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HAWAIIAN VOLCANO OBSERVATORY

SUMMARY 24

October, November, and December, 1961

By

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Chronological summary

Coincident with the injection of magma into a long section of Kilauea's east rift zone during the brief 1961 eruption (Sept. 21-25), the summit of the volcano subsided rapidly. Although the total subsidence during the 1961 eruption was only about one half as great as that associated with the 1960 flank eruption at Kapoho, the rate of subsidence in 1961 was far greater than in 1960. In contrast to the 1960 subsidence, which continued slowly for months after the eruption, the 1961 collapse terminated with the eruption, and the cycle of inflation at Kilauea which began late in 1960 resumed. Slow swelling of the volcano continued through the rest of the year.

The tilting diagram (fig. 1) showing the 1961 collapse is based on changes between July 23 and October 8, and it obscures the high rates of subsidence that occurred during the brief eruption. A more detailed, qualitative picture of swelling and subsidence at Kilauea is provided by a graph of the daily readings of the short-base liquid-level tiltmeter in Uwekahuna vault (fig. 2), which summarizes the history of tilting at that station from July 1956 to August 1962. For comparison, tilt coordinates and changes from December 1959 to October 1961 at the Uwekahuna field tilt-base are listed in table 3.

During the later stages of the 1960 collapse, a great swarm of shallow earthquakes originated in and around Kilauea caldera. During February and March 1960, about 350 earthquakes were reported felt, and thousands were recorded by the seismographs. No such swarm of earthquakes at the summit of Kilauea accompanied the 1961 collapse, although many earthquakes originated along the rift zone just before and during the eruption. Apparently the collapse in 1961, like the first week of collapse in 1960, did not strain rocks surrounding the shrinking reservoir beyond the elastic limit. The lower pre-eruption level of the Kilauea summit, the smaller total subsidence, and the earlier cessation of subsidence in 1961, as compared to 1960, might also have checked the development of a swarm of collapse earthquakes in 1961.

Feeble shallow earthquakes at Kilauea caldera averaged about 20 per day throughout the quarter. A sequence of earthquakes from Kilauea's southwest rift zone continued through the quarter; daily counts of these earthquakes ranged from 1 to 31 and averaged about 10.

The most important seismic activity of the quarter originated in a zone about 30 km beneath Halemaumau (southwest edge of Kilauea caldera). Earthquakes from this source became prominent when Kilauea

began to reinflate in the fall of 1960, following the 1960 collapse. During the last quarter of 1961 quakes of this family occurred in groups of 40 or 50 over periods of 2 or 3 hours. About 150 of them were large enough for study. Foci of these earthquakes seemed to follow no regular pattern of migration, but they showed a "normal" scatter which indicated a source region that was broader than it was high.

Daily counts of these earthquakes are shown in table 4. Only one earthquake of this group had a magnitude larger than 2.4 during October; but in November there were 34 such earthquakes, and in December there were 17. The largest earthquakes from this deep source occurred on November 21 (magnitude 3.8), November 23 (magnitude 3.8), November 25 (magnitude 3.7), December 2 (magnitude 3.9), and December 31 (magnitude 3.9). Earthquakes of magnitude 2.9 were at the threshold of sensibility, and nearly all larger ones were reported felt. Ten were reported felt during November and 5 during December.

Most of the other earthquakes felt in Hawaii during this quarter originated in Kona. They are listed in table 5.

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 (table 1), 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 (table 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 tilting of 1 micro-radian (1 mm per km) 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 more than 3,000 km from Hawaii. As an index of seismic activity at Hawaiian volcanoes, daily counts of earthquakes and minutes of tremor recorded by seismographs in Hawaii are listed in table 4. The earthquakes are separated into groups on the basis of region of origin as determined by analysis of records obtained daily at the Observatory (U, M, A, D, N). Earthquakes of magnitude 2.5 or

greater are generally sufficiently well recorded to be located with greater precision; they are listed individually in table 5. Data on identifiable phases from distant earthquakes are listed in table 6.

Locations of the seismograph stations are shown on figure 3, and essential data on the stations are given in Summary 21.

Year	1969	1970	1971	1972	1973
1	410	598	412	562	
8	410	607	414	555	
15	411	577	415	554	
22	412	577	415	556	
29	414	584	415	552	
36	408	528	415	534	
43	409	500	418	502	

Table 1.--Tilt coordinates at Uwekahuna vault, October, November, and December, 1961

Date	N-S	E-W	Date	N-S	E-W
Oct. 1	410	588	Nov. 19	412	562
8	410	584	26	414	556
15	411	577	Dec. 3	415	554
22	412	572	10	415	556
29	414	568	17	415	555
Nov. 5	408	569	24	415	554
12	409	566	31	416	552

