wired into HVO-2 recording system)
Hilo	Hi	19°43.2'	155°05.3'	20	HVO-1: Z. Wood-Anderson; N, E.
Kealakua	Ka	19°03.8'	155°35.2'	205	1.0 sec. EV-17 jug buried; Z.
Pahoa	Pa	19°29.7'	154°56.8'	205	HVO-1; Z.
Kamuela	Ka	20°01.9'	155°42.0'	740	HVO-1; Z.
Haleakala, Maui	Ha	20°46.0'	156°15.0'	2,090	HVO-1; Z. Wood-Anderson; N, E.

North Bay	NB	19°29.7'	155°34.8'	4,005	0.8 sec. EV-17; Z. with helicorder.
Kealakekua	Ke	19°31.2'	155°55.3'	505	1.0 sec. EV-17; ~~Z. with helicorder; H, E.~~ N-S 1.0 sec EV-17H, E-W, 1.0 sec, EV-17H
~~Pumi Pa~~	~~PP~~	~~19°58.8'~~	~~155°42.3'~~	790	Data made available for HVO through Geotech team #22.
Kipapa, Oahu	Kip	21°25.4'	158°00.9'	76	HVO-1; Z.

1/ HVO-1 is a moving coil, hinged, vertical-component seismograph with seismometer and galvanometer periods of 0.5 second. Over-damping of both seismometer and galvanometer is used to control the strong galvanometer reaction. This seismograph has a peak magnification about 20,000 at a period of 0.25 second. Recording is optical, on photographic paper.

2/ HVO-2 is a moving coil, vertical-component seismograph with a seismometer period of 0.8 second. Its signal is transmitted over telephone wires to the Hawaiian Volcano Observatory, where it is recorded on smoked paper. The response of this seismograph is similar to that of HVO-1. Recordings of these seismographs at the N, A, D, N, and WP, stations are recorded on a 3-component drum to permit an accurate comparison of arrival times at these stations.

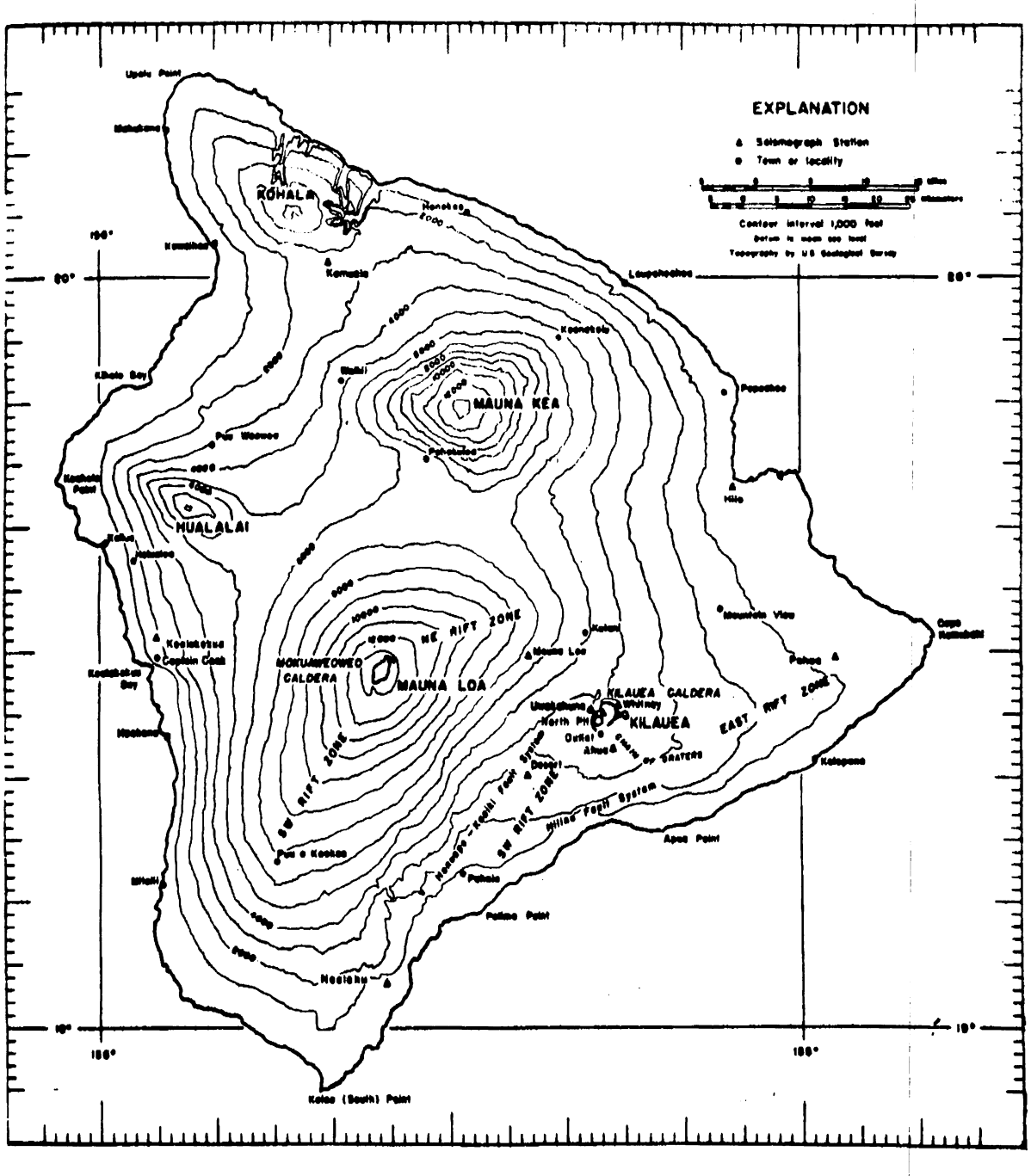


Figure 1.--Map of the island of Hawaii showing seismograph stations operated by the Geological Survey and localities mentioned in the text. Epicenters of earthquakes are given in terms of geographic coordinates, which are indicated at the edges of the map.

Table 3.--Numbers of earthquakes and minutes of tremor recorded mostly on seismographs

U, M, O, D, and N around Kilauea caldera

Categories: Halemaumau rock slides -- which are detected by the characteristic record they produce on the North Pit (N) seismograph; shallow earthquakes in the Kilauea caldera region -- again, seen and counted mostly on the North Pit record; shallow earthquakes along the SW. rift zone of Kilauea and the adjacent portion of the Kaoiki fault system - these are recorded most efficiently on the Desert (D) seismograph; earthquakes along the eastern half of Kilauea's east rift zone - detected by residents in Pahoa, or recorded by a seismograph at that town or by a portable meter in the neighborhood; earthquakes at depths between 15 and 30 km and roughly beneath Kilauea caldera - these are determined by character and by relative arrival time across the Kilauea seismic net; other notable seismic events -- such as tremor, teleseism or quakes local to other volcano systems (see Fig. 1) are briefly noted in this final column.

Data appearing in this table concern events which experienced seismologists can glean "at sight" from the ~~daily~~ records. Table 3, therefore, is an attempt at a daily record of the history of Hawaiian volcanoes; it presents more detailed statistics than 3A (which it will replace in Summary 17) and it is less exact and more general than Table 4.

Date (1959)	Tremor (in minutes)			Earthquakes					
	Deep	Intermediate	Shallow	Halemaumau slides	Kilauea caldera shallow	SW. rift and Kaoiki	Lower east rift	Kilauea 15 to 30 km depth	Others
Oct. 1					75	2			T-phase
2			5		130	4			1-pressure pulse
3					165	5		1@Km30, 1@Km45	~~1-offshore N of Hawaii~~ 1-offshore E of Hawaii
4					260	3			~~Shallow~~ 1-[illegible] FELT [illegible]
5					410	1			1-S. FLANK M.LOA @ Km 45 1-teleseism

Date (1959)	Tremor (in minutes)			Earthquakes					
	Deep	Inter-mediate	Shallow	Hale-maumau slides	Kilauea caldera shallow	SW. rift and Kaoiki	Lower east rift	Kilauea 15 to 30 km depth	Others
Oct. 6					380	4		km 22 km 30 ?	1- km 45 1-Kona
7	32				340				1- M. Loa
8					380	5			
9					430		3 km 13		1-teleseism
10	36 + 39				480	2		1	2 periods deep tremor

Date (1959)	Tremor (in minutes)			Earthquakes					
	Deep	Intermediate	Shallow	Halemaumau slides	Kilauea caldera shallow	SW. rift and Kaoiki	Lower east rift	Kilauea 15 to 50 km depth	Others
Oct. 11	—	—	—	—	380	4		1 - KM 22 1 - KM 45	1 - KONA 1 - M. LOA
OCT. 12	—	—	—	—	420	2	—	—	1 — NORTH HAWAII
OCT. 13	—	—	2 MIN.	—	350	3	—	—	1 — SOUTH M. LOA
OCT 14	—	—	—	—	390	3	—	—	1 - telesm 1 - M. Loa flank
OCT. 15	—	—	—	—	340	3	—	—	1 - telesm 2 - M. Loa flank
OCT. 16	—	—	—	—	430	—	—	—	1 - telesm 1 - offshore Maui
OCT. 17	—	—	—	—	600	5	—	—	1 - M. Loa flank
OCT. 18	—	—	—	—	540	6	—	1	3 - tele
OCT. 19	—	—	—	—	545	3	—	5	—
OCT. 20	—	—	—	—	520	5	—	7	—
OCT. 21	—	—	—	—	450	9	—	—	1 - OFFSHORE S. OF KAU
OCT. 22	32 MIN. + 30 MIN.	DEEP	—	—	480	2	—	1	BLUE FLAMES SEEN AT HALEMAUMAU 1 - OFFSHORE NORTH OF HILO
OCT. 23	—	—	—	—	6[illegible]	2	—	1	CONTINUED PLUME FROM N. WALL, HALEMAUMAU
OCT. 24	—	—	—	—	[illegible]	3	—	3	—

Date (1959)	Tremor (in minutes)			Earthquakes					
	Deep	Inter-mediate	Shallow	Hale-maumau slides	Kilauea caldera shallow	SW. rift and Kaoiki	Lower east rift	Kilauea 15 to 50 km depth	Others
OCT. 25					730	3			2 - [illegible] 1 - HALEMAUMAU E. RIFT
OCT. 26					490	3			1 - [illegible] 1 - M. LOA, S. [illegible]
OCT 27					350				1 - M. LOA, S. FLANK 1 - OFFSHORE [illegible]
OCT. 29					[illegible]	6			2 - [illegible]
OCT. 29					270	4		1 - 30 KM	1 - [illegible] 1 - PIEMAUMAU [illegible]
OCT. 30					280				1 - [illegible] 1 - M. [illegible]
OCT. 31					165	9		1	1 - SW. RIFT OF M. LOA
NOV. 1					90	1		1	[illegible]
NOV. 2					144	4	1		
NOV. 3					310	5			
NOV. 4					200	6			1 - [illegible]
NOV. 5					150	5			
NOV. 6					260	19		1 - 30 KM W. FLANK M.L.	1 @ M3.1 FROM [illegible] FAULT 1 @ M3.1 FROM W. M. LOA
NOV. 7					25	10			[illegible] N. [illegible]
NOV. 8			2 MIN, SHALLOW		ca 1200	2			BLUE [illegible] PUU [illegible] 2 MIN, [illegible]

Date (1959)	Tremor (in minutes)			Earthquakes					
	Deep	Inter-mediate	Shallow	Hale-maumau slides	Kilauea caldera shallow	SW. rift and Kaoiki	Lower east rift	Kilauea 15 to 50 km depth	Others
NOV. 9					ca. 1400	1			PRESS-EWING LONG-TERM WANDERING CONTINUES
NOV. 10					ca 1300	3			E.I. RISE ERROR CONTINUES TO FLUCTUATE
NOV. 11	24 MIN, DEEP & SPASMODIC PLUS 95 MIN, DITTO				CA 1300	6			DITTO ON PRESS-EWING
NOV. 12					CA 2200	10			DITTO ON PRESS-EWING
NOV. 13					CA 2200+	4		4	PRESS-EWING LESS UNSTABLE
NOV. 14					CA 650 1000 to 1700	3			
	KILAUEA IKI ERUPTED AT 20:08 HST. EARLY IN THE AFTERNOON QUAKES, TILT AND TREMOR* BEGAN. THESE PHENOMENA INCREASED IN TEMPO MAKING IT DIFFICULT TO ACCURATELY ASSIGN NUMBERS TO THE CATEGORIES LISTED IN THIS TABLE, ALTHOUGH 12 SHALLOW QUAKES WERE FELT PRIOR TO THE ERUPTION (see Table 4) (SEE TABLE A FOR RECORD OF PRESS-EWING BEHAVIOUR DURING KILAUEA IKI ERUPTION.)								
NOV. 15	CONTINUOUS, but gradually diminished eruption tremor				11 (@ reduced gain)	4	1		

* USUALLY TREMOR IS ASSOCIATED WITH SUB-SURFACE LAVA MOVEMENT MOST "TREMOR" DURING AN ERUPTION HOWEVER, SEEMS TO RELATE DIRECTLY TO VERY SHALLOW VENT GEOMETRY AND GAS EXPANSION AND RELEASE. THUS A FOURTH CATEGORY --- ERUPTION TREMOR --- IS LISTED IN THE FOLLOWING

Date (1959)	Tremor (in minutes)			Earthquakes					
	Deep	Inter-mediate	Shallow	Hale-maumau slides	Kilauea caldera shallow	SW. rift and Kaoiki	Lower east rift	Kilauea 15 to 50 km depth	Others
NOV. 16	CONTINUOUS ERUPTION TREMOR		—	—	12 (1/10 GAIN)	5	—		2 = KILAUEA-IKI VENT 1 = M. LOA, 1 = KOHALA
NOV. 17	CONTINUOUS ERUPTION TREMOR		—	—	4 (1/10 GAIN)	4	—		
NOV. 18	CONTINUOUS ERUPTION TREMOR		—	—	6 (1/10 GAIN)	3	—	1 = KM 25	NEW ZEALAND M = 7
NOV. 19	CONTINUOUS ERUPTION TREMOR		—	—	8 (1/10 GAIN)	1	—		1 = KAU COAST
NOV. 20	CONTINUOUS ERUPTION TREMOR		—		11 (1/10 GAIN)	1	—	—	
NOV. 21	@ 19:26 ERUPTION TREMOR ENDS. SHALLOW TREMOR CONTINUOUS @ N.P. AND UWE - 2.		—	—	13 (1/10 GAIN)	5	—	1 = KM 35	1 = SHALLOW & NORTH OF UPPER EAST RIFT
NOV. 22	CONTINUOUS SHALLOW TREMOR AT NORTH PIT ONLY AND AT FULL GAIN		—	—	12 (FULL GAIN)	—	—	1 = KM 23	
NOV. 23	CONTINUOUS SHALLOW TREMOR AT NORTH PIT ONLY. (AT FULL GAIN)		—	—	31	3	—	1 = KM 30	1 = NORTH OF KOHALA, FELT 1 = M. LOA FLANK