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

Tilt base (location)	Date (1961)	Tilt coordinates		Rate (10^{-6} rad/mo) and direction of tilting since last reading	Date of last reading (1961)
		N-S	E-W		
Uwekahuna ($19^{\circ}25.5'$ N., $155^{\circ}17.4'$ W.)	Oct. 6	358.9	565.2	54.8 S. 32° E.	Sept. 22
Tree Molds ($19^{\circ}26.3'$ N., $155^{\circ}17.3'$ W.)	7	389.5	528.6	27.8 S. 16° E.	July 25
Sand Spit ($19^{\circ}24.1'$ N., $155^{\circ}16.8'$ W.)	11	839.0	696.2	54.0 S. 15° E.	25
Kalihipaa ($19^{\circ}21.4'$ N., $155^{\circ}15.3'$ W.)	8	580.4	421.3	16.4 N. 20° W.	22
	8	580.3	421.3	34.3 N. 29° W.	Sept. 22
Keamoku ($19^{\circ}25.1'$ N., $155^{\circ}19.0'$ W.)	8	443.2	677.8	49.7 S. 58° E.	July 21
Kamokukolau ($19^{\circ}22.7'$ N., $155^{\circ}16.6'$ W.)	7	769.4	469.4	90.0 N. 18° W.	21
Kipuka Nene ($19^{\circ}19.4'$ N., $155^{\circ}16.7'$ W.)	9	516.3	495.4	3.0 N. 34° W.	24
Hilina Pali ($19^{\circ}18.2'$ N., $155^{\circ}18.6'$ W.)	9	511.0	497.8	2.9 N. 32° W.	23
Mehana ($19^{\circ}26.2'$ N., $155^{\circ}14.3'$ W.)	Nov. 2	524.5	527.6	10.8 S. 47° W.	25
		525.5	530.8	4.5 N. 72° E.	Oct. 10

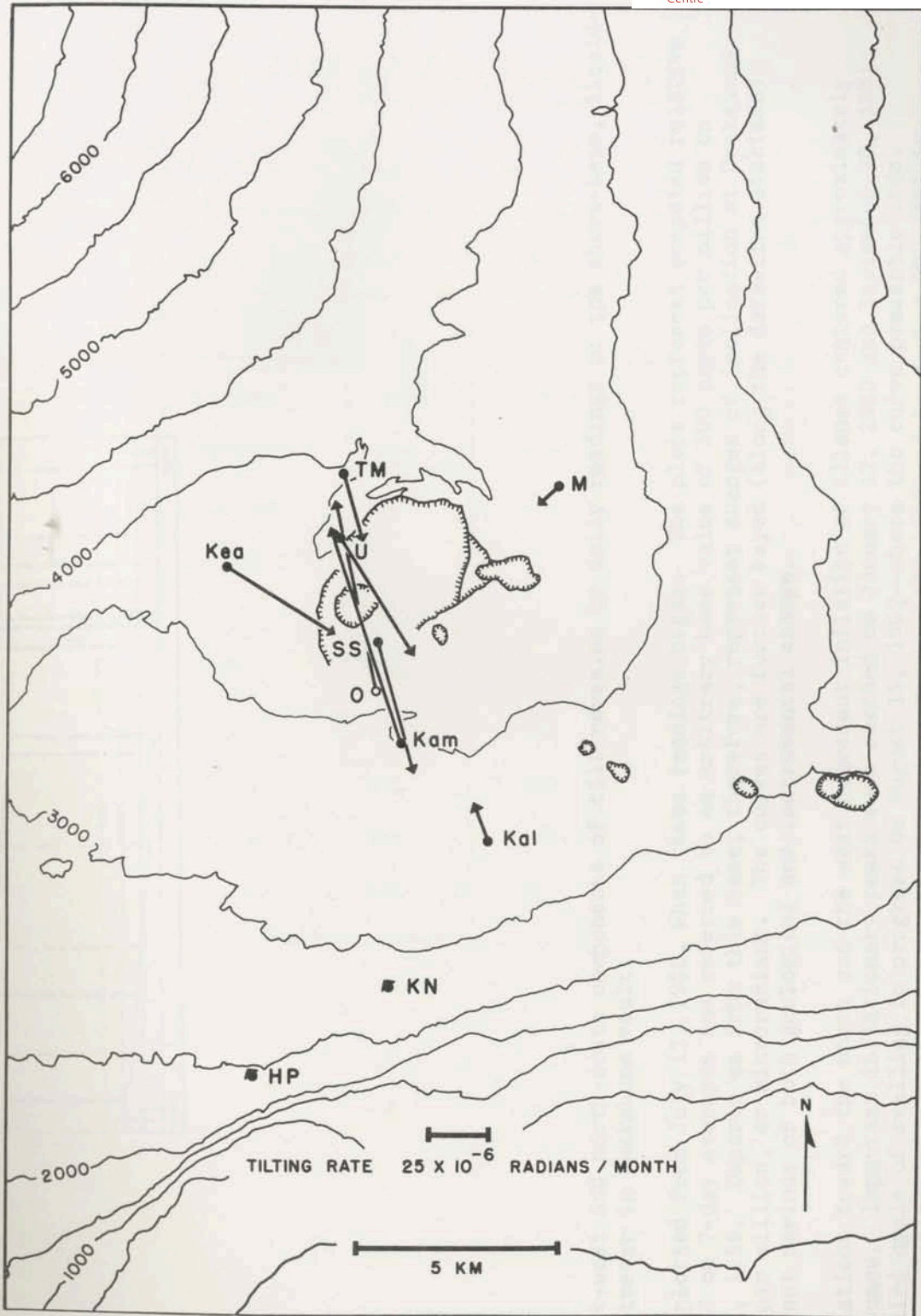


Figure 1.--Tilting of the ground around Kilauea caldera, July 23, 1961, to Oct. 8, 1961. The vector depicting tilting at a given tilt base points in the direction of maximum relative subsidence and has a length proportional to the rate of tilting during the measurement interval. Closed circles represent field tilt bases; open circles, short-base water-tube tiltmeters.