Date (1959)	Tremor (in minutes)			Earthquakes					
	Deep	Intermediate	Shallow	Halemaumau slides	Kilauea caldera shallow	SW. rift and Kaoiki	Lower east rift	Kilauea 15 to 50 km depth	Others
NOV. 24	CONTINUOUS SHALLOW TREMOR ON NORTH PIT AND OUTLET RECORDS			—	32	1	—	—	—
NOV. 25	ERUPTION TREMOR FROM PHASE 2 builds gradually			—	5	2	—	—	1 = M.LOA'S' NE FLANK
NOV. 26	00:43 = START OF ERUPTION TREMOR FOR PHASE 2 16:45 = END OF ERUPTION TREMOR			—	19 (MINOR AFTER ERUPTION)	8	—	—	2 EVENTS M ≈ 2 FROM SW RIFT OF KILAUEA OR KAOIKI FAULT. DATA NOT SUFFICIENT TO LOCATE
NOV. 27				—	CA 125	1			MUCH WIND NOISE AT DESERT OBSCURES CONT OF SW RIFT QUAKES.
NOV. 28	17:20 = gradual start of eruption tremor FOR Phase 3			—	5 (AT 1/10 GAIN)	2	—		
NOV. 29	21:47 END OF ERUPTION-tremor DUE TO PHASE 3			—	NONE AT 1/10 GAIN	4	—	—	

Date (1959)	Tremor (in minutes)			Earthquakes					
	Deep	Inter-mediate	Shallow	Hale-maumau slides	Kilauea caldera shallow	SW. rift and Kaoiki	Lower east rift	Kilauea 15 to 50 km depth	Others
NOV. 30	CONTINUOUS shallow TREMOR [illegible] PIT			—	Ca 100	2	—		
DEC. 1	TREMOR REDUCED ON [illegible] GONE			—	Ca 140	10	—		1 = S. FLANK OF KILAUEA
2.	NO TREMOR				310	4			2 = NE RIFT OF MAUNA LOA. 1 = SW RIFT M. LOA 1 = N. FLANK OF MAUNA KEA. 1 = S. FLANK OF KILAUEA 1 - KONA
3	@ 00:49, 12/4/59 start of eruption tremor PHASE III				300 (before tremor)	12			1 = S. FLANK OF KILAUEA 1 = UPPER EAST RIFT OF KILAUEA
4	CONTINUOUS ERUPTION TREMOR				NONE @ 1/10 GAIN				
5	@09.27 end of Phase III and eruption tremor 23:20 to 23:35 = 15 min. shallow tremor				270 (after tremor)	7		6 = Km 30	

Date (1959)	Tremor (in minutes)			Earthquakes				
	Deep	Inter-mediate	Shallow	Halemaumau slides	Kilauea caldera shallow	SW. rift & Kaoiki	Lower east rift	Kilauea 15 to 50 km, depth	Others
Dec 6	05:30 to 06:50 = shallow tremor including ca 200 quakes @ 14:35 eruption tremor starts (phase II) @ 00:20, 12/7/59 — eruption tremor ends					3			1 = offshore, 20 km E of Hi
7	@ about 14:00 = eruption tremor, phase VI @ 02:44 = phase VI eruption tremor ends				none at 1/10 gain	5			
8	@ 16:49 = start of phase VII tremor @ 20:13 = end of phase VII 21:00 to 01:00 = shallow tremor				lost, if present	2			
9.	10				ca 400	2			1 = Kohala mtn. 1 = SE flank of Kilauea

Date (1959)	Tremor (in minutes)			Hale mau mau slides	Earthquakes				
	Deep	Inter-mediate	Shallow		Kilauea caldera shallow	SW. rift & Kaoiki	Lower east rift	Kilauea 15 to 50 km, depth	Others
10	CA 01:00, 12/11/59 = ~~SLOW START OF VIII~~ 10:49 on 12/11/59 = ABRUPT STOP IN VIII AND TREMOR				CA 90 BEFORE ERUPTION	8		2 = KM 30	1 = E. RIFT OF KILAUEA
11			13 Shallow		CA 40 (after VIII & before deeps)	1			1 = OFFSHORE, NE OF HAWAII
	CA 14:00, TREMOR AND DEEP QUAKES FIRST SEEN ON DESERT RECORD							CA 1700 @ KM 45	
12	SEVERE DEEP TREMOR DECREASING TOWARD END OF 12/12/59							CA 2200 @ Km 42	ALL OTHER EVENTS BLOCKED BY TREMOR AND/OR DEEP QUAKES - Average high rate = 3 QUAKES/MINUTE

Date (1959)	Tremor (in minutes)			Earthquakes					
	Deep	Inter-mediate	Shallow	Hale mau mau slides	Kilauea caldera shallow	SW. rift & Kaoiki	Lower east rift	Kilauea 15 to 50 km, depth	Others
13	05:08 = START OF phase IX								
	13:40 = end of PHASE IX + TREMOR							CA 550 @ KM 42 (thru eruption)	
	14:57 to 15:05 = 8 MINUTES shallow								
	19:02 to 19:36 = 34 MINUTES Shallow								
	22:30 = START OF CONTINUOUS, shallow TREMOR (SMALL)								
14	CA 10:50 = START OF ERUPTION TREMOR PHASE X					5		CA 390 @ KM 42	
	15:37 = DRAMATIC END OF ERUPTION TREMOR, PHASE X								

Date (1959)	Tremor (in minutes)				Earthquakes				
	Deep	Inter-mediate	Shallow	Halemaumau slides	Kilauea caldera shallow	SW. rift & Kaoiki	Lower east rift	Kilauea 15 to 50 km, depth	Others
Dec 15	06:30 = START OF TREMOR DUE PHASE XII 10:28 END OF PHASE XII ERUPTION TREMOR 11:26 to 12:25 = 59 MINUTES STRONG, SHALLOW TREMOR 12:53 to 13:34 = 41 MINUTES STRONG, SHALLOW TREMOR 19:53 = START OF PHASE XII ERUPTION TREMOR 21:30 = GRADUAL END OF PHASE XII ERUPTION TREMOR. 23:26 to 23:29 = 3-MINUTE BURST OF VERY STRONG, SHALLOW TREMOR.				CA 20	4		10 = KM 42	

Date (1959)	Tremor (in minutes)			Earthquakes				
	Deep	Inter-mediate	Shallow	Hale mau mau slides	Kilauea caldera shallow	SW. rift & Kaoiki	Lower east rift	Kilauea 15 to 50 km, depth	Others
Dec 16	CA 02:00 = START OF CONTINUOUS, SHALLOW TREMOR 13:48 = START OF PHASE XIII ERUPTION TREMOR. 17:21 = DRAMATIC END OF XIII TREMOR				20	15		3 = Km 42	
Dec 17	02:30 to 04:04 = DURATION OF PHASE XIV ERUPTION TREMOR. 13:57 to 15:32 = DURATION OF PHASE XV ERUPTION TREMOR.				CA 20	7		1 = KM 42	

Date (1959)	Tremor (in minutes)				Earthquakes				
	Deep	Inter-mediate	Shallow	Hale mau mau slides	Kilauea caldera shallow	SW. rift & Kaoiki	Lower east rift	Kilauea 15 to 50 km, depth	Others
DEC. 18	06:32 = START OF GROWING, SHALLOW TREMOR WHICH INCREASES AT 08:59 AND IS STILL EVIDENT BY 03:10 12-18-59				LOST IN TREMOR	5		Z=Km 42	1 = S. FLANK KILAUEA
19.	03:10 = GRADUAL START OF PHASE XVI ERUPTION TREMOR. 06:15 = 2-MINUTE REDUCTION IN TREMOR (END OF SURFACE ERUPTION) THEREAFTER RESUMED TREMOR CONTINUES TILL NEXT DAY.				11	2			

Date (1959)	Tremor (in minutes)			Earthquakes				
	Deep	Inter-mediate	Shallow	Hale mau mau slides	Kilauea caldera shallow	SW. rift & Kaoiki	Lower east rift	Kilauea 15 to 50 km, depth	Others
Dec. 20	CONTINUOUS SHALLOW TREMOR				30 (IN TREMOR)				1 = OFFSHORE, SW RIFT OF KILAUEA. 1 = E. RIFT OF KILAUEA
21.	CONTINUOUS SHALLOW TREMOR ON SUMMIT RECORDS, O & N				5	3			1 = W. FLANK MAUNA LOA 1 = NE RIFT OF MAUNA LOA
22	CONTINUOUS, SHALLOW TREMOR.				27	1	2 (SMALL)		4 = SHALLOW, KALAPANA TRAIL 1 = S. FLANK KILAUEA 1 = SE. FLANK KILAUEA

These are the first, large examples of very-poorly-located, shallow-depth quakes which come from the "Pali" systems south of Kilauea's East Rift zone. These events were prominent in 1961 and 1962 and are thought to indicate failures of Kilauea's un-buttressed south flank. Such failures may be the result of excessive loading of the summit storage region --- as seems to be the present case --- or they may be the result of unknown, outside forces (perhaps gravity). When summit storage is at a high level, such slippage can enhance movement of lava from summit to the rift zone(s); when such slippage occurs (from outside causes) at times of low summit storage, only small amounts of lava move in the rift zone conduits, and there are either small, brief eruptions or none at all.

Date (1959)	Tremor (in minutes)			Earthquakes				
	Deep	Inter-mediate	Shallow	Hale mau mau slides	Kilauea caldera shallow	SW. rift & Kaoiki	Lower east rift	Kilauea 15 to 50 km, depth	Others
Dec 23	CONTINUOUS, BUT DECREASING - SMALL, SHALLOW TREMOR				40	5	2 (SMALL)		1 = OFFSHORE KONA
24	SMALL, SHALLOW, CONTINUOUS TREMOR 14:25 to 15:15 = INTERMITTENT BURSTS OF DEEP TREMOR				130	6			1 = EAST RIFT OF HALEAKALA, MAUI
25.	SMALL, SHALLOW, CONTINUOUS TREMOR				105	22	2 (SMALL)		1 = S. FLANK MAUNA LOA 1 = KOHALA VOLCANO 1 = SE FLANK MAUNA LOA

Date (1959)	Tremor (in minutes)				Earthquakes				
	Deep	Inter-mediate	Shallow	Hale mau mau slides	Kilauea caldera shallow	SW. rift & Kaoiki	Lower east rift	Kilauea 15 to 50 km, depth	Others
Dec 26	VERY SMALL TRACE OF CONTINUOUS, SHALLOW TREMOR.				120	25	9 (SMALL)		
27	SHALLOW TREMOR VERY WEAK OR QUESTIONABLE.				120	15	30 (SMALL)		1 = S. FLANK KILAUEA 2 = LOWER KAOIKI FAULT 1 = E. FLANK MAUNA KEA
28	NO TREMOR VISIBLE				125	25	1 (OFFSHORE) 40 (SMALL)		
29	NO TREMOR VISIBLE				100	25	2 (OFFSHORE) 45 (SMALL)		1 = SE FLANK MAUNA LOA 1 = KM 30, SUMMIT OF MAUNA KEA. 1 = KM 20, SUMMIT OF MAUNA KEA

Date (1959)	Tremor (in minutes)				Earthquakes				
	Deep	Inter-mediate	Shallow	Hale mau mau slides	Kilauea caldera shallow	SW. rift & Kaoiki	Lower east rift	Kilauea 15 to 50 km, depth	Others
Dec 30					115	40	3 (OFFSHORE)		
							12 (SMALL)		
31					110	35	1 (offshore)		1 = KONA COAST
							22 (SMALL)		

Table 3a*.--Local earthquakes and tremor recorded by the HVO-1 seismograph at Uwekahuna, in October, November, and December of 1959

Week beginning	Number of earthquakes		Minutes of continuous tremor
	Greater than magnitude 2.5	Greater than magnitude 2.5	
Oct. 4	8	52	32 (deep) 36 (deep) 39 (deep)
11	4	80	
18	3	155	
25	3	48	
Nov. 1	2	82	
8	7	350	4 (deep) 24 (deep) 35 (deep) 300 (shallow, pre-erup) Continuous tremor during Phase I.
15	4	50**	Continuous erution tremor until 11/21/59.
22	2	214**	Continuous shallow tremor except for eruption tremor, Phases II and II.
29	5	183**	Continuous shallow tremor except eruption tremor Phase IV.
Dec. 6	CA 150	CA 1150**	Continuous plus eruption tremor Phases V, VI, VII and VIII.
13	CA 13	CA 170**	Continuous shallow tremor plus eruption tremor Phases IX, X, XI, XII, XIII, XIV, XV and XVI.
20	8	90	Six days of light, shallow tremor, quiet on 11/26/59.
27-31	11	59	

* In future summaries the weekly statistical count (represented by 3a) will no longer be presented. It will be replaced by the daily counting schedule as per table 3, above.

** Conservative count; eruption tremor could mask many small events.

Table 4.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, October, November, and December, ~~1960~~ 1959

Entries for a given quake are: date, origin time (Hawaiian Standard Time), magnitude, depth, epicenter, and felt report or other comments. Usually the list consists of all events of magnitude 2.5 and larger; in this summary all clearly readable events are located and listed because of possible correlations between seismicity and surface volcanism starting 14 November 1959.

In the following list deep quakes belonging to a swarm will be listed by depth as "KM 45", "KM 47", etc. The first entry only will give epicentral data unless these change.

In Summary 24 "Kaoiki" was introduced as a symbol for listing any of a family of quakes with mean focus 19°24'N., 155°24'W., h = 3 to 8 km. This symbol is used in the following list.

The local events listed in Table 4 are ~~they~~ described ~~xxxxxxxxxxxxxxxxx~~ as carefully as possible according to size, depth and geographical coordinates. In addition there is included a verbal ~~xxxxxxxxxxxx~~ location related to prominent geographic features or to seismograph installations shown on the Map of Hawaii Island in Figure 1. cultural

use of CA rounded to nearest minute

Date 1969	ORIGIN Time h	m	s	Magnitude	Depth (km)	Epicenter Lat.N.	Long. W.	Description	Felt Report OR OTHER COMMENTS
1 Oct.	20	29	04.5	1.8	5	19°27.4'	155°27.5'	8 Km. NW of Desert Seis.	omit line here
3 Oct.	15	36	08.0	3.2	50	19°32.4'	154°43.0'	25 Km. east of Pahoa	
3 Oct.	23	40	31.2	2.5	45	19°20.3'	154°59.7'	3 Km. SW of [illegible]	
4 Oct.	05	37	08.5	4.4	15	20°44.1'	155°43.4'	80 Km North of Kamuela beneath east rift of Haleakala	KONA, OLINDA & KULA - Maui = felt
4 Oct.	17	00	25.0	2.8	40	19°14.1'	155°31.5'	20 Km SW of Desert seis.	
4 Oct.	17	17	02.5	1.7	8	19°25.6'	155°23.8'	11 Km W. of Uwekahuna	
6 Oct.	09	50	43.0	1.0	5	19°26.3'	155°23.5'	7 Km S. of ML seis of 1880 flow	
7 Oct.	00	41	46.0	3.4	15	19°49.7'	156°12.0'	offshore, 30 KM NW of Kailua	
7 Oct.	01	26	20.7	1.5	22	19°22.2'	155°18.2'	6 KM S. of UWEKAHUNA	
7 Oct.	04	32	44.0	1.2	8	19°27.5'	155°27.5	13 KM W. of MOKUAWEOWEO	
7 Oct.	08	00	58.7	2.4	13	19°13.0'	155°00.3	offshore, 45 KM SE of KULANI	
8 Oct	13	19	38.6	1.7	5	19°24.6'	155°24.5	7 Km. N. of Desert Seis.	NORTH OF KAOILI FAULT SYSTEM
8 Oct.	13	20	25.9	1.3	5	"	"	SIMILAR TO ABOVE	
9 Oct.	12	16	11.1	2.0	13	19°15.9N	155°10.3W	2Km E. of Apua Point	2 stations were lost in this quake
9 Oct.	13	32	23.6	2.1	13	"	"	SIMILAR TO ABOVE	
12 Oct.	16	14	33.1	3.4	8	20°03.0 N	155°33.0 W	14 Km E. of KAMUELA	NOT reported felt
14 Oct	06	36	06.5	3.5	3 to 5	19°20.3'	155°29.7'	14 KM NW. Desert seis.	NOT FELT: UNINHABITED
14 Oct	19	20	31.9	1.7	8	19°25.1'	155°25.3	M.Loa FLANK, 13 Km W. OF UWEKAHUNA	
15 Oct	15	15	46.7	2.5	42	19°18.3	155°01.7	39 Km E. of Desert Sta	
15 Oct	19	43	23.0	2.0	3	19°23.3	155°26.2	7 KM NW. OF DESERT SEIS	M. Loa Flank
16 Oct	03	37	37.0	3.0	~30	21°04.7	156°18.5	35 KM N. OF HALEAKALA	SEIS., MAUI
17 Oct	21	20	01.2	1.4	8	19°23.2	155°13.5	10 Km NW of Desert Seis	M.Loa FLANK
21 Oct	03	10	03.5	3.4	40	21°02'	157°16'	30 KM South of Honolulu - OAHU	NOT REPORTED FELT
23 Oct	00	11	37.5	2.5	13	20°47'	155°31'	80 KM EAST OF MAUI SEIS	beneath E. Rift of Haleakala
24 Oct	12	49	02.0	2.0	~10	19°26.5'	155°26.5'	9 KM SW OF M.LOA SEIS.	W. FLANK OF M.LOA
25 Oct	01	43	14.2	2.9	~8	20°54'	155°29'	offshore, 85 KM E of HALEAKALA SEIS	MAUI
26 Oct.	14	35	01.7	2.2	8	19°09.5	155°36.8	10 KM N. OF NAALEHU	S FLANK OF M.LOA
27 Oct	04	28	50.0	2.8	~22	19°17.6'	155°32.5	27 KM. SW OF M.LOA SEIS	S. FLANK OF M.LOA
27 Oct	06	56	01.5	2.7	8	19°50'	156°20'	offshore, 55 Km NW OF KEALAKEKUA SEIS	
27 Oct.	08	52	52.5	1.4	8	19°24.8	155°29.0'	13 KM SW. OF M.LOA SEIS	SE. FLANK OF M.LOA
29 Oct.	05	59	48.6	2.5	30	19°30.1	155°07.3	23 Km S. OF HILO	
29 OCT	20	28	36 I	—	SHALLOW	DEFORMATION NEAR	HALEMAUMAU	(DOWN, SOUTH & EAST 1ST MOTION P2)	
30 OCT	04	57	36.2	1.0	10	19°24.1	155°19.9	4 KM SW OF UWEKAHUNA	

Date 1959	Time h	Time m	Time s	Magnitude	Depth (km)	Epicenter Lat.N.	Epicenter Long. W.	Epicenter Description	Felt Report OR OTHER COMMENTS
31 Oct.	00	43	51.5?	2.1	~13	19°58'	W 155°32'	13 KM ESE OF KAMUELA	N FLANK OF M. KEA
31 Oct	02	42	56.0	2.1	~5	19°22.0'	155°38.6	SW RIFT OF M. LOA	19 KM NE OF PUU O KEOKEO
31 Oct	09	09	08.5	1.0	~10	19°24.1	155°19.8	SW RIFT OF KILAUEA	6 KM SW OF ULUEKAHUNA
1 Nov.	18	38	13.2	1.6	~10	19°19'	155°15'	S. FLANK OF KILAUEA	13 KM SE OF ULUEKAHUNA
2 Nov.	20	13	57.4	1.9	~5	19°19'	155°03	E. RIFT OF KILAUEA	43 Km. S. OF Hilo
4 Nov.	10	55	02	~1.1	~5	HALEMAUMAU - SUMMIT	OF KILAUEA	POOR FIT	Possible [illegible] ~5 KM
5 Nov	13	21	47.8	1.4	8	19°31.2	155°25.5	E. RIFT OF MAUNA LOA	5 KM NW OF M. LOA SEIS
5 Nov	13	28	05.5	1.9	8	19°35.7	155°30.6'	NE FLANK OF MAUNA LOA	
6 Nov.	03	07	54.5	1.8	10	19°22.8'	155°18.8'	7 KM SW OF ULUEKAHUNA	
6 Nov.	11	14	33.4	3.1	5	19°22.7'	155°24.1	4 Km N. OF DESERT SEIS	PROBABLY FELT, NO REPORT KF.
6 Nov.	19	54	48.7	1.5	11	19°25.0'	155°20.7'	11 KM NE OF DESERT SEIS	
6 Nov	23	25	36	~3.1	~30	19°29'	155°48'	Ca 40 KM W. OF M. LOA SEIS	
7 Nov.	06	44	41.6	2.2	11	19°24.2	155°18.8'	11 KM NE OF DESERT SEIS.	
7 Nov.	07	11	14.6	1.8	11	19°24.2'	155°18.8'	ditto in all respects	
7 Nov.	07	40	46.0	2.0	11	19°24.2'	155°18.8'	SIMILAR TO PREVIOUS TWO	
7 Nov.	07	53	29.0	1.5	8	19°23.5	155°19.3	10 KM NE OF DESERT SEIS	FIRST-MOTION SIMILAR TO THREE PREVIOUS QUAKES
8 Nov.	02	12	02.6	2.4	50	19°35'	155°44'	45 KM NW OF DESERT SEIS	POOR LOCATION, 10 KM ERROR
9 Nov.	07	10	04.5	2.0	13	19°26.4	155°18.6'	2 KM NW OF ULUEKAHUNA	
10 Nov.	00	02	20.3	2.3	35	19°15.7	155°01.4'	50 KM S. OF HILO SEIS.	
10 Nov.	00	11	18.4	2.2	10	19°22.3	155°25.0'	3 KM NW OF DESERT SEIS	
11 Nov.	07	22	52.3	4.0	~13	19°39	155°15'	OFFSHORE, 300 KM. W OF M. LOA SEIS. 210 KM S OF KAENA POINT, OAHU	
11 Nov.	08	42	27.1	2.1	25	19°32.5	155°14.5	20 KM N. OF OUTLET SEIS.	
11 Nov.	16	13	39.7	2.5	15	19°36.0	155°04.9	13 KM S OF HILO	NOT REPORTED FELT
12 Nov	00	21	12.2	3.2	15	19°01.2	155°30.2	11 Km SE OF NAALEHU	1: OFFSHORE
12 Nov	00	31	22.5	3.2	15	19°01.2	155°30.2	ditto in all respects except	reversed 1st motion at Hilo
12 Nov	18	04	36.7	2.3	3	19°23.3'	155°16.0	3 KM SE OF ULUEKAHUNA	FELT, KILAUEA SUMMIT
13 Nov	01	00	46.6	1.2	14	19°24.5	155°17.3	beneath KILAUEA CALDERA	
13 Nov	03	01	59.5	2.8	ca 20	19°46.5'	155°54.0'	70 KM NW OF DESERT SEIS,	BENEATH HUALALAI
13 Nov	16	40	32.0	1.4	8	19°25.0'	155°16.2'	beneath KILAUEA CALDERA	FELT, KILAUEA SUMMIT
THE FOLLOWING ERUPTION BEGAN AT 20:08 HST ON 14				SIMILAR, INTER-RELATED EVENTS		APPEAR TO BE PREMONITORY; THE KILAUEA-IKI NOV. 1959.			

Date 1959	Time h	m	s	Magnitude	Depth (km)	Epicenter lat.N.	Long. W.	Description	Felt Report OR other comments
14-Nov.	12	09	13.5	0.5				NOT ON PRESS-EWING	
"	14	05	TREMOR STARTS ON OUTLET AND					PROBABLY NP	
"	14	09	43.1	1.5				NOT ON PRESS-EWING	PROBABLY FELT
"	14	48	46.6	1.4				SMALL PRESS-EWING DEFL.	PROBABLY FELT
"	14	54	53.1	1.5				NOT ON PRESS-EWING	PROBABLY FELT
"	15	14	36.8	1.0				NOT ON PRESS-EWING	
"	15	41	01.7	1.2				NOT ON PRESS-EWING	
"	16	05	21.2	1.8				SMALL PRESS-EWING DEFL.	FELT
"	16	26	30.7	1.1				NOT ON PRESS-EWING	
"	16	33	44.3	3.5				PRESS-EWING DEFLECTED	FELT AND/OR HEARD IN KILAUEA/SUMMIT REGION
"	16	37	56.5	1.2				NOT ON PRESS-EWING	
"	17	17	33.1	2.1				SMALL PRESS-EWING DEFL.	FELT
"	17	28	26.0	1.9				SMALL PRESS-EWING DEFLECTION	FELT
"	17	38	47.5	2.2				PRESS-EWING AFFECTED	FELT
"	18	02	45.5	1.1				NOT ON PRESS-EWING	FELT
"	18	39	13.7	2.3				PRESS-EWING AFFECTED	FELT
"	18	43	00.0	1.8				SMALL PRESS-EWING DEFLECTION	FELT
"	18	52	20.6	1.9				SMALL PRESS-EWING DEFLECTN	FELT
"	19	26	03.8	2.1				PRESS-EWING AFFECTED	FELT
"	20	09	39.5	2.1				PRESS-EWING AFFECTED	FELT
"	20	12	25.3	1.4				NOT ON PRESS EWING	

ALL OF THE QUAKES ON NOV. 14, 1959 (ABOVE) MADE UNIFORMLY POOR RECORDS. IT WAS POSSIBLE TO LOCATE THEM ONLY BY ASSUMING THAT THEY HAD A COMMON FOCUS AND THEN BY USING ALL AVAILABLE DATA IN A STATISTICAL MANNER. THE RESULTING LOCATION WAS COINCIDENT WITH THE MAIN VENT OF KILAUEA-IKI (SEE ILLUSTRATION.) A DEPTH OF 1.5 KM WAS INDICATED

IN ADDITION TO THE ABOVE, CLEARLY-RECORDED EVENTS, THE FOLLOWING, SMALLER QUAKES WERE REPORTED FELT. (SEE "UNITED STATES EARTHQUAKES, 1959, U.S. COAST AND GEODETIC SURVEY, pg. 61)

14 NOV 1959: 17:24 M=2.5 / 17:32 M=1.0 / 17:41 M=1.1 / 17:44 M=1.2 /
17:48 M=1.0 / 18:25 M=0.9 / 18:27 M=1.0 / 18:30 M=0.6

Date 1959	Time h	Time m	Time s	Magnitude	Depth (km)	Epicenter Lat.N.	Epicenter Long. W.	Epicenter Description	Felt Report OR OTHER COMMENTS
	14 NOV. 1959 (CONT'D.)					18:35 M=0.5 / 18:49 M=0.9		18:36 M=0.5 / 18:54 M=0.9	18:43 M=1.0
Nov. 16	02	40	14.0	1.8	0-3	19° 20.3'	155° 11.4'	South of Chain-of-Craters,	22 KM. EAST OF DESERT
16 Nov.	17	06	56.4	1.9	1.5	19°25'	155° 15'	Near KILAUEA-IKI VENT	PRESS-EWING DEFLECTED
17 Nov.	06	38	15.2	2.9	13	19°53.2'	155° 37.0'	NW FLANK OF MAUNA LOA.	
17 Nov.	11	51	35.3	2.7	13	20° 06.6'	155° 54.7'	W. FLANK OF KOHALA MTN.	
18 Nov.	12	07	29.1	2.2	25	19° 22.8'	155° 19.2'	BENEATH SW Flank OF KILAUEA	READABLE ONLY ON M & D
21 Nov.	14	11	38.2	2.8	25	19° 16.8'	155° 13.0'	S. FLANK OF KILAUEA	
21 Nov.	17	21	34.6	2.7	5	19° 19.2'	155° 09.3'	3 Km NORTH OF CHAIN-OF	CRATERS — NAPAU CRATER
22 Nov.	20	47	49.1	2.0	23	19° 30.9	155° 18.0'	9 KM NORTH OF UWEKAHUNA	(BENEATH KULANI CONE)
23 Nov.	07	02	15.0	2.5	CA 13	POOR FIT ON INSUFFICIENT DATA. PROBABLY NEAR			KAUAHAI.
23 Nov.	14	24	18.1	4.9	CA 28	19° 08.3	155° 26.6	Deep, beneath SW RIFT	OF KILAUEA.
23 Nov.	18	01	40.0	4.2	CA 25	20° 18'	155° 39'	30 KM NORTH OF KAMUELA	FELT NE COAST OF HAWAII
25 Nov.	14	53	17.5	2.1	20	19° 35.4'	155° 20.3	12 KM NE OF M. LOA SEIS.	NW FLANK OF M. LOA
27 Nov.	12	41	29.7	2.3	0-3	19° 22.4	155° 09.4	12 KM E. OF AHUA SEIS	ON UPPER EAST RIFT OF KILAUEA
27 Nov.	15	20	15.9	1.9	8	19° 21.9'	155° 25.9'	4 KM NW OF DESERT SEIS	~ KAOIKI FAULT SYS ~
1 Dec.	13	56	47.5	1.5	5	19° 17.5'	155° 15.5'	13 KM S. OF KILAUEA-IKI	S. FLANK OF KILAUEA
2	02	22	46.1	3.7	3	19° 10.5'	155° 43.3'	18 KM NW OF NAALEHU	FELT- CAPT. COOK AND KEALAKEKUA
								SW RIFT OF M. LOA	
2	12	46	17.7	2.2	8	19° 10.8'	155° 14.3	12 KM W OF NAALEHU	
2	13	43	23.4	<2.5	13	19° 40.1	155° 14.3	SIMILAR LOCATIONS BUT	OPPOSITE FIRST-MOTION
2	13	43	27.5	2.5	13	19° 40.1	155° 14.3	16 KM W OF HILO;	POSSIBLY RELATED TO
								NE RIFT OF M. LOA	
2	17	09	09.5	2.4	13	20° 03.2	155° 22.3	32 KM E. OF KAMUELA	N COAST OF HAWAII
2	19	46	01.5	1.4	5	19° 15'	155° 15'	20 KM S OF UWEKAHUNA	S FLANK OF KILAUEA
3	02	44	35.4	2.7	CA 10	19° 35'	155° 57'	8 KM NW OF KEALAKEKUA	KONA (POOR LOCATION)
3	07	35	45.5	2.1	10	19° 16.8'	155° 18.3	16 Km S OF UWEKAHUNA	S. FLANK OF KILAUEA
4	06	16	35.0	2.6	8	19° 24.3	155° 09.0	14 KM E OF UWEKAHUNA	NORTH OF EAST RIFT ZONE, KILAUEA

Date 1959	Time			Magnitude	Depth (km)	Epicenter			Felt Reports
	h	m	s			Lat.N.	Long. W.	Descrition	
6 Dec.	17	16	59.3	2.7	35	19° 42.1'	154° 54.2'	20 Km. E. OF HILO	
9	11	26	07.6	2.3	CA 8	20° 03'	155° 49'	NEAR KAWAIHAE, KOHALA MTN. POOR LOCATION	
9	23	18	31.6	1.6	8	19° 13.2	155° 12.2	28 KM SE. OF UWEKAHUNA, SE FLANK OF KILAUEA	
10	06	10	50.1	2.4	CA 10	19° 23'	155° 07'	18 KM E. OF UWEKAHUNA, E. RIFT OF KILAUEA	
11	12	26	01.4	2.4	CA 20	19° 54'	155° 49'	75 KM NW. OF UWEKAHUNA, POOR LOCATION	
11	15	28	21.8	2.1	8	19° 25.2'	155° 26.3	KAOIKI FAULT SYSTEM	
			deep	QUAKES	START	HERE	WITH	SPECIAL HILO SECTION	LISTED FIRST

Dec. 11 The deep swarm (h greater than 42 km) began to record at Hilo around 17:30. From 18:30 to 24:00, weak to moderate spasmodic tremor /1/ is seen. But at the same time, this tremor at summit stations was so large that identification of individual quakes was not possible. Therefore, the following origin times and magnitudes are the best possible estimates based on Hilo readings alone. Assuming that greater p-travel-times for these early events indicate greater depth, the following depth and magnitude estimates are based on measured p-travel times -- also listed. It is further assumed that p-travel-times, 7.8, 7.9, 8.0 and 8.1 are normal variations of the final class of these events from a depth of 42 km.