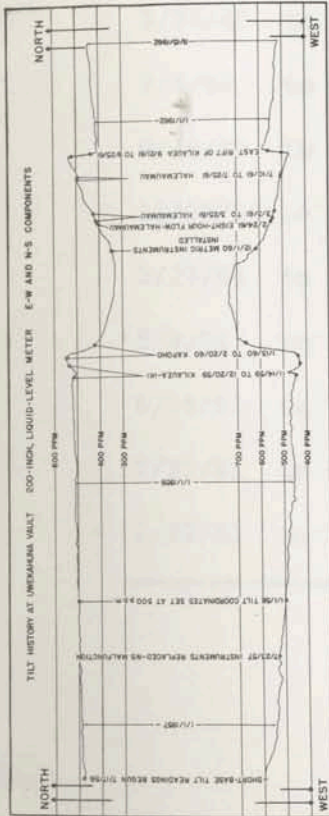


Figure 2.--East-west and north-south components of tilt revealed by daily readings at the short-base, liquid-level tiltmeter in Uwekahuna vault.

Data are plotted from July 17, 1956, when these readings began. The plots represent computed relative tilt based on 7-day averages and referred to an arbitrary base value of 500 parts per million on January 1, 1958. Departures from this base, therefore, represent changes of inclination at Uwekahuna in parts per million, or microradians. The curves are further keyed (along the date-line abscissa) to important periods of both geological and instrumental change.

Tilt variations toward the north and the west represent inflation of Kilauea centered approximately at Halemaumau. Important inflationary peaks were reached on January 12, 1960 and September 20, 1961 with a third cycle of swelling in progress on August 15, 1962--where the curve presently ends. Conversely, deflation such as Kilauea experienced on January 13, 1960 and September 20, 1961 is demonstrated by inclination of this tilt base toward the southeast.

Table 3.--Tilt coordinates and changes at the Uwekahuna field tilt-base from December 1959 to October 1961

[In general, tilting toward the northwest at Uwekahuna indicates swelling of Kilauea and tilting toward the southeast indicates subsidence]

Dates	Tilt coordinates		Rate (u-rad/mo)	Azimuth
	N-S	E-W		
12/28/59 to 3/28/60	518	480	118	S. 34° E.
3/28/60 to 7/5/60	219	679	19	S. 32° E.
7/5/60 to 9/16/60	216	678	1	S. 21° W.
9/16/60 to 11/29/60	283	609	39	N. 46° W.
11/29/60 to 2/23/61	375	548	38	N. 34° W.
2/23/61 to 5/8/61	444	514	31	N. 26° W.
5/8/61 to 6/26/61	468	503	16	N. 25° W.
6/26/61 to 7/22/61	477	492	16	N. 51° W.
7/22/61 to 9/22/61	404	546	44	S. 37° E.
9/22/61 to 10/6/61	360	565	55	S. 32° E.