18	40	35.5	2.8	60	19°32.3'	155°20.7	7 KM NORTHEAST OF [illegible]	UP
ORIGIN TIME			MAG.	THIS FOCUS IS DESIGNATED BY KM h IN THE REST OF THIS LIST			SEISMOGRAM P-TRAVEL DEPTH	FELT REPORT
19	21	17.8	2.8	—	60 Km	—	KM 52 8.8 ~52 Km	DN
19	30	38.7	2.6	—	—	—	KM 52 "	DN
19	31	41.0	2.8	—	—	—	KM 52 "	DN
20	07	41.9	2.6	—	—	—	KM 52 "	UP
20	28	43.4	2.6	—	—	—	KM 52 "	DN
20	32	26.5	2.6	—	—	—	KM 52 "	UP
20	33	40.2	2.6	—	—	—	KM 52 "	DN
20	51	02.1	2.8	—	—	—	KM 52 "	DN
20	55	14.2	2.10	—	—	—	KM 52 "	UP
21	13	53.6	2.8	—	—	—	KM 52 "	UP
21	14	57.6	2.9	—	—	—	KM 52 "	UP
21	28	27.6	2.6	—	—	—	KM 52 "	DN
21	36	26.1	3.4	—	—	—	KM 52 "	UP
21	43	22.5	2.7	—	—	—	KM 52 "	DN
21	45	04.9	2.5	—	—	—	KM 52 "	DN
21	46	30.6	2.9	—	—	—	KM 52	DN
21	46	57.1	2.8	—	—	—	KM 52	DN
21	51	22.6	2.7	—	—	—	KM 52	DN
22	05	41.9	2.7	—	50 Km	—	KM 50 8.6 ~50 Km	UP
22	12	41.4	2.7	—	—	—	KM 50	DN
22	27	20.7	2.6	—	—	—	KM 50	DN
23	13	07.9	3.0	—	↓	—	KM 50	DN
23	31	04.2	2.7	—	—	—	KM 42 8.2 ~46	UP

SPECIAL SECTION OF TABLE IV, SHOWING ALL DEEP SWARM QUAKES WHICH CAN BE READ AT HILO. AT THE TIME OF THESE RECORDINGS, SUMMIT STATIONS WERE TOO DISTURBED BY TREMOR AND EARTHQUAKE NOISE TO PERMIT USE OF THEIR DATA; HILO READINGS ARE THE ONLY ONES AVAILABLE.

Date 1959	Time h	m	s	Magnitude	Depth (km)	Epicenter Lat.N.	Long. W.	Description DEPTH	P-TRAVEL-TIME	~~Felt Report~~ FIRST MOTION OF P
DEC. 12	00	13	28.6	2.6	—	—	—	KM 42	8.2	UP
	00	21	34.5	2.5	—	—	—	KM 42		DN
	00	23	23.7	2.6	—	—	—	KM 42	8.3+	UP
	00	26	[illegible]	[illegible]	—	—	—	KM 42		UP
	00	31	[illegible]	[illegible]	—	—	—	KM 49	8.5 249 KM	DN
	00	[illegible]	[illegible]	[illegible]	—	—	—	KM 42		UP
	00	37	[illegible]	[illegible]	—	—	—	KM 42		DN
	00	[illegible]	18.8	2.5	—	—	—	KM 48	8.4-48	UP
	00	[illegible]	[illegible]	2.9	—	—	—	KM 42		UP
	00	54	[illegible]	2.6	—	—	—	KM 49	8.5 ~49	DN
	00	59	[illegible]	3.0	—	—	—	KM 42	8.2	DN
	01	02	[illegible]	[illegible]	—	—	—	KM 49	8.5 249	UP
	01	[illegible]	[illegible]	[illegible]	—	—	—	KM 42	8.2	UP
	01	12	[illegible]	2.6	—	—	—	KM 42		UP
	01	15	17.6	2.7	—	—	—	KM 42		UP
	01	25	[illegible]	2.5	—	—	—	KM 42		UP
	01	31	[illegible]	3.3	—	—	—	KM 42		UP
	02	00	[illegible]	3.6	—	—	—	KM 42	8.1	UP
	02	[illegible]	[illegible]	[illegible]	—	—	—	KM 42		UP
	02	15	23.3	[illegible]	—	—	—	KM 42		UP
	02	25	37.1	2.8	—	—	—	KM 42		UP
	02	28	41.0	2.5	—	—	—	KM 42	8.0	UP
	02	54	49.0	2.8	—	—	—	KM 42	8.2	UP
	02	55	38.9	2.6	—	—	—	KM 42		DN
	02	56	39.7	2.5	—	—	—	KM 42	8.1	UP
	03	02	38.5	2.8	—	—	—	KM 42		DN
	03	03	49.2	2.8	—	—	—	KM 42	8.2	UP
	03	16	48.9	3.0	—	—	—	KM 42	7.8	UP
	03	23	32.6	2.8	—	—	—	KM 42	8.1	UP
	03	24	26.6	2.7	—	—	—	KM 42	8.2	UP
	03	26	36.8	2.8	—	—	—	KM 42	7.9	UP
	03	34	47.6	2.0	—	—	—	KM 42	8.1	DN
	03	35	51.0	2.8	—	—	—	KM 42	8.2	DN

SPECIAL SECTION OF TABLE IV, SHOWING ALL DEEP SWARM QUAKES WHICH CAN BE READ AT HILO ONE (LISTED BELOW) WAS ALSO READABLE AT SUMMIT STATIONS; IT WILL BE REPEATED IN THE MAIN CHRONOLOGY OF EVENTS.

Date 1959	Time h	m	s	Magnitude	Depth (km)	Epicenter Lat.N.	Long. W.	Description DEPTH	P TRAVEL TIME	~~Report~~ FIRST MOTION P
DEC. 12	03	42	57.3	2.5	—	—	—	KM 42	8.2	UP
	03	44	06.8	2.5	—	—	—	KM 42	8.4	UP
	03	46	33.7	2.9	—	—	—	KM 49	8.5 ~49	DN
	03	54	41.7	2.7	—	—	—	KM 42	8.2	UP
	03	54	59.1	2.7	—	—	—	KM 42	8.4	DN
	04	02	32.8	2.8	—	—	—	KM 42	8.1	UP
	04	03	19.8	2.7	—	—	—	KM 42	8.1	DN
	04	03	31.6	2.8	—	—	—	KM 42	7.9	UP
	04	04	29.1	2.8	—	—	—	KM 42	8.2	UP
	04	06	51.4	2.8	—	—	—	KM 42	8.2	DN
	04	08	28.5	3.0	—	—	—	KM 42	7.9	UP
	04	53	57.6	3.2	—	—	—	KM 42	7.9	UP
	05	46	19.4	2.6	—	—	—	KM 42	8.2	UP
	06	02	44.1	2.5	—	—	—	KM 52	8.8 ~52	UP
	06	33	00.5	2.7	—	—	—	KM 42	8.2	UP
	06	46	11.4	2.7	—	—	—	KM 42	8.1	UP
	07	46	51.0	2.5	—	—	—	KM 42	?	UP
	07	47	03	2.8	—	—	—	KM 42	? (LOST IN NOISE)	?
	07	58	37.8	2.7	—	—	—	KM 42	7.8	DN
	08	28	36.2	2.5	—	—	—	KM 42	8.2	UP
	08	49	52.4	2.8	—	—	—	KM 42	8.1	UP
	08	50	55.7	2.7	—	—	—	KM 42	8.1	UP?
	08	51	07.0	2.8	—	—	—	KM 42	8.1	UP?
	09	09	33.6	2.5				KM 42	7.5	UP
	09	16	01.0	2.5				KM 42	8.2	DN
	09	31	30.7	2.5				KM 42	8.1	UP
	09	32	16.0	2.5				KM 42	8.2	UP
	09	37	02.7	2.7				KM 42	8.2	UP
	09	38	22.5	2.6				KM 50	8.6 ~50	DN
	09	44	15.4	2.6				KM 42	8.1	DN
	(10	06	32.8	2.9 ★					8.1	UP)

(*) THESE ARE EVENTS FOR WHICH OTHER INSTRUMENTAL DATA ARE AVAILABLE; THEY WILL BE REPEATED IN THE NEXT SECTION OF THIS TABLE.

SPECIAL SECTION OF TABLE IV, SHOWING ALL DEEP SWARM QUAKES WHICH CAN BE READ AT HILO
A FEW OF THEM ALSO WERE READABLE AT THE SUMMIT:; AND THOSE WILL BE REPEATED.

Date 1959	Time h	m	s	Magnitude	Depth (km)	Epicenter Lat.N.	Long. W.	Description DEPTH	TRAVEL TIME OF P	~~Edit Report~~ FIRST MOTION OF P
DEC 12	10	20	09.6	2.7 *				KM 42	8.0	UP
	10	36	39.1	2.7				KM 42	8.2	UP
	10	39	59.0	2.7				KM 42	8.0	UP
	10	48	05.8	2.6				KM 42	8.0	UP
	11	04	58.5	2.7				KM 42	8.0	UP
	11	07	13.7	2.7				KM 42	8.0	UP
	11	14	36.5	2.7				KM 42	8.3	DN
	11	23	08.2	2.6				KM 42	8.3	UP
	11	23	14.5	2.6				KM 42	8.1 ?	DN ?
	11	30	31.9	2.7 *				KM 42	7.8	UP
	11	31	14.0	2.6				KM 42	8.1	UP
	11	35	29.3	2.8 *				KM 42	7.9	UP
	11	36	46.0	2.6				KM 42	8.2	UP
	11	37	21.9	2.5				KM 42	8.2	UP
	11	38	59.0	2.5 *				KM 42	8.2	UP
	11	41	15.7	2.5				KM 42	8.2	UP
	11	43	00.4	2.8 *				KM 42	8.1	UP
	11	48	46.7	2.5				KM 42	8.1	UP
	11	51	27.9	3.0				KM 42	8.1	DN
	11	56	34.2	2.7				KM 42	8.1	UP
	11	57	44.6	2.7				KM 42	8.1	UP
	12	03	43.1	2.8				KM 42	8.1	UP
	12	04	11.7	2.5				KM 42	7.9	UP
	12	13	21.0	2.8				KM 42	8.2	UP
	12	13	37.8	2.5				KM 42	8.2	DN
	12	22	23.6	2.1				KM 42	8.2	DN
	12	24	28.5	2.7 *				KM 42	8.1	UP
	12	35	48.9	2.4				KM 42	8.4	UP
	12	47	21.6	2.8				KM 42	7.7	DN
	12	48	22.7	2.5				Km 42	8.0	DN
	12	48	46.2	2.5				KM 42	8.1	UP

(*) THESE ARE EVENTS FOR WHICH OTHER INSTRUMENTAL DATA ARE AVAILABLE; THEY WILL BE REPEATED IN THE NEXT SECTION OF THIS TABLE.

SPECIAL SECTION OF TABLE IV, SHOWING ALL DEEP SWARM QUAKES WHICH CAN BE READ AT HILO.

Date 1959	Time h	m	s	Magnitude	Depth (km)	Epicenter Lat.N.	Long. W.	Description DEPTH	TRAVEL TIME OF P	~~Form Report~~ FIRST MOTION OF P
DEC. 12	12	52	33.5	2.5	—	—	—	Km 42	7.7	DN
	12	52	44.2	2.7				Km 42	8.1	?
	12	52	47.8	2.7				Km 42	8.1	DN
	12	55	29.1	2.7				Km 42	7.9	UP
	12	56	07.3	2.7				Km 42	7.3	?
	12	56	29.6	2.7				Km 42	8.1	UP
	12	57	15.4	3.1				Km 42	7.9	UP
	12	58	30.6	2.7				Km 42	7.9	?
	13	04	57.4	2.7				Km 42	7.9	UP
	13	06	51.4	2.7				Km 42	7.8	DN
	13	09	24.1	2.7				Km 42	7.8	UP
	13	10	12.9	2.5				Km 42	7.7	UP
	13	10	32.7	3.1				Km 42	7.8	UP
	13	12	25.7	2.8				Km 42	7.8	UP
	13	17	20.9	2.5				Km 42	7.9	DN
	13	18	48.4	2.5				Km 42	7.9	UP
	13	21	01.5	2.8				Km 42	7.9	UP
	13	41	58.1	2.8 *				Km 42	8.1	UP
	14	02	24.8	2.5				Km 42	7.9	DN
	14	30	04.3	2.6 *				Km 42	7.8	UP
	14	49	35.8	1.8				Km 42	7.8	UP
	14	52	39.2	1.8				Km 42	7.8	UP
	14	53	28.6	2.1				Km 42	7.8	DN
	15	01	26.5	2.0				Km 42	7.7	DN
	15	16	56.8	2.0				Km 42	7.7	UP
	15	18	07.4	1.8				Km 42	8.0	UP
	15	22	06.6	2.0				Km 42	8.0	UP
	15	24	49.9	2.8				Km 42	8.2	UP
	15	35	28.5	2.0				Km 42	7.8	DN
	15	36	55.2	1.8				Km 42	8.0	DN
	16	03	50.9	2.0				Km 42	8.1	UP
	16	04	34.0	2.0				Km 42	8.1	DN

(*) THESE ARE EVENTS FOR WHICH OTHER INSTRUMENTAL DATA ARE AVAILABLE: THEY WILL BE REPEATED IN THE NEXT SECTION OF THIS TABLE

SPECIAL SECTION OF TABLE IV, SHOWING ALL DEEP SWARM QUAKES WHICH CAN BE READ AT HILO. A FEW OF THEM WERE ALSO READABLE ON SUMMIT SEISMOGRAMS; THOSE WILL BE INDLUDED IN BOTH THIS LISTING AND IN THE REGULAR SCHEDULE OF TABLE IV, TO BELOW.