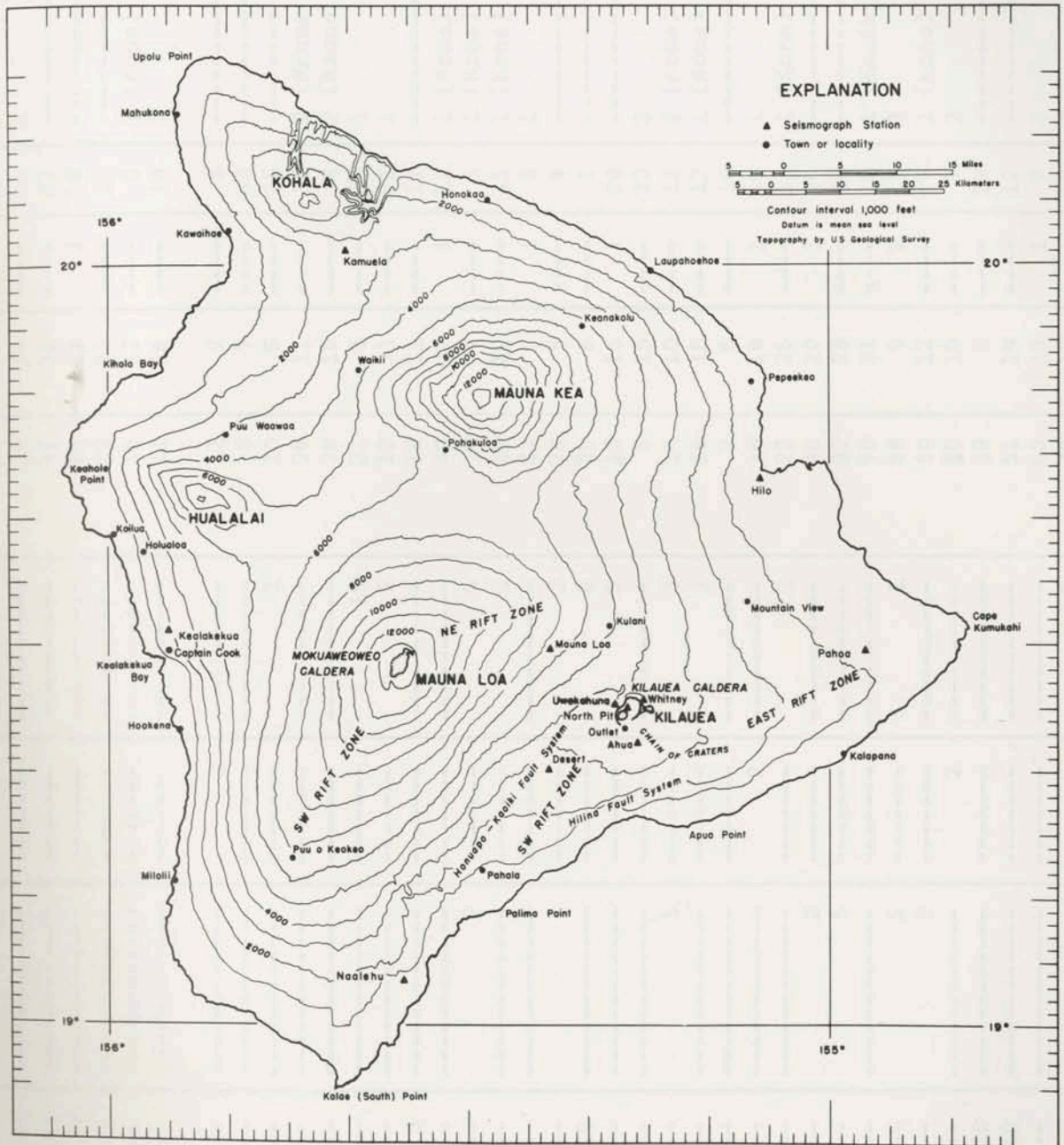


Figure 3.--Map of the island of Hawaii showing seismograph stations operated by the Geological Survey and localities mentioned in the text. Epicenters of local earthquakes are given in terms of geographic coordinates, which are indicated at the edges of the map.

Table 4.--Numbers of earthquakes and minutes of tremor recorded on seismographs around Kilauea caldera (U, M, A, D, and N)

[Tremor is separated into three categories--(1) deep, (2) intermediate, and (3) shallow--on the basis of relative amplitudes on seismographs in the summit region. Unless otherwise stated, tremor is presumed to be associated with movement of magma within the central complex of Kilauea.

Halemaumau rock slides (4) are detected by the characteristic record they produce on the North Pit seismograph.

Earthquake categories are: 5, shallow earthquakes in the Kilauea caldera region;
 6, shallow earthquakes along the SW. rift zone of Kilauea and the adjacent portion of the Kaoiki fault system;
 7, earthquakes along the eastern half of Kilauea's east rift zone;
 8, earthquakes from a source about 30 km beneath Halemaumau (SE. edge of Kilauea caldera);
 9, earthquakes from other regions: Kona, Mauna Kea, etc.]

Date (1961)	Tremor (in minutes)		Halemaumau slides	Kilauea caldera	SW. rift	E. rift	30 km	Others	
	Deep	Intermediate							Shallow
	1	2	3	4	5	6	7	8	9
Oct. 1	---	---	---	3	36	10	1	5	---
2	---	---	---	1	35	14	1	1	1
3	---	---	---	2	18	7	2	2	---
4	---	---	---	1	25	1	---	2	2
5	---	---	3	---	21	19	---	---	---
6	21	---	---	---	22	8	---	1	---
7	33	---	---	---	28	12	---	5	---
8	---	---	---	---	29	11	1	2	---
9	---	---	3	7	53	18	4	1	1
10	4	---	5	16	54	9	1	3	---
11	---	---	12	---	13	13	1	3	---
12	---	---	5	2	9	6	---	1	---
13	32	---	---	2	38	8	---	4	1 (60 km)
14	---	---	---	---	33	8	---	5	---

Table 5.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, October, November, and December, 1961

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

In the following list some origin times are followed only by "KM 30" and a statement of magnitude. These are all members of a continuing family of quakes noted in other reports as well. They were especially predominant in this quarter and thus are listed in this abbreviated fashion. The most accurately located mean epicenter for this group is under Halemaumau at a depth of 30 km (19°24.1' N., 155°17.1' W).

Date (1961)	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Oct. 1	22	10	25.0	2.5	19°15.5'	155°30.3'	6 km NNW. of Pahala-----	At shallow depth.
2	00	17	46.5	2.3	19°18.8'	155°05.0'	45 km S. of Hilo, E. rift zone of Kilauea.	3 km deep.
4	06	01	25.7	2.3	19°22.7'	155°19.8'	6 km W. of Ahua seismo-meter.	25 km deep.
5	02	25	37.5	3.3	19°29.8'	155°43.5'	20 km ESE. of Kealakekua-	3 km deep.
6	12	46	22.5	2.7	19°09.1'	155°26.7'	6 km SE. of Pahala, SW. rift zone of Kilauea.	8 km deep.
15	19	05	22.3	2.5	19°37.1'	155°16.2'	22 km SW. of Hilo-----	55 km deep.
18	08	34	29.5	2.6	19°47.7'	155°39.8'	7.5 km S. of Waikii-----	8 km deep.
18	17	15	32.5	2.6	19°46.4'	155°49.9'	Beneath Puu Waawaa. Felt in N. Kona and Kamuela.	At shallow depth.

Table 5.--Local earthquakes recorded by seismographs of the U.S. Geological Survey,
 October, November, and December, 1961--Continued

Date (1961)	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Oct. 22	09	49	45.5	2.8	19°11.7'	155°35.3'	14 km N. of Naalehu----- KM 30.	3 km deep.
23	05	04	49.0	2.6				
29	07	25	21.0	2.2	19°29.2'	155°51.2'	10 km SE. of Kealakekua. Felt near Kealakekua.	At shallow depth.
29	11	39	09.7	2.5	19°43.2'	155°13.6'	15 km W. of Hilo-----	30 km deep.
Nov. 3	09	13	14.5	2.6	19°53.0'	155°34.9'	18 km SE. of Kamuela-----	At shallow depth.
4	06	24	29.0	3.0	19°22.1'	155°29.4'	18 km NNW. of Pahala-----	8 km deep.
5	06	56	27.0	3.0	19°47.2'	155°34.8'	11 km SE. of Waikii. Felt near Puu Waawaa.	12.5 km deep.
5	07	20	52.3	2.5			KM 30.	
5	14	14	37.5	2.6	19°21.5'	155°32.4'	20 km NW. of Pahala-----	12.5 km deep.
8	11	51	00.5	2.4	19°26.5'	155°18.5'	11 km SE. of Mauna Loa seismometer.	Do.
10	05	38	17.4	3.4	19°25.8'	155°18.8'	11 km SE. of Mauna Loa seismometer. Felt in Hilo and Kilauea caldera region.	Do.