Date 1959	Time h	m	s	Magnitude	Depth (km)	Epicenter Lat. N.	Long. W.	Description DEPTH	TRAVEL-TIME OF P	Report FIRST-MOTION OF P
DEC. 12	16	05	58.3	2.5 *	—	—	—	KM 42	8.0	?
	16	11	44.7	2.5 *	—	—	—	KM 42	7.8	DN
	16	16	56.1	2.7 *	—	—	—	KM 42	7.8	DN
	16	23	44.9	1.8	—	—	—	KM 42	8.1	DN
	16	27	37.7	2.7	—	—	—	KM 42	8.0	DN
	16	31	13.5	1.7	—	—	—	KM 42	8.1	UP
	16	36	34.1	1.7	—	—	—	KM 42	8.1	UP
	16	44	?	2.3	—	—	—	KM 42	?	?
	16	49	19.1	3.0 *	—	—	—	KM 42	8.1	UP
	16	53	37.9	2.4	—	—	—	KM 42	8.2	DN
	17	18	32.0	1.7	—	—	—	KM 42	7.8	DN
	18	03	49.4	2.5	—	—	—	KM 42	7.8	DN
	18	08	43.6	2.5	—	—	—	KM 42	7.9	DN
	18	17	01.5	2.0	—	—	—	K	7.9	DN
	18	21	51.9	2.0	—	—	—	KM 42	7.9	UP
	18	24	49.4	2.4 *	—	—	—	KM 42	8.2	UP
	18	27	41.1	2.0 *	—	—	—	KM 42	8.0	UP
	19	28	54.8	2.5 *	—	—	—	KM 42	8.0	UP
	19	34	53.2	2.8 *	—	—	—	KM 42	8.0	UP
	20	35	19.0	2.5	—	—	—	KM 42	7.7	UP
	20	50	36.1	2.5 *	—	—	—	KM 42	8.1	UP
	21	26	25.9	2.7 *	—	—	—	KM 42	8.0	UP
	21	36	02.6	2.8 *	—	—	—	KM 42	7.8	UP
	21	42	14.3	2.0				KM 42	7.8	UP
	21	54	03.6	2.0 *	—	—	—	KM 42	8.0	UP
	21	55	18.6	2.0	—	—	—	KM 42	8.0	UP
	22	56	16.8	1.7	—	—	—	KM 42	8.0	DN
	23	00	10.4	2.0	—	—	—	KM 42	7.9	UP
	23	19	29.7	2.4 *	—	—	—	KM 42	7.9	UP
	23	23	30.8	1.7 *	—	—	—	KM 42	8.0	UP
	23	42	36.4	2.4	—	—	—	KM 42	8.1	UP

(*) THESE ARE EVENTS FOR WHICH OTHER INSTRUMENTAL DATA ARE AVAILABLE; THEY WILL BE REPEATED IN THE NEXT SECTION OF THIS TABLE.

SPECIAL SECTION OF TABLE IV, SHOWING ALL DEEP SWARM QUAKES WHICH CAN BE READ AT HILO. A FEW OF THEM WERE ALSO READABLE ON SUMMIT SEISMOGRAMS; THOSE WILL BE INCLUDED IN BOTH THIS LISTING AND IN THE REGULAR SCHEDULE OF TABLE IV, TO FOLLOW.

Date 1960	Time h	m	s	Magnitude	Depth (km)	Epicenter Lat. N.	Long. W.	Description DEPTH	TRAVEL TIME OF P	~~Felt Report~~ FIRST MOT P
DEC. 13	01	18	36.7	2.7 *	—	—	—	KM 42	8.5	UP
	01	35	13.5	2.6 *	—	—	—	KM 42	7.8	UP
	01	57	30.9	3.1 *	—	—	—	KM 42	7.8	DN
	01	58	37.2	2.7 *	—	—	—	KM 42	8.0	UP
	02	21	06.1	2.7 *	—	—	—	KM 42	8.0	UP
	03	11	07.6	2.7	—	—	—	KM 42	8.1	UP
	03	57	44.1	2.0	—	—	—	KM 42	7.8	UP
	03	58	37.9	3.0 *	—	—	—	KM 42	8.1	UP
	05	04	43.6	2.7 *	—	—	—	KM 42	8.0	UP
	05	49	21.7	2.5 *	—	—	—	KM 42	8.1	DN
	07	43	20.4	2.5	—	—	—	KM 42	8.1	UP
	08	30	04.1	2.8	—	—	—	KM 42	8.0	DN
	09	56	15.2	2.7	—	—	—	KM 42	8.1	UP
	10	59	51.3	1.7	—	—	—	KM 42	8.0	UP
	11	44	56.4	2.0	—	—	—	KM 42	8.1	UP
	11	49	23.9	1.7	—	—	—	KM 42	8.0	UP
	11	49	49.5	2.0	—	—	—	KM 42	8.0	UP
	12	23	28.9	1.3	—	—	—	KM 42	8.1	UP
	12	24	27.2	2.0	—	—	—	KM 42	8.0	UP
	14	26	21.4	2.4	—	—	—	KM 42	7.9	UP
	15	42	41.1	2.4	—	—	—	KM 42	8.2	DN
	18	00	40.8	1.7 *	—	—	—	KM 42	8.0	UP
	18	03	44.4	1.7	—	—	—	KM 42	8.1	UP
	19	02	43.8	2.4 *	—	—	—	KM 42	8.1	UP
	19	43	18.5	2.4 *	—	—	—	KM 42	8.1	UP
	20	42	47.3	2.4	—	—	—	KM 42	8.0	DN
	21	06	05.7	1.7	—	—	—	KM 42	8.1	UP
	21	58	47.9	1.6	—	—	—	KM 42	8.0	DN
	22	38	09.9	1.4	—	—	—	KM 42	8.1	UP
212	22	45	18.5	1.6 *	—	—	—	KM 42	8.0	UP
Dec. 14	05	05	28.5	2.4 *	—	—	—	KM 42	8.0	UP

(*) THESE ARE EVENTS FOR WHICH OTHER INSTRUMENTAL DATA ARE AVAILABLE; THEY WILL BE REPEATED IN THE NEXT SECTION OF THIS TABLE.

SPECIAL SECTION OF TABLE IV, SHOWING ALL DEEP SWARM QUAKES WHICH CAN BE READ AT HILO. A FEW OF THEM WERE ALSO READABLE ON SUMMIT SEISMOGRAMS; THOSE WILL BE INCLUDED IN BOTH THIS LISTING AND IN THE REGULAR SCHEDULE OF TABLE IV, TO FOLLOW.

Date 1969	Time h	m	s	Magnitude	Depth (km)	Epicenter Lat.N.	Long. W.	Description DEPTH	TRAVEL TIME OF P	FIRST MOTION
DEC. 14	09	51	39.9	1.7 *	—	—	—	KM 42	8.0	UP
	11	56	47.5	2.0	—	—	—	KM 42	8.2	UP
	13	33	49.6	1.7	—	—	—	KM 42	8—	UP?
	15	45	09.6	1.7 *	—	—	—	KM 42	8—	UP
	17	23	09.7	1.4	—	—	—	KM 42	7.8	DN
	19	00	37.1	1.7 *	—	—	—	KM 42	8.1	UP
	21	47	29.8	2.0 *	—	—	—	KM 42	8.0	DN
	22	22	47.9	1.7 *	—	—	—	KM 42	8.1	DN
	22	34	09.3	2.4 *	—	—	—	KM 42	8.5	UP
	23	30	39.0	1.7	—	—	—	KM 42	8.1	UP
DEC. 15	0 03	40	20.5	2.4 *	—	—	—	KM 42	8.5	UP

(*) THESE ARE EVENTS FOR WHICH OTHER INSTRUMENTAL DATA ARE AVAILABLE; THEY WILL BE REPEATED IN THE NEXT SECTION OF THIS TABLE.

THIS IS THE CONCLUSION OF THE SPECIAL SECTION OF TABLE IV, SHOWING ALL DEEP SWARM QUAKES WHICH CAN BE READ AT HILO. THERE ARE ABOUT 220 OF THESE EVENTS OF MAGNITUDE 1.4 OR GREATER, WHEREAS ONLY ABOUT 80 EVENTS WERE READABLE BOTH ON HILO AND ON SUMMIT RECORDS. THIS SEEMING INCONSISTENCY IS DUE TO THE HIGH LEVEL OF TREMOR AND QUAKE ACTIVITY WHICH RECORDED AT SUMMIT STATIONS AND OBLITERATED MANY EVENTS FOR READING PURPOSES. IN GENERAL QUAKES OF MAGNITUDE 2.0 OR LARGER WERE EASILY FOUND ON THE HILO RECORD --- ALTHOUGH SPECIAL EFFORTS WERE MADE TO LOCATE AND TO READ SMALLER EVENTS FOR WHICH SUMMIT READINGS WERE GOOD.

Date 1959	Time h	m	s	Magnitude	Depth (km)	Epicenter Lat.N.	Long. W.	Description	Felt Reports AND OTHER COMMENTS
Dec. 12	10	06	33.0	2.9	42	19°32.3'	155°20.7'	7 km northeast of Mauna Loa seismometer station	
						THIS FOCUS WILL BE DESIGNATED BY KM 42 IN REST OF THIS LIST			
12	10	20	09.5	2.7				KM 42	
	11	30	31.7	2.6				KM 42	
	11	35	29.3	2.9				KM 42	
	11	38	59.0	2.6				KM 42	
	11	43	00.4	2.8				KM 42	
	12	24	28.5	2.7				KM 42	
	13	41	58.2	2.7				KM 42	
	14	22	46.9	2.6				KM 42	
	14	30	04.3	2.6				KM 42	
	15	48	05.4	2.5				KM 42	
	15	50	23.6	2.6				KM 42	
	15	53	48.4	2.5				KM 42	
	16	05	58.1	2.5				KM 42	
	16	11	44.6	2.6				KM 42	
	16	17	56.1	2.7				KM 42	
	16	49	19.2	3.0				KM 42	
	17	33	06.7	2.6				KM 42	
	18	00	30.1	2.7				KM 42	
	18	24	49.7	2.6				KM 42	
	18	27	41.3	2.5				KM 42	
	18	55	14.3	2.5				KM 42	
	19	28	54.3	3.1				KM 42	REPORTED FELT
	19	34	53.3	2.7				KM 42	
	20	32	17.8	2.5				KM 42	
	20	42	32.6	2.6				KM 42	
	20	50	36.4	3.0				KM 42	
	21	26	26.3	2.6				KM 42	

CONTINUED ON NEXT SHEET

★ TOO SMALL TO READ ON HILO WWSSN; CONTAINS DATA ONLY FROM UWEKAHUNA, MAUNA LOA, OUTLET AND DESERT SEISMOGRAPHS.

Date 1969	Time h	Time m	Time s	Magnitude	Depth (km)	Epicenter Lat.N.	Epicenter Long. W.	Epicenter Description	Felt Reports AND OTHER COMMENTS
DEC 12	21	32	23.7	2.2 *	—			KM 42	
	21	36	02.5	2.8	—			KM 42	
	21	54	03.7	2.5	—			KM 42	
	22	22	33.8	2.3 *	—			KM 42	
	23	19	29.7	2.5	—			KM 42	
	23	23	30.8	2.3	—			KM 42	
DEC. 13	00	18	54.2	2.5 *	—			KM 42	
	00	24	13.8	2.2 *	—			KM 42	
	01	16	09.4	2.3 *	—			KM 42	
	01	35	13.8	2.4	—			KM 42	
	01	57	30.8	3.0	—			KM 42	
	01	58	37.4	2.6	—			KM 42	
	01	59	39.5	2.2 *	—			KM 42	
	02	00	57.4	2.3 *	—			KM 42	
	02	07	23.0	2.5 *	—			KM 42	
	02	10	56.4	2.4 *	—			KM 42	
	02	13	50.0	2.0 *	—			KM 42	
	02	14	27.1	2.5 *	—			KM 42	
	02	21	06.1	2.7	—			KM 42	
	02	43	15.9	2.5 *	—			KM 42	
	03	58	38.0	3.0	—			KM 42	
	05	04	44.2	2.7	—			KM 42	
	05	49	22.0	2.5	—			KM 42	
	18	00	41.1	2.1	—			KM 42	
	19	02	44.6	2.4	—			KM 42	
	19	43	19.6	2.5	—			KM 42	
	21	05	08.4	2.5 *	—			KM 42	
	22	45	19.3	2.2	—			KM 42	

* TOO SMALL TO READ ON HILO RECORD

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Date 1959	Time h	m	s	Magnitude	Depth (km)	Epicenter Lat. N.	Long. W.	Description	~~Data~~ Report
DEC 14	00	09	49.6	2.2*	—	—	—	KM 42	
	01	45	34.6	2.0*	—	—	—	KM 42	
	01	56	10.6	2.3*	—	—	—	KM 42	
	03	04	22.0	2.0*	—	—	—	KM 42	
	06	18	26.8	2.4	—	—	—	KM 42	
	06	48	28.5	2.5*	—	—	—	KM 42	
	09	51	40.1	2.4	—	—	—	KM 42	
	15	45	10.0	2.2	—	—	—	KM 42	
	16	35	53.2	2.2*	—	—	—	KM 42	
	19	00	37.5	2.1	—	—	—	KM 42	
	20	53	55.3	1.9*	—	—	—	KM 42	
	21	47	30.1	2.2	—	—	—	KM 42	
	22	22	48.3	2.1*	—	—	—	KM 42	
Dec. 16	23	22	13.0	1.5	8	19°23.2'	155°26.2	Kaoiki Fault System	
18	04	01	48.5	1.8	5	19°17.8'	155°16.0	15 KM S. OF HALEMAUMAU	S. FLANK OF KILAUEA
19	17	39	30.1	1.6	<3	19°03.4	155°28.3	3 Km N OF PAHALA	POSSIBLY KAOIKI FAULT
20	21	23	59.7	3.4	5	19°07.5'	155°04.0'	offshore 40 Km Southwest of Uwekahuna	E. RIFT OF KILAUEA
20	21	26	55.0	2.9	3	19°20.5	155°00.8'	40 Km East of Desert	NE RIFT OF M. LOA.
21	07	17	47.0	2.7	15	19°35.6'	155°20.8'	12 KM NE OF M.LOA SEIS	W. Flank of M. LOA
21	09	30	47.0	1.5	8	19°28.4'	155°25.3'	5 KM W OF M.LOA SEIS,	S. FLANK OF KILAUEA
23	00	20	40.0	3.6?	0-3	19°01'	155°04	50 Km SW OF UWEKAHUNA	
			(POOR LOCATION DUE TO QUESTIONABLE FIRST ARRIVALS)						
23	02	13	32.0	3.1	5	19°16.0'	155°07.9	23 KM SE OF UWEKAHUNA	SE FLANK OF KILAUEA
24	02	20	55.0	2.5	~10	19°33'	155°59'	70 Km W of M.LOA Seis	offshore KONA
25	04	14	40	2.6	~10	20°46'	155° 16'	OFFSHORE, 100 KM E OF MAUI	SEIS, EAST RIFT OF HALEAKALA
25	14	09	10.1	2.2	3	19° 12.2'	155°35.7'	15 KM NORTH OF NAALEHU	S FLANK OF M. LOA
25	17	44	47.1	3.5	30	20°03.8'	155°43.7'	8 KM NW OF KAMUELA	KOHALA VOLCANO
26	03	08	31.0	2.2	20	19°25'	155°30'	13 KM NW OF DESERT SEIS	SE FLANK OF M. LOA
26	17	04	08.8	1.5	8	19°18.0	155°22.5	4 KM SE OF DESERT SEIS	SW RIFT, KILAUEA