Table 5.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, October, November, and December, 1961--Continued

Date (1961)	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Nov. 12	15	45	22.0	2.7	19°20.5'	155°09.8'	29 km SW. of Pahoa, E. rift zone of Kilauea.	3 km deep.
14	04	51	27.0	3.3	19°25.4'	155°55.3'	11 km S. of Kealakekua. Felt in Honaunau.	Do.
16	06	17	12.4	2.5			KM 30.	
16	15	10	16.1	2.6			KM 30.	
16	16	50	41.9	2.7			KM 30.	
16	19	03	51.2	2.5	19°12.9'	155°21.2'	30 km NE. of Naalehu-----	35 km deep.
17	17	48	47.0	2.4			KM 30.	
17	19	33	26.0	2.5			KM 30.	
17	19	56	49.5	3.0	19°44.3'	155°57.6'	25 km NNW. of Kealakekua. Felt near Puu Waawaa.	At shallow depth.
17	23	22	37.4	2.8			KM 30.	
18	03	44	00.5	2.5			KM 30.	
18	08	09	14.5	3.0	19°26.3'	155°54.7'	9 km S. of Kealakekua. Felt throughout Kona.	At shallow depth.
18	09	41	01.5	2.7			KM 30.	

Table 5.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, October, November, and December, 1961--Continued

Date (1961)	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Nov. 20	01	40	24.0	2.9			KM 30.	
20	03	14	07.1	2.6	19°21.7'	155°06.4'	8 km E. of Makaopuhi Crater, E. rift zone of Kilauea.	5 km deep.
20	19	40	27.2	2.5			KM 30.	
21	00	41	25.5	2.9			KM 30. Felt on E. rim of Kilauea caldera.	
21	02	42	56.9	2.4			KM 30.	
21	23	22	39.3	3.8			KM 30. Felt in Hilo, Kilauea caldera region, and N. Kona.	
21	23	25	56.8	2.4			KM 30.	
21	23	27	05.4	2.6			KM 30.	
21	23	46	01.9	3.0			KM 30. Felt on E. rim of Kilauea caldera.	
21	23	48	18.9	3.0			KM 30.	
22	00	09	20.7	2.7			KM 30.	
22	03	27	35.5	2.9			KM 30.	

Table 5.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, October, November, and December, 1961--Continued

Date (1961)	Time			Magnitude	Epicenter		Remarks
	h	m	s		Lat. N.	Long. W.	
Nov. 22	05	44	48.1	3.1			KM 30.
22	10	55	55.5	3.2			KM 30. Felt on N. rim of Kilauea caldera.
22	16	32	41.8	2.6			KM 30.
23	06	39	41.2	2.4			KM 30.
23	07	24	54.5	2.7			KM 30.
23	16	29	36.6	3.0			KM 30. Felt on NE. rim of Kilauea caldera.
23	17	09	55.7	3.3			Do.
23	17	14	30.6	3.8			KM 30. Felt throughout Kilauea caldera region.
23	17	30	41.4	2.5			KM 30.
24	05	35	40.7	2.9			KM 30. Felt on NE. rim of Kilauea caldera.
24	10	31	11.8	2.7	19°18.1'	155°07.7'	17 km SE. of Ahua seismo- meter. 8 km deep.
24	20	46	55.5	2.4	19°21.2'	155°47.5'	23 km SE. of Kealakekua--- At shallow depth.

Table 5.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, October, November, and December, 1961--Continued

Date (1961)	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Nov. 25	06	14	11.0	2.4	19°17.3'	155°11.6'	12.5 km SE. of Ahua seismometer.	12.5 km deep.
25	06	14	21.5	2.7	19°17.9'	155°08.5'	17 km SE. of Ahua seismometer.	3 km deep.
25	13	26	03.0	3.7			KM 30. Felt in N. Kona and Kilauea caldera area.	
25	20	22	55.5	2.3	19°44.0'	155°31.1'	47 km W. of Hilo-----	8 km deep.
27	01	32	35.8	2.8			KM 30.	
27	04	51	23.5	3.4			KM 30. Felt from Kilauea caldera region to Kona.	
27	09	44	45.5	2.5			KM 30.	
27	15	55	40.0	2.5			KM 30.	
30	14	30	49.5	2.6			KM 30.	
30	16	51	17.5	2.4			KM 30.	
30	18	58	46.5	2.6			KM 30.	
30	20	14	26.1	2.5			KM 30.	

Table 5.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, October, November, and December, 1961--Continued

Date (1961)	Time			Magnitude	Epicenter		Remarks	
	h	m	s		Lat. N.	Long. W.		Description
Dec. 1	06	37	43.6	2.8		KM 30.		
1	07	33	58.0	2.9	19°22.2'	155°42.0'	23 km E. of Hookena, SW. rift of Mauna Loa. At shallow depth.	
1	09	09	38.1	2.6		KM 30.		
2	18	57	59.8	3.9		KM 30.	Felt throughout the island.	
2	20	28	45.0	2.3		KM 30.		
3	01	01	35.8	2.6	19°24.2'	155°25.3'	8 km NNW. of Desert seismometer. 5 km deep.	
3	11	33	37.6	2.4		KM 30.		
4	01	06	50.3	2.3		KM 30.		
4	04	12	17.5	2.3		KM 30.		
4	14	08	03.5	3.1		KM 30.		
4	23	27	50.0	2.6	19°19.8'	155°44.6'	20 km SE. of Hookena, SW. rift of Mauna Loa. At shallow depth.	
5	01	54	19.0	2.5	19°18.7'	155°09.2'	30 km SW. of Pahoa----- 3 km deep.	