Date 1959	Time h	m	s	Magnitude	Depth (km)	Epicenter Lat.N.	Long. W.	Description	~~Test~~ Report
DEC. 27	08	06	38.0	1.4	3	19°18'	155°12	4 KM N. OF APUA POINT	S. FLANK OF KILAUEA
27	18	40	42.0	2.4	8-9	19°12.4	155°25.3	2 KM NW OF DESERT SEIS,	LOWER RAOIKI FAULT
28	00	29	16.0	2.6	10	19°12.4	155°25.3	do	do
28	01	47	39.7	3.8	30	19°48.8	155°21.3	34 KM N OF M.LOA SEIS	EAST FLANK OF M.KEA
28	15	29	09.0	3.2	5	19°26.0	154°51.2	12 KM SE OF PAHOA KILAUEA OFFSHORE	EAST RIFT OF
29	08	19	06.0	2.1	8	19°25.0	155°27.6	17 KM W. OF UWEKAHUNA,	SE FLANK OF M.LOA
29	12	16	30.9	2.7	CA 30	19°49'	155°30'	beneath SUMMIT OF	MAUNA KEA
29	18	53	19.5	2.6	8	19°25.9	154°46.2	45 KM SE OF HILO KILAUEA OFFSHORE	EAST RIFT OF
29	23	38	58.7	3.6	CA 5	19°27'	154°48	50 KM E OF UWEKAHUNA KILAUEA OFFSHORE	EAST RIFT OF
30	01	55	34.1	3.7	20	19°53.3	155°32.7	55 KM NW OF UWEKAHUNA NEAR SUMMIT OF MAUNA KEA	
30	13	14	32.0	3.5	30	19°14'	155°14'	M.LOA, 120 KM E OF DESERT SEIS	
30	15	26	19.5	2.8	8	19°28.8	154°48.2	15 KM E OF PAHOA OF KILAUEA OFFSHORE	EAST RIFT
30	21	59	07.0	2.9	CA 10	19°29.0	154°47.2	17 KM E OF PAHOA, OF KILAUEA OFFSHORE	EAST RIFT
31	13	12	07.0	2.8	CA 20	19°30'	154°41'	27 KM E OF PAHOA	EAST RIFT-OFFSHORE
31	17	43	47.4	2.5	CA 8	19°16'	156°00	65 KM W. OF DESERT SEIS. OF HAWAII ISLAND	WEST COAST -OFFSHORE

Table 5.--Distant earthquakes

Times are reported in Greenwich Civil Time, which is 10 hours faster than Hawaiian Standard Time. A "c" following the time of P indicates compressional first motion; a "d" indicates dilatational first motion. Station symbols, locations, and instrumentation will be presented in table 6, Summary 17 (the first summary of 1960). Location of epicenter, origin times, focal depths, and magnitude reported by other institutions are taken from Seismological Bulletins MSI-226, MSI-227, and MSI-228 published by the U.S. Coast and Geodetic Survey to cover October, November, and December of 1959. Reference will also be made to United States Earthquakes, 1959, another publication of the U.S. Coast and Geodetic Survey.

October 2, 1959

M	Z	T-phase	13:43-13:46
O	Z	T-phase	13:43-13:46
D	Z	T-phase	13:43-13:46
N	Z	T-phase	13:43-13:46
U	Z	T-phase	13:43-13:46
Hi	Z	T-phase	13:44-13:45
Ha	Z	T-phase	13:43-13:45

Not listed in United States Earthquakes, 1959, or in MSI-226

October 2, 1959

U	PEZ	Start of the phenomena was about 23:22:30 (150-sec. period).
U	PEN	Start of the phenomena was about 23:22:30 (100-sec. period).
U	PEE	Start of the phenomena was about 23:22:30 (50-sec. period).

Pressure pulse due to weather or to atomospheric nuclear test.
No such events listed in United States Earthquakes, 1959, or in MSI-226.

October 6, 1959

M	Z	eP	05:56:48.5 c
O	Z	eP	05:56:48.3 c
N	Z	iP	05:56:49.0 c
U	Z	iP	05:56:48.5 c

United States Earthquakes, 1959

05:44:37
0.5° N., 122.5° E.
Celebes
h about 200 km.

Table 5.--Distant earthquakes--Continued

October 10, 1959

M	Z	iP	02:15:03.4 d
O	Z	eP	02:15:03.3 d

Not listed in United States Earthquakes, 1959 or in MSI-226.

October 15, 1959

M	Z	iP	06:28:12.5 c
O	Z	eP	06:28:12.8 c
U	PEZ	iP	06:28:18.0 c
U	PEZ	iP?	06:39:26
U	PEZ	eR	06:55:08
U	PEN	iG	06:50:39

MSI-226
06:15:32
0.5° N., 120.5° E.
Celebes
Magnitude 6.5.

October 16, 1959

M	Z	eP	16:27:35.0 c
O	Z	eP	16:27:35.2 c

MSI-226
16:14:53
6° N., 125° E.
Near south coast of Mindanao, Philippine Islands.

October 19, 1959

M	Z	eP	08:36:31.7 d
O	Z	eP	08:36:31.2 d
U	PEN	eS	08:43:50
U	PEZ	eR	08:50:48

MSI-226
08:27:21
27.5° S., 177° W.
Kermadec Islands
Magnitude 6.25.

October 19, 1959

M	Z	iP	14:00:27.3 d
O	Z	iP	26.9 d
D	Z	iP	27.2 d
U	Z	eP	26.9 d
Hi	Z	iP	29.4 c
Ha	Z	iP	32.1 c

MSI-226
13:52:40
22.0° S., 179.5° W.
Fiji Islands Region
h about 600 km.

October 19, 1959

M	Z	iP	16:14:41.7 d
O	Z	iP	41.2 d
D	Z	eP	40.8 d
U	Z	eP	41.1 d

MSI-226
15:55:30
54.5° S., 29.0° W.
Sandwich Islands Region.

October 26, 1959

M	Z	eP	07:44:51.2 d
O	Z	e?	51.8 c
D	Z	e?	51.6 c
U	Z	i?	53.2 c
U	PEZ	eP	52 d
U	PEZ	iS	52:42
U	PEZ	iR	59:59
U	PEN	eSS	58:39
U	PEE	eQ?	58:09
Hi	Z	iP	07:44:53.6 c

MSI-226
07:35:12
37.5° N., 142.5° E.
Near east coast of Honshu, Japan
h about 60 km
Magnitude 6.5.

Table 5.--Distant earthquakes--Continued

October 26, 1959

M	Z	iP	10:37:45.6 d
O	Z	e?	45.8 d
D	Z	eP	46.4 d
U	Z	i?	46.6 c
Hi	Z	iP	44.4 c

MSI-226

10:29:09
51.5° N., 157.5° E.
Near east coast of Kamchatka
h about 150 km.

October 27, 1959

M	Z	T-phase	06:53-06:55
O	Z	T-phase	06:53-06:55
D	Z	T-phase	06:53-06:55
N	Z	T-phase	06:53-06:55
U	Z	T-phase	06:53-06:55
Hi	Z	Tmax	06:53:22
Hi	N	eQ	06:26:17
Ha	Z	Tmax	06:53:55

MSI-226

06:12:17
42.5° N., 127.0° W.
Off coast of Oregon
Magnitude 5-5.25 (Brk).

October 27, 1959

M	Z	eP?	07:01:48.3 c
O	Z	eP?	48.4 c
D	Z	eP?	48.8 c
U	PEZ	eP?	58.0 c
U	PEZ	iS	07:09:04
U	PEZ	iR	07:15:36
U	PEN	iG?	07:12:49
U	Z	eP	07:01:43.5 d
Hi	Z	eP	07:01:55.8 c

MSI-226

06:52:50
45.5° N., 151.0° E.
Kurile Islands
h about 100 km
Magnitude 6.5.

October 29, 1959

M	Z	iP	14:29:07.8 d
M	Z	ipP	23.7 d
O	Z	iP	07.4 d
O	Z	ipP	23.7 d
D	Z	eP	06.5? d
N	Z	iP	07.5 d
N	Z	ipP	23.7 d
U	Z	iP	04.3 c
U	Z	ipP	23 c
U	PEZ	eR?	14:43:41
U	PEN	eS	14:36:45
U	PEN	eR	14:43:49
Hi	Z	iP	14:29:09.9 c

MSI-226

14:19:51
29.5° S., 176.5° W.
Kermadec Islands
Felt on Raoul
h about 60 km
Magnitude 5.75 (Brk).

October 29, 1959

M	Z	iP	14:40:15.1 c
O	Z	iP	15.7 c
D	Z	iP	15.4 c
N	Z	iP	15.2 c
U	Z	iP	14:40:15.3 c
Ha	Z	iP	14:41:06.3 c
Hi	Z	iP	14:40:15.4 c

MSI-226

14:30:24
43° N., 131.0° E.
China-Korea border
h about 550 km
Magnitude 6.25.

October 30, 1959

M	Z	iP	07:12:21.2 c
O	Z	eP	20.2 d
N	Z	iP	19.8 c
U	Z	eP	20.6 c
Hi	Z	iP	23.2 d

Table 5.--Distant earthquakes--Continued

October 30, 1959--Continued

MSI-226

07:04:48
19° S., 177.5° W.
Fiji Islands
h about 450 km.

October 31, 1959

M	Z	iP	04:34:28.7 c
O	Z	iP	28.0 c
D	Z	iP	28.0 c?
N	Z	iP	27.7 c
U	Z	iP	28.3 c
Ha	Z	iP	33.6 d
Hi	Z	iP	32.0 d

MSI-226

04:27:12
16.5° S., 178.0° W.
Fiji Islands (Felt at Apia)
h about 450 km
Magnitude 6.5-6.75.

November 2, 1959

M	Z	iP	20:13:26.6 d
O	Z	iP	26.6 d
D	Z	iP	26.2 d
N	Z	iP	27.0 d
U	Z	iP	27.0 d
U	PEZ--Records lost----------		
U	PEE--Records lost----------		
U	PEN--Records lost----------		

MSI-227

20:03:32
5.5° S., 151.5° E.
New Britain, felt at Pomio, Karlai, Rabaul, and Walindi.
h about 60 km
Magnitude 6.75.

November 5, 1959

M	Z	eP	11:59:04.5 c
O	Z	eP	03.4 c
D	Z	eP	03.6 c
N	Z	eP	04.6 c
U	Z	eP	05.9 c
U	PEZ	eS?	12:05:57
U	PEZ	eR?	12:45
U	PEN	eS?	10:52
U	PEN	eR?	12:19
Ha	Z	iP?	11:59:07 c
Hi	Z	eP	11:59:24.0 c

MSI-227

11:50:17
13.0° S., 166.5° E.
New Hebrides Islands
h about 100 km.

November 8, 1959

M	Z	iP	14:04:54.1 d
O	Z	iP	55.1 d
D	Z	iP	54.8 d
N	Z	iP?	52.6? ?
U	Z	iP	54.8 d
U	SpZ	iP	55.1 d
U	PEZ	iP	55.2 d
U	PEZ	eS?	14:12:59.2
U	PEN	eS?	14:13:01.2
Hi	Z	iP	14:04:55.0 c
Ha	Z	iP	14:04:44.8 d

MSI-227

13:54:55
44.0° N., 140.5° E.
Near west coast of Hokkaido, felt.
Magnitude 6.5.

November 17, 1959

Ha Z T-phase at 02:43±

Not recorded on other instruments. Unable to locate in MSI-227 or in table 2, United States Earthquakes, 1959.

Table 5.--Distant earthquakes--Continued

November 19, 1959

M	Z	iP	11:19:00.9	d
D	Z	iP	00.0	d
U	SpZ	eP	18:58.7	d
U	PEZ	eP?	18:59	?
U	PEN	iS	11:27:23	N
U	PEN	i?	11:34:33	S
U	PEE	iS	11:27:27	W
U	PEE	e?	11:34:35	E
Ha	Z	iP	11:18:59	d

MSI-227

11:08:41
5.5° S., 146.0° E.
Near north coast of New Guinea.
Slight damage at Lae and Madang.
h about 100 km
Magnitude 7.

November 20, 1959

Ha	Z	Tmax	00:35±

MSI-227

23:53:49
42.5° N., 126.5° W.
Off coast of Oregon
Not on other records.

November 22, 1959

M	Z	eP?	12:58:55.7	d
Hi	Z	eP	12:58:58.0	c

(not seen on other records)

MSI-227

12:47:56
3.0° S., 140.0° E.
Near north coast of New Guinea.

November 22, 1959

U	PEN	17:00±
U	PEE	17:00±

(Rayleigh (only) from due south)

MSI-227

16:26:34
54° S., 136° W.
South Pacific Ocean.

November 27, 1959

U	PEN, PEE	00:00±

(Rayleigh (only) from west)

MSI-227

23:09:23 (Nov. 26)
5.5° S., 103.0° E.
Near coast of Sumatra.
Magnitude 6.75.

December 2, 1959

M	Z	iP	09:46:29.9	c
O	Z	eP	30.0	c
D	Z	iP	29.2	c
N	Z	iP	29.6	c
U	Z	iP	31.0	c
U	PEZ	eP	31	c
U	PEZ	eR	10:12:11	
U	PEN	eS	09:56:31	N
U	PEN	iG	10:08:11	N

MSI-228

09:34:00
1° S., 123° E.
Celebes
Magnitude 6.5-6.75.

Table 5.--Distant earthquakes--Continued

December 5, 1959

Ha	Z	T-phase	08:55-08:56

MSI-228

08:13:36
40.5° N., 126.0° W.
Off coast of northern California.
Felt in Humbolt County.
Magnitude 5 (Brk).

December 14, 1959

M	Z	ipP	18:10:18.9 c
O	Z	ipP	16.2 c
D	Z	ipP	18.7 c
U	Z	ipP	19.0 c
Ha	Z	iP	14.1 c

MSI-228

17:58:33
5.5° N., 125.5° E.
Near south coast of Mindanao,
Philippine Islands.
Felt at Davao, General Santos
and Hinazuan.
h about 200 km.

December 14, 1959

U	PEZ	iS	22:13:10
U	PEZ	eR	22:16:10
U	PEZ	iQ	22:19:04
U	PEN	iR	22:16:00

(Short-period records do not show P, or it is lost in eruption tremor.)

MSI-228

22:00:50
52.5° N., 168.0° W.
Fox Islands
Magnitude 6.