Table 5.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, October, November, and December, 1961--Continued

Date (1961)	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Dec. 5	06	32	52.0	2.9	19°21.2'	155°47.3'	13 km ESE. of Hookena--- KM 30.	At shallow depth.
5	13	19	31.8	2.9				
5	17	11	13.8	2.4	19°21.2'	155°47.3'	13 km ESE. of Hookena---	At shallow depth.
5	20	41	28.0	3.3	19°10.0'	155°38.3'	13 km NW. of Naalehu. Felt in Pahala.	25 km deep.
6	03	08	05.5	2.6	19°13.6'	155°00.3'	21 km SSW. of Pahoa-----	35 km deep.
7	09	42	59.7	2.6			KM 30.	
9	16	59	19.8	2.9			KM 30. Felt on E. rim of Kilauea caldera.	
9	19	37	52.5	2.7	19°44.5'	155°57.4'	12 km NNE. of Kailua----	8 km deep.
10	20	47	34.0	2.6	19°59.7'	155°31.0'	10 km SW. of Honokaa-----	Do.
11	17	03	18.3	3.0	19°24.3'	155°44.8'	17 km E. of Hookena-----	At shallow depth.
11	21	55	31.5	3.0			KM 30. Felt throughout Kilauea caldera region.	
13	01	36	32.5	2.6			KM 30.	

Table 5.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, October, November, and December, 1961--Continued

Date (1961)	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Dec. 15	10	37	20.9	2.5	19°31.4'	154°50.3'	35 km SE. of Hilo, E. rift zone of Kilauea.	8 km deep.
15	11	17	57.4	3.2			KM 30. Felt on E. rim of Kilauea caldera.	
16	20	48	58.8	2.3	19°37.1'	155°16.2'	21 km WSW. of Hilo-----	12.5 km deep.
17	05	46	15.0	2.2			KM 30.	
17	07	19	44.4	2.3			KM 30.	
17	07	50	52.5	3.4	19°37.7'	155°51.2'	10 km E. of Holualoa. Felt near Kealakekua.	12.5 km deep.
21	03	04	55.5	2.5	19°57.7'	155°19.6'	10 km SW. of Laupahoehoe	Do.
22	05	57	43.1	2.8	19°22.8'	155°48.7'	10 km E. of Hookena-----	3 km deep.
23	06	37	13.5	2.6	19°20.7'	155°30.6'	16 km NNW. of Pahala-----	Do.
23	08	18	32.8	2.5			KM 30.	
24	10	54	40.6	3.0			KM 30.	
24	22	29	34.9	2.5	19°26.2'	155°26.1'	9 km SW. of Mauna Loa seismometer.	8 km deep.

Table 5.--Local earthquakes recorded by seismographs of the U.S. Geological Survey, October, November, and December, 1961--Continued

Date (1961)	Time			Magnitude	Epicenter			Remarks
	h	m	s		Lat. N.	Long. W.	Description	
Dec. 25	10	17	45.0	2.4	19°28.3'	155°28.3'	30 km N. of Pahala-----	5 km deep.
26	19	48	04.3	2.9	19°29.2'	155°50.9'	8 km ESE. of Kealakekua--	3 km deep.
27	17	14	27.7	2.7	19°14.2'	155°35.0'	19 km N. of Naalehu-----	Do.
28	00	28	46.0	2.7	19°24.2'	155°06.1'	20 km SW. of Pahoa, E. rift zone of Kilauea.	Do.
28	22	42	57.6	3.1			KM 30.	
28	22	43	33.6	2.5			KM 30.	
30	12	09	30.0	2.6	19°46.7'	155°26.3'	37 km WNW. of HILO-----	8 km deep.
30	13	08	22.0	2.5			KM 30.	
31	06	03	23.2	3.0	19°47.0'	155°31.8'	5 km N. of Pohakuloa. Felt in Pohakuloa.	8 km deep.
31	07	43	44.8	2.9	19°20.8'	155°26.3'	35 km NW. of Naalehu-----	3 km deep.
31	08	13	06.8	2.5	19°14.5'	155°12.8'	40 km SW. of Pahoa-----	5 km deep.
31	08	52	09.9	3.9			KM 30. Felt on E. rim of Kilauea caldera.	
31	11	38	17.0	3.6	20°54'	154°46'	139 km NNE. of HILO-----	12.5 km deep.
31	19	07	22.7	2.9			KM 30.	

Table 6.--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 are presented in Summary 21. Magnitudes calculated from the Hawaii seismograms are followed by (HVO). Location of epicenter, origin times, and focal depths, and magnitudes reported by other institutions are taken from "Preliminary Determination of Epicenters" published by the U.S. Coast and Geodetic Survey]

<u>Oct. 2</u>				<u>Oct. 8--Continued</u>			
M	Z	eP	07:12:34.2 c	U	Z	iP	23:52:22.7 d
A	Z	iP	07:12:33.5 c	C&GS card 82-61: 1.6° N., 127.3° E. 23:41:32.2. Halmahera. h about 102 km.			
D	Z	eP	07:12:34.0 c	<u>Oct. 18</u>			
U	PEZ	eR	07:29:07	U	PEZ	ePP	17:15:54
From a southerly direction.				U	PEZ	iPPP	17:17:58
No preliminary C&GS listing.				U	PEZ	iS	17:23:28
<u>Oct. 4</u>				U	PEZ	eR	17:35:32
U	PEN	eS	02:39:11	M	Z	Tmax	18:51:05
U	PEZ	eS	02:39:35	Magnitude 6.8 (HVO).			
U	PEZ	eR	02:46:47	C&GS card 84-61: 36.7° S., 72.6° W. 16:52:00.2. Near coast of southern Chile. h about 67 km. Magnitude 6.5 (Pas).			
C&GS card 81-61: 13.2° S., 166.5° E. 02:23:23.5. New Hebrides region. h about 66 km.				<u>Oct. 21</u>			
<u>Oct. 5</u>				M	Z	iP	11:50:57.9 d
Pa	Z	iP	18:17:52.8 c	A	Z	iP	11:50:57.4 d
No preliminary C&GS listing.				D	Z	eP	11:50:57.6 d
<u>Oct. 8</u>				N	Z	eP	11:50:57.1 d
M	Z	iP	23:52:22.3 d	U	Z	iP	11:50:57.6 d
A	Z	iP	23:52:23.8 d				
D	Z	iP	23:52:23.4 d				

Table 6.--Distant earthquakes--Continued

<u>Oct. 21--Continued</u>	<u>Oct. 23--Continued</u>
Ka Z eP 11:50:58.3 c	U PEE eR 15:14:15
Na Z iP 11:50:54.0 c	U PEN eR 15:14:19
Pa Z iP 11:50:59.8 c	U PEZ eR 15:14:27
Hi Z iP 11:50:59.9 d	C&GS card 91-61: 3.5° N., 126.4° E. 14:39:33.5. Molucca Passage, h about 25 km. Magnitude 6.5 (Pas) 6.25 (Berk).
Ha Z iP 11:51:02.7 c	
C&GS card 84-61: 18.0° S., 178.5° W. 11:43:41.3. Fiji Islands. h about 618 km.	
<u>Oct. 21</u>	<u>Oct. 23</u>
M Z iP 17:43:01.8 c	M Z iP 15:04:27.4 d
A Z eP 17:43:02.1 d	A Z iP 15:04:28.5 d
D Z iP 17:43:00.6 c	D Z iP 15:04:27.3 d
Pa Z iP 17:43:02.8 d	U Z iP 15:04:27.8 d
Hi Z eP 17:43:04.6 c	C&GS card 96-61: 3.5° N., 126.6° E. 14:52:28.2. Molucca Passage, h about 32 km.
C&GS card 85-61: 10.8° S., 166.0° E. 17:34:36.8. Santa Cruz Islands. h about 192 km.	<u>Oct. 23</u>
<u>Oct. 23</u>	U PEN 16:49:00
M Z iP 14:51:33.0 d	Start of pressure waves caused by Russian nuclear explosion. First waves had average period of 105 seconds.
A Z iP 14:51:33.4 d	
D Z iP 14:51:32.6 d	<u>Oct. 24</u>
U Z iP 14:51:32.9 d	M Z iP 05:34:36.7 d
U PEE eS 15:02:20	A Z iP 05:34:37.8 d
	D Z iP 05:34:37.3 d

Table 6.--Distant earthquakes--Continued

Oct. 24--Continued	Oct. 29
U Z iP 05:34:37.1 c	U PEN eL 09:27:29
From a northerly direction.	Hi Z eL 09:27:33
No preliminary C&GS listing.	Ha Z eL 09:28:02
	Ha Z Tmax 09:56:43
<u>Oct. 26</u>	M Z Tmax 09:57:13
M Z eP 00:48:35.6 c	A Z Tmax 09:57:26
A Z eP 00:48:35.8 c	D Z Tmax 09:57:26
D Z eP 00:48:35.2 c	U Z Tmax 09:57:25
U PEZ eP 00:48:35 c	Pa Z Tmax 09:57:27
U PEZ eSS 01:00:42	
U PEZ iR 01:05:40	C&GS card 86-61:
U PEE iS 00:56:45	49.0° N., 128.7° W.
U PEE eG 01:03:20	09:12:15.7.
U PEN eG 01:03:25	Vancouver Island region.
	h about 16 km.
Magnitude 6.5 (HVO).	<u>Oct. 29</u>
C&GS card 89-61:	Pa Z Tmax 10:47:22
3.1° S., 147.4° E.	Pa Z Tmax 11:55:19
00:38:20.3.	Pa Z Tmax 12:01:53
Bismarck Sea.	Pa Z Tmax 14:45:07
h about 14 km.	Pa Z Tmax 17:01:29
Magnitude 6.5 (Pas and Berk).	Pa Z Tmax 19:12:18
	Pa Z Tmax 20:13:43
<u>Oct. 28</u>	Pa Z Tmax 23:09:51
U PEZ eS 23:00:53	
U PEZ eR 23:07:16	These T-phases have no preliminary C&GS listing. They are assumed to have originated off the Vancouver Island-Oregon coasts.
C&GS card 88-61:	
13.9° S., 166.0° E.	
22:44:33.6.	
New Hebrides Islands.	
h about 89 km.	