December 14, 1959

Ha	Z	iP?	23:41:07.3 c
Ha	Z	ipP	13.7 d
M	Z	iP	23:41:06.2 c
M	Z	ipP	10.4 d
U	PEZ	i?	23:42:52
U	PEE	obscured by tilt drift.	

MSI-228

23:21:56
59.5° S., 31.0° W.
Sandwich Islands
Magnitude 7.

December 22, 1959

M	Z	T-phase	03:20-03:22
O	Z	T-phase	03:20-03:22
N	Z	lost in tremor	
U	Z	T-phase	03:20-03:22
Ha	Z	T-phase	03:19-03:21

MSI-228

02:39:02
40.5° N., 124.0° W.
California (felt in Humbolt Co.)
Magnitude 4.5° (Brk).

December 24, 1959

M	Z	i?	13:20:26.1 d
O	Z	eP?	26.2 c
D	Z	e?	28.3 d

MSI-228

13:08:34
9° N., 126.5° E.
Near north coast of Mindanao,
Philippines.

Table 5.--Distant earthquakes--Continued

December 27, 1959

M	Z	iP?	16:01:41.2 c
O	Z	iP?	42.0 c
D	Z	i?	40.7 c
U	Z	i?	47.5 d
U	PEZ	iP?	01-37 d
U	PEZ	i?	03-20
U	PEZ	iS?	08-39
U	PEZ	iR?	14-49
U	PEN	iS	08-20
U	PEE	iS	08-31
Ha	Z	T-phase	16:51-16:53

MSI-228

15:52:55
56° N., 162.5° E.
Near east coast of Kamchatka
Magnitude 6.75-7.

December 28, 1959

M	Z	iP	07:29:12.0 c
O	Z	eP	12.3 c
D	Z	iP?	14.3 c
N	Z	eP	12.3 c
U	Z	eP	13.2 d
U	PEZ	iS?	36:14
U	PEZ	iR	42:07
U	PEN	eS	36:05

MSI-228

07:20:32
52.5° N., 160° E.
Near southeast coast of Kamchatka
Magnitude 6.5.

12/7/66

[redacted]

I am sending you the last of the "chapters" in the Table of Contents, Summary 16. It is probably not vital to the period under discussion; a better place would be Summary 17 during which quarter several stations were improved. Also that would be a good time for the introduction of the enclosed table comparing SW rift seismicity with that on the east rift as represented on the L-O vs. the HVO-1.

The tables I have sent you provide the material for a final chapter of the Summary of Activities, that is: ~~Post~~-eruption events. That brief account could contain the SW vs. east data, tilting and deformation after 13 November, and significant quakes in Hawaii after 14 Nov. 1959.

I hope you have the time and interest to help finalize Summary 16. Its printing and distribution will certainly expedite completion of 17 and the rest of the back-log.

harold

H.

If you are missing any of the proposed text, tables or illustrations of #16, please let Ellen. Ticil is typing mats for Tables 4 & 5 (There are no modern MS. on hand

Pahoa (East Rift)

SW Rift	L-O	Z	
0	0	—	12/20/59
3	0	—	12/21
1	2	—	12/22
5	2	—	12/23
6	0	—	12/24
22	2	—	12/25
25	9	—	12/26
15	30	—	12/27
25	40	—	12/28
25	45	—	12/29
40	12	—	12/30
35	22	—	12/31
	15	—	1/1/60
	15	44	1/2/60
	8	57	1/3/60
	11	35	1/4/60
	10	38	1/5/60
	23	50	1/6/60
	5	25	1/7/60
	55	83	1/8/60
	50	108	1/9/60

Jerry --- the above is an abstract from the notes of 4th. quarter 1959, plus some data ~~you had listed for the first 9 days of~~ 1960. What you wanted to do was to compare L-O with the Pahoa HVO-1. I want to add the southwest rift ~~dimension so as to show that~~ (up to a point in time) both the east ~~and the~~ southwest rifts of Kilauea were equally seismic. In fact, southwest had more activity on some days. For the purpose of my hypothesis I am lumping all local events on Desert as southwest rifters; this is despite the strong probability that some of them are Kaoiki. I could use the table above and stop with 12/31; or I could refrain from mentioning it and let you make the complete analysis in Summary 17. Please advise. To fill in the blanks above, simply look up the daily HVO sheets and use the Desert totals labelled SW or Kaoiki Fault.

This looks OK, Harold. If you'd begin at 12/31 you should be even. [illegible] numbers [illegible] quiet

harold

"Official" starting & finishing times of the 1959 Kilauea Iki eruption

1)	11-14-59	8:08 pm	2008	9)	12-13-59	5:08 am	
	11-21-59	7:25 pm	1925		12-13-59	1:40 pm	8 1/2
2)	11-26-59	1:00 am	15	10)	12-14-59	7:05 am	
	11-26-59	4:35 pm			12-14-59	10:40am*/	8 1/2
					12-14-59	3:36 pm	
3)	11-28-59	4:45 pm	3/				
	11-29-59	9:47 pm		11)	12-15-59	6:11 am	5
					12-15-59	10:25 am	
4)	12-4-59	1:00 am					
	12-5-59	9:27 am	32 1/2	12)	12-15-59	7:30 pm	2
					12-15-59	9:25 pm	
5)	12-6-59	2:48 pm					
	12-7-59	12:23 am	11 1/2	13)	12-16-59	1:35 pm	
					12-16-59	5:19 pm	3 1/2
6)	12-7-59	3:30 pm					
	12-8-59	2:45 am	11 1/2	14)	12-17-59	2:15 am	
					12-17-59	4:02 am	2
7)	12-8-59	1:00 pm					
	12-8-59	3:55 pm*/		15)	12-17-59	11:10 am	
	12-8-59	8:12 pm	7		12-17-59	1:50 pm*/	4 1/2
					12-17-59	3:32 pm	
8)	12-10-59	3:15 pm					
	12-11-59	2:30 am*/	31 1/2	16)	12-19-59	3:01 am	3
	12-11-59	10:48 pm			12-19-59	6:16 am	
			7 1/4				

*/ Beginning of discernible lava output.

Volumetric Progress of 1959 Kilauea eruption in Kilauea Iki

Date	Time	Duration (Hours)	Depth of lake (Feet)	Elevation of lake (Feet)	Area of lake (Acres)	Vol. increase or decrease ($Yds^3 \times 10^6$)	Total volume ($Yds^3 \times 10^6$)	Rate ($\frac{Yds^3}{Hour} \times 10^3$)
				1st phase				
Nov. 14	8:08 p.m.	0	0	3130	37	--	0	0
15	6:00 p.m.	22	15	3145	39	0.9	0.9	40
16	12:15 p.m.	18¼	25	3155	40	0.6	1.5	35
16	2:00 p.m.	1-3/4	27	3157	40½	0.1	1.6	60
17	10:45 a.m.	20-3/4	55	3185	45	1.9	3.5	90
17	2:00 p.m.	3¼	60	3190	46½	0.4	3.9	125
17	8:30 p.m.	6½	72	3202	48	0.9	4.8	140
18	12:00 noon	15½	112	3242	56	3.3	8.1	210
18	11:15 p.m.	11¼	150	3280	66	3.7	11.8	330
19	11:50 a.m.	12½	190	3320	78	4.6	16.4	370
19	9:15 p.m.	9½	225	3355	88	4.7	21.1	495
20	12:10 p.m.	15	270	3400	106	7.0	28.1	465
21	9:30 a.m.	21¼	320	3450	120	9.1	37.2	425
21	7:25 p.m.	10	335	3465	125	2.9	40.1	290

23	10:00 a.m.	38½ (1)	328	3458	123	-1.4	38.7	-35
				2nd phase				
26	1:00 a.m. to 4:35 p.m.	15½	351	3481	130	4.7	43.4	300
26	7:40 p.m.	10 ?	341	3471	127	-2.0	41.4	-200
27	12:30 p.m.	17	321 (2)	3451 (2)	121	-3.9	37.5	-230
				3rd phase				
28 to 29	4:45 p.m. to 3:00 p.m.	22	331	3461	124	2.0	39.5	90
29	9:47 p.m.	6-3/4	341	3471	126	2.0	41.5	300
Dec. 1	3:00 p.m.	41¼	329 (3)	3459 (3)	123	-2.4	39.1	-60
				4th phase				
4	1:00 a.m. to 11:25 p.m.	22½ (4)	375	3505	138	9.7	48.8	430
5	3:30 a.m.	4	385	3515	142	2.2	51.0	550
5	6:30 a.m.	3	395	3525	145	2.3	53.3	770
5	7:30 a.m.	1	387 (5)	3517 (5)	142	-1.9	51.4	-1900
5	9:27 a.m.	2	394	3524	145	1.6	53.0	800

5	11:55 a.m.	2½	379	3509	140	-3.3[6] 14.4	49.7[6]	-1320
5	12:30 p.m.	½	374	3504	137	-1.1 15.5	48.6	-2200
6	2:48 p.m.	26	361	3491	134	-2.7 18.2	45.9	-104
				5th phase				
6	2:48 p.m. to 11:00 p.m.	8	400	3530	147	8.6	54.5	1080
7	12:23 a.m.	1½	403	3533	148	0.7	55.2	470
7	3:30 p.m.	13	375	3505	138	-6.2 24.4	49.0	-480
				6th phase				
7 to 8	3:30 p.m. to 2:45 a.m.	11¼	413	3543	152	8.6	57.6	760
8	3:15 a.m.	½	411	3541	151	-0.5 24.9	57.1	-1000
8	12:00 noon	8½	389	3519	143	-4.9 29.8	52.2	-580
				7th phase				
8	1:00 p.m.[7] to 8:12 p.m.	7¼[7]	411	3541	151	4.9	57.1	1150
9	10:45 a.m.	14½	390	3520	143	-4.7 34.5	52.4	-320
10	3:15 p.m.	28½	378	3508	139	-2.6 37.1	49.8	-91

8th phase

10 3:15 p.m. to 11 10:48 a.m.	19½[8]	414	3544	153	8.1		57.9	980
11 11:30 a.m.	3/4	409	3539	150	-1.2	38.3	56.7	-1600
11 12:00 noon	1/2	407	3537	150	-0.5	38.8	56.2	-1000
12 10:00 a.m.	22	382	3512	141	-5.5	44.3	50.7	-250
13 7:20 a.m.	21½	379	3509	140	-.6	44.9	50.1	-28

9th phase

13 5:08 a.m. to 13 1:40 p.m.	8½	413	3543	152	7.5		57.6	880
13 3:45 p.m.	2	395	3525	145	-4.1	49.0	53.5	-2050
14 10:00 a.m.	18¼	369	3499	136	-5.0	54.0	48.5	-270

10th phase

14 7:05 a.m.[9] to 14 3:36 p.m.	8½[9]	409	3539	150	8.3		56.8	1380
14 4:05 p.m.	1/2	406	3536	149	-0.6[10]	54.6	56.2[10]	-3000
15 8:00 a.m.	16	379	3509	140	-5.8	60.4	50.4	-360

11th phase

15	6:11 a.m. to 8:00 a.m.	1-3/4	388	3518	143	1.7		52.1	970
15	10:25 a.m.	2½	405	3535	149	3.5		55.6	1400
15	11:15 a.m.	3/4	400	3530	147	-1.1	61.5	54.5	-1500
15	8:30 p.m.	9¼	382	3512	141	-3.4	64.9	51.1	-370

12th phase

15	7:30 p.m. to 8:30 p.m.	1	387	3517	142	1.0		52.1	1000
15	9:25 p.m.	1	396	3526	146	1.9		54.0	1900
16	10:15 a.m.	13	376	3506	138	-4.1	69.0	49.9	-315

13th phase

16	1:35 p.m. to 4:25 p.m.	3	392	3522	144	3.3		53.2	1100
16	4:50 p.m.	½	394	3524	143	0.5		53.7	1000
16	5:19 p.m.	½	396	3526	146	0.4		54.1	800
17	2:45 a.m. 12:45?	7½	381	3511	140	-3.2	72.2	50.9	-430

14th phase

17	2:15 a.m. to 4:02 a.m. 17	1-3/4	393(11)	3523	144	2.4		53.3	1350
17	11:00 a.m.	7	387	3517	142	-1.3	73.5	52.0	-190

15th phase

17	11:10 a.m. to 3:32 p.m.	4¼	398	3528	146	2.2		54.2	1250
17	6:00 p.m.	2½	395	3525	145	-0.6	74.1	53.6	-240
18	3:00 p.m.	21	378	3508	139	-3.6	77.7	50.0	-170

16th phase

19	3:01 a.m. to 6:16 a.m. 19	3¼	403	3533	148	5.4		55.4	1600
19	11:15 a.m.	5	392	3522	144	-2.2	79.9	53.2	-480
20	1:00 p.m.	25-3/4	382	3512	141	-2.1	82.0	51.1	-82
			367	3497	136	-3.0	85.0	48.1	

3130

367.

51.1 at 382

48.5 at 369

2.6

3

13

2.6

48
87
135

Footnotes:

(1) This subsidence probably occurred largely during the first few hours of the period.

(2) These figures are approximate. Total subsidence of east pond was 25-30 feet; smaller west pond subsided 35-45 feet.

(3) These figures are approximate. Subsidence of east pond was approximately 7 feet; smaller west pond subsided irregularly between 15-30 feet.

(4) Strong lava extrusion only during last half of this period.

(5) Visual estimate of subsidence in pond during eruption.

(6) Volume figures from end of 4th phase through the 16th phase, have taken into consideration the volume of the "Black Ledge".

(7) No appreciable lava output until 3:55 p.m., December 8, 1959.

(8) No appreciable lava output until 2:30 a.m., December 11, 1959.

(9) No appreciable lava output until 10:40 a.m., December 14, 1959.

(10) From 10th phase through 16th phase no appreciable lava flowed over small west pond.

(11) Estimated. Lava level never rose above "Black Ledge."

(12) No appreciable lava output until 1:50 p.m., December 17, 1959.

Table B: Eruption Statistics Compiled from Several National Park Information Releases

1959 Eruption Statistics (as of January 1, 1960)

Kilauea Iki Crater, the site of the 1959 eruption, is at the head of the SE rift zone of Kilauea Volcano and is less than a mile from the Kilauea summit crater. When this eruption began, lava fountains played along the rift outbreak about 1/2 mile long on the south wall of Kilauea Iki. Within 24 hours the activity was restricted to a single fountain playing at the west end of the crater. All further activity centered around this fountain. After each phase of the eruption the lake level lowered, as the crust cooled and as lava poured back into the vent.

Phase	Starting hour (HST)	Date	Finishing hour	Duration (hours)	Maximum Fountain Height (feet)	Maximum Lake Depth (feet)	Minimum Lake Depth (after this phase) (feet)
1	20:08	Nov. 14-21	19:25	168	1,250	335	328
2	01:00	Nov. 26	16:35	15-1/2	1,000	351	321
3	16:45	Nov. 28-29	21:47	29	1,700	341	329
4	01:00	Dec. 4-5	09:27	32-1/2	650	395	361
5	14:48	Dec. 6-7	12:23	9-1/2	1,250	403	375
6	15:20	Dec. 7-8	02:45	11-1/4	800	413	389
7	13:00	Dec. 8	20:12	7-1/4	1,400	411	378
8	15:15	Dec. 10-11	10:48	19-1/2	1,100	414	379
9	05:08	Dec. 13	13:40	8-1/2	800	413	369
10	07:05	Dec. 14	15:36	8-1/2	1,100	409	379
11	06:11	Dec. 15	10:25	4-1/4	1,200	405	382
12	19:30	Dec. 15	21:25	2	1,100	396	376
13	13:35	Dec. 16	17:19	3-3/4	1,150	396	381
14	14:15	Dec. 17	04:02	1-3/4	1,150	393	387
15	11:10	Dec. 17	15:32	4-1/4	1,900*	398	378
16	03:01	Dec. 19	06:16	3-1/4	1,500	403	382

* Highest measured in Hawaii.