Table 6.--Distant earthquakes--Continued

Oct. 29

U	PEN	eL	15:03:49
Ha	Z	Tmax	15:31:41
Pa	Z	Tmax	15:32:21
M	Z	Tmax	15:32:14
U	Z	Tmax	15:32:16

C&GS card 90-61:
 48.7° N., 128.3° W.
 14:47:18.3.
 Vancouver Island region.
 h about 73 km.

Oct. 30

Pa	Z	Tmax	02:25:50
Ha	Z	Tmax	02:25:55

No C&GS listing.

Oct. 30

U	PEN	eL	02:31:01
Ha	Z	Tmax	02:57:29
Ka	Z	Tmax	02:57:50
Pa	Z	Tmax	02:57:41
M	Z	Tmax	02:58:03
A	Z	Tmax	02:57:59
D	Z	Tmax	02:58:01
U	Z	Tmax	02:58:00

Oct. 30--Continued

C&GS card 86-61:
 42.3° N., 126.7° W.
 02:16:32.7.
 Off coast of Oregon.
 h about 36 km.

Oct. 30

U PEN 17:01:00

Start of pressure waves caused
 by Russian nuclear explosion.
 First waves had average
 period of 140 seconds.

Nov. 4

M	Z	eP	03:47:18.7 d
A	Z	eP	03:47:19.4 d

C&GS card 89-61:
 50.0° N., 155.5° E.
 03:38:30.1.
 Kurile Islands.
 h about 32 km.

Nov. 5

M	Z	iP	10:45:46.9 c
A	Z	iP	10:45:47.9 c
D	Z	iP	10:45:47.5 c
U	Z	iP	10:45:47.6 c
Pa	Z	iP	10:45:53.0 c
Hi	Z	eP	10:45:47.6 c
Na	Z	iP	10:45:47.8 c

Table 6.--Distant earthquakes--Continued

Nov. 5--Continued

C&GS card 89-61:
 45.7° N., 147.9° E.
 10:36:39.5.
 Kurile Islands.
 h about 142 km.

Nov. 10

M	Z	iP	18:08:06.7	c
A	Z	iP	18:08:06.0	c
D	Z	iP	18:08:06.1	c
U	Z	iP	18:08:06.1	c
Hi	Z	iP	18:08:09.5	c
Pa	Z	iP	18:08:08.3	c
Na	Z	iP	18:08:03.0	c
Ka	Z	iP	18:08:09.3	d
Ha	Z	iP	18:08:11.7	c

C&GS card 91-61:
 17.5° S., 178.8° W.
 18:00:49.6.
 Fiji Islands.
 h about 586 km.

Nov. 15

M	Z	eP	07:26:41.9	c
A	Z	eP	07:26:43.0	d
D	Z	eP	07:26:42.4	c
U	Z	eP	07:26:42.4	d
Hi	Z	iP	07:26:41.5	c
Pa	Z	eP	07:26:44.1	c
Ka	Z	iP	07:26:37.0	d

Nov. 15--Continued

Ha Z eP 07:26:33.1 d

Magnitude 7.0 (HVO).

C&GS card 91-61.
 43.1° N., 145.1° E.
 07:17:12.4.

Felt near coast of Hokkaido,
 Japan.
 h about 43 km.

Nov. 19

M	Z	iP	23:33:54.9	d
A	Z	iP	23:33:55.2	d
D	Z	iP	23:33:54.4	d
U	Z	iP	23:33:55.0	d
Hi	Z	iP	23:33:55.8	d

C&GS card 96-61:
 0.8° N., 124.3° E.
 23:21:55.5.
 Northern Celebes.
 h about 157 km.

Nov. 20

U	PEZ	iS	12:01:19
U	PEZ	iSS	12:04:51
U	PEZ	iR	12:09:05

Magnitude 6.0 (HVO).

C&GS card 97-61:
 21.8° S., 169.9° E.
 11:44:19.4.
 Loyalty Islands region.
 h about 33 km.

Table 6.--Distant earthquakes--Continued

<u>Nov. 21</u>					<u>Dec. 1--Continued</u>				
M	Z	iP	11:19:15.4	c	C&GS card 100-61: 26.5° N., 124.9° E. 21:13:04.1. East China Sea. h about 206 km.				
U	Z	iP	11:19:15.2	c					
N	Z	iP	11:19:15.6	c					
C&GS card 94-61: 0.9° N., 122.5° E. 11:06:38.1. Northern Celebes. h about 85 km.									
<u>Nov. 27</u>					<u>Dec. 5</u>				
M	Z	iP	17:22:39.2	d	M	Z	eP	13:11:16.2	c
A	Z	iP	17:22:38.8	c	A	Z	iP	13:11:16.6	c
U	Z	eP	17:22:39.5	d	D	Z	eP	13:11:15.8	c
U	PEN	eG	17:42:51		U	Z	eP	13:11:17.3	c
U	PEZ	eR	17:46:29		Pa	Z	iP	13:11:19.9	c
Magnitude 6.0 (HVO).					Ha	Z	iP	13:11:19.4	c
C&GS card 104-61: 0.6° S., 127.1° E. 17:10:33.3. Halmahera region. h about 25 km. Magnitude 6.25 to 6.5 (Pas).					U	PEN	iPs	13:23:56	
					U	PEZ	iR	13:42:56	
					C&GS card 102-61: 50.8° S., 139.8° E. 13:01:04.7. Southwest of Tasmania. h about 64 km.				
<u>Dec. 1</u>					<u>Dec. 6</u>				
M	Z	eP	21:24:12.1	d	M	Z	eP	16:48:31	c
A	Z	eP	21:24:12.7	d	U	PEZ