Original to Jerry
Carbon to Chester

April 12, 1961

FOR USE IN SUMMARY 15 or 16

1956 Volcanic and Seismological Conditions, HVO summaries 1,2,3, and 4, 5 pages each. U.S. Geological Survey

1957 Volcanic and Seismological Conditions, HVO Summaries 5, 6, 7, and 8. 5 pages each. U.S. Geological Survey

Theory of the Electromagnetic Seismograph, J.P. Eaton, S.S.A. Bull., vol. 47, p. 37-75, Jan. 1957

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November 1959 - Monthly Report

An eruption of Kilauea volcano started Saturday night, Nov. 14, in Kilauea Iki, a pit crater immediately adjacent to the summit caldera. After first breaking out on a wide front, the lava is now issuing from a single large vent in a fiery fountain 700 feet high. It is an awesome sight, especially at night. We are so occupied that we must beg off giving a detailed account at this time.

original sent to Ed Roedder
for his files + JT Pecora
12/7/60

9-1225 (Mar 1958)	Dept of Interior - Geological Survey Geochemistry & Petrology Branch PROJECT MONTHLY REPORT	For the period: From Sept. 21, 1959 To Oct. 17, 1959

Project Number and Title	Project Leader
910501 Hawaiian Volcano Observatory	K. J. Murata

REPORT WHEN APPROPRIATE ON THE FOLLOWING TOPICS:

I. Referred samples completed and on hand at the end of the month.
II. Manuscripts reviewed, memorandum and progress reports written, and status of manuscripts in active preparation.
III. Technical progress of project, significant results, problems encountered.
IV. Trips, visitors, conferences and committee tasks.

II, III.

Kilauea continues to show much subsurface activity. It apparently has reversed its trend of the past two months and seems to be bulging upward again. Much manpower (Eaton, Krivoy, Loucks, Forbes, Richter, and Francis) is being devoted to obtaining additional tiltmeter data needed to evaluate the new trend. Small, shallow earthquakes are also being recorded at a rate of several hundred per day at a single station on the edge of Halemaumau pit. The meaning of these highly localized earthquakes is, at present, conjectural. Eaton, Krivoy, and Yamamoto made a ground-microphone survey all around Halemaumau in an attempt to detect any sound from the shallow disturbances but found none.

Richter and Murata prepared illustrations and continued writing the paper entitled "Kinetics of eruption and composition of basaltic lavas".

Wentworth is organizing the Observatory file of photographs and incorporating into it the collection left to the Observatory by the late Harry O. Wood.

Ault and Kojima are studying the effects of amplifier stability, scanning rate, and sample pressure control on the sensitivity of the mass spectrometer. Using liquid air delivered from Honolulu, they have also started concentrating the minor constituents of the gas samples by freezing out the major constituents.

Okamura continued separating and analyzing olivines from Mauna Kea basalts.

IV. Visitors

G. Boudette) G. Taylor)	U.S.G.S. Enroute to Antarctica	Field examination of Hawaiian basalts
Rear Admiral F. D. Foley, USN, Honolulu) H. Sugiyama, Statistician, Osaka University) L. Bjerrum, Norwegian Geotechnical Institute)		General visit of Observatory

9-1225 (Mar 1958)	Dept of Interior - Geological Survey Geochemistry & Petrology Branch PROJECT MONTHLY REPORT	For the period: From Nov 17, 1959 To Dec 18, 1959

Project Number and Title	Project Leader
910501 Hawaiian Volcano Observatory	K. J. Murata

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II, III

The eruption at Kilauea Iki has developed a periodicity heretofore not recorded for Hawaiian volcanoes. The initial week-long phase deposited about 40 million cubic yards of lava in the pit crater. The pond of lava rose high enough to encroach upon the vent, situated half way up the side of the crater. In succeeding eruptions, when the lava fountain (max. height 1,900 ft) quit about 8 million cubic yards of the fresh lava poured back down the vent. This cycle of eruption and withdrawal of lava has happened 14 times to date.

Eaton and Krivoy by seismic prospecting have located the probable shallow magma chamber involved in this peculiar geyser-like activity. They took advantage of a prolonged series of deep earthquakes to outline an area in the summit region of Kilauea in which the deep quakes were detected very poorly or not at all.

Richter and Wentworth have been keeping track of volumes of lava discharged. Richter and Eaton are preparing a preliminary account of the eruption for Geotimes.

Ault and Kojima have been collecting and analyzing the gases. SO_2 is so strong in many gas vents that approach is impossible without masks. H_2S cannot be detected. After choking on SO_2 for a while one is convinced that SO_2, not H_2S, is the primary magmatic sulfur gas.

Murata and Okamura have been collecting lavas and determining precent SiO_2. After varying between 46.3 and 49.5 percent in the early stages, silica has more or less stabilized at around 46.8 percent.

9-1225 (Mar 1958)	Dept of Interior - Geological Survey Geochemistry & Petrology Branch PROJECT MONTHLY REPORT	For the period. From December 19, 1959 To January 20, 1960
Project Number and Title		Project Leader
0-910501 Hawaiian Volcano Observatory		K. J. Murata

REPORT WHEN APPROPRIATE ON THE FOLLOWING TOPICS:

I. Referred samples completed and on hand at the end of the month.
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I, III.

After the eruption at the summit stopped on Dec. 19, Kilauea Volcano was relatively quiet for a couple of weeks. Then a rash of earthquakes were recorded in the East rift zone 30 miles down the volcano. Eaton and Krivoy installed a more sensitive seismograph in our Pahoa station and also reconnoitered the district with their portable seismograph. Many earthquakes were recorded by them at a rate of 3 a minute around the village of Kapoho in the rift zone.

On January 13, an old graben at Kapoho sank about 3 feet and Civil Defense called for voluntary evacuation of the village. Many strong quakes jarred us unpleasantly down there all day. At 7:35 that evening a rift 0.7 mile long suddenly opened in the middle of the graben and the typical line of fire fountains heralded the start of the current flank eruption. As to date, the graben has become completely filled with 20 to 50 feet of lava which is now filling out on both sides.

All project members are taking turns going down the mountain to make observation on the eruption. Jerry and Don are making daily flights in a National Guard plane to plot the movements of the lava. Wayne and Kojima are collecting and analyzing the gases while Okamura is determining silica in lava samples that Murata collects daily. The staff armed with the experience of the recent summit eruption is working effectively but the terrible destructiveness of the volcano in this one fertile valley is depressing.

9-1225 (Mar 1958)	Dept of Interior - Geological Survey Geochemistry & Petrology Branch PROJECT MONTHLY REPORT	For the Month: From Feb. 20, 1960 To Mar. 18, 1960
Project Number and Title 0-910501 Hawaiian Volcano Observatory		Project Leader R. T. Minkler

REPORT WHEN APPROPRIATE ON THE FOLLOWING TOPICS:

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II, III. The Kapoho cone stopped erupting on Feb. 19. Another portion of the floor of Halemaumau pit collapsed on March 11. The daily number of earthquakes at both places has dropped to normal levels. The 1959-60 eruption of Kilauea Volcano appears to be over finally.

Eaton and Krivoy were occupied with the continuing swarm of shallow earthquakes that were generated as the summit kept detumescing. There were so many quakes that the daily seismograms could only be given a preliminary scanning and then added to the big backlog awaiting systematic examination and measurement. Eaton kept close tab on the Pahoa seismograph for indications of possible resurgence of activity at Kapoho.

Krivoy finished the field work on the first phase of the gravimetry of Kilauea and returned the gravimeter to the Geophysics Branch. His progress report on this work has been reviewed by Joesting and Pakiser of that Branch.

Richter and Eaton completed a manuscript entitled "The 1959-60 eruption of Kilauea Volcano," for the New Scientist. Richter continued mapping the collapse features in Halemaumau and began a more detailed geologic mapping of the Kapoho area.

Wentworth studied bombs and other ejecta from the Kapoho cone.

Ault and Kojima continued sampling gases from the Kilauea Iki cone, Kapoho cone, and Sulfur Banks. They found widely different CO_2/SO_2 ratios from different localities, viz., Kapoho, 0.6 to 1.8; Sulfur Bank, 100; and Halemaumau, 2000.

Murata and Okamura continued determining silica in lavas and pumice from Kapoho. Murata started writing a paper entitled "Composition of Hawaiian olivines".

IV. Conferences

Chas. Anderson, James Balsley, and James Heroy met with the staff to discuss the program and staffing of the project.

Geo. Kennedy, UCLA, and G. Higgins, U. Calif. conferred with the staff on a project to drill into the molten pond of lava in Kilauea Iki.

E. J. Ellis, DSIR, New Zealand, lectured to staff on the geology and chemistry of geothermal power in New Zealand.

Monthly Report
March 14, 1960

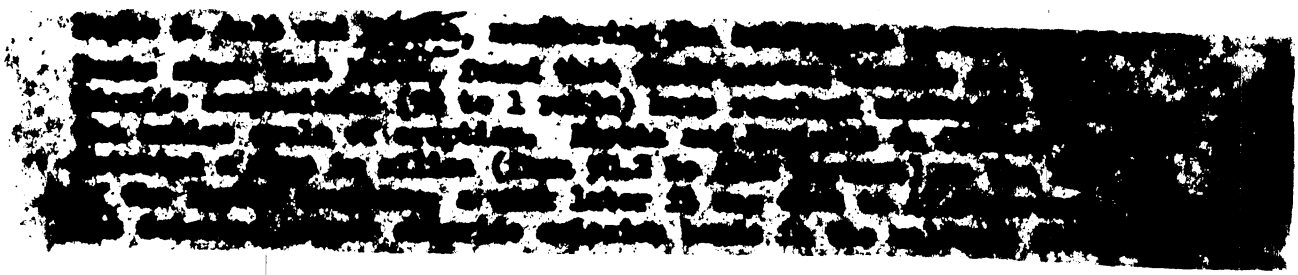
The first discovery of Eocene (=Tertiary b) and Oligocene (=Tertiary c) in the Fiji Islands has been made by W. Storrs Cole from a suite of small collections made by the Fiji Geological Survey in the course of their detailed mapping program. The assemblages of larger foraminifera are closely related to those from Guam, Saipan, and Eniwetok.

Geochemistry and Petrology Branch

Kiguma J. Murata, Scientist in Charge of the Hawaiian Volcano Observatory, reports that volcanic activity at Kilauea has diminished to a relatively feeble eruption at Kapoho, and that further outbursts are less likely. He writes: "The flank eruption of Kilauea within the Kapoho graben poured out over 160 million cubic yards of lava and, as yet, unmeasured amounts of pumice to fill the graben to overflowing and to make about 400 acres of new land around Cape Kumukahi. The villages of Kapoho and Koae were virtually destroyed. Plantations and forests of the region now lie under 10 to 100 feet of lava. All of the barriers erected by Hawaii Civil Defense to stop the flows were overwhelmed and buried. Since February 6, the vent system has stopped erupting lava and is putting out variable amounts of cinder and pumice which are forming a cone over 400 feet high.

"The rapid and voluminous outpouring of lava at Kapoho not only caused the usual deflation of the summit of the Volcano, but led to a sudden collapse of the floor of Halemaumau pit which fell 350 feet on February 7. The sequence starting with the summit eruption (Kilauea Iki), followed by the flank eruption (Kapoho), and finally (we hope) by the collapse at the summit represents a remarkably complete manifestation of the eruptive scheme of the Volcano."

Jerry P. Eaton and Harold L. Krivoy, assisted by Burton J. Loucks, John C. Forbes, William H. Francis, and Akira Yamamoto, worked night and day keeping track of the deflation of the summit seismologically and through tilt measurements. The intense earthquake activity that marked the original inflation of the Volcano reappeared during its deflation. Eaton and Krivoy also temporarily installed the portable seismograph in the Naalehu station in order to get better fixes on the deep earthquakes accompanying the deflation of the summit. Krivoy made extensive series of gravity measurements both in the summit region and around Kapoho. The results for the summit region show a remarkably well defined positive anomaly at the summit. Donald H. Richter bore the brunt of daily observation of the eruption at Kapoho both on the ground and from the air, and kept Civil Defense officials advised about the movements of the lava. He is preparing maps of the Halemaumau collapse and the Kilauea Iki eruption.



9-1225 (Mar 1958)	Dept of Interior - Geological Survey Geochemistry & Petrology Branch PROJECT MONTHLY REPORT	For the period: From Mar. 19, 1960 To April 19, 1960
Project Number and Title 0-910501 Hawaiian Volcano Observatory		Project Leader K. J. Murata

REPORT WHEN APPROPRIATE ON THE FOLLOWING TOPICS:

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Sitting practically in the backyard of the Observatory at Kilauea Iki is the slowly cooling pond of molten lava almost 2,500 ft. in diameter and 365 ft deep. The pond now has a firm crust about 10 ft. thick and can be walked over freely. It is a sort of thing rarely available for study anywhere in the world. We have plans for various geological, geophysical, and geochemical experiments on the pond, and the entire staff was involved in some exploratory work last month. A hole 7 1/2 feet deep was put down into the crust with a small electric drill and a carbide-tipped bit. Temperatures at various depths were as follows: 2 ft-260°C; 4 ft-505°C; 6 ft-675°C; and 7 1/2 ft-760°C; indicating a gradient of about 100°C per foot. The hot rock toward the bottom of the hole tended to yield plastically and had to be chilled with water before the bit would cut into it.

Eaton, Krivoy, Loucks, Forbes, Yamamoto, and Francis made another series of tilt measurements around the net of station. The subsidence of the summit in the vicinity of Halemaumau between Jan. 21 and April 1 attained the astonishing total of 5 ft. Eaton prepared the following documents (1) Critique of lava barriers, (2) Review memo of Survey involvement with barriers during the past decade, and (3) A review article (with Murata) entitled "Watching volcanoes grow" for publication in Science.

Krivoy computed and plotted transient gravity values determined during the eruption and started writing a second progress report on the gravity work. He also started working away on the big backlog of seismograms that has accumulated.

Richter laid out and leveled a baseline across the Kilauea Iki lava pond for orienting the various investigations to be carried out there. He also started organizing the available material for a comprehensive paper on the physical aspects of the 1959-60 Kilauea eruption.

Ault and Kojima experimented with methods of sampling gases which would maintain the relative amounts of the components at equilibrium at the higher temperatures. They discovered the important role of water in the kinetics of the reaction $2H_2S + SO_2 \rightarrow 3/2\ S_2 + 2H_2O$. In a wet sample the reaction proceeds rapidly to completion, but in a dry sample the reactants persist for about a day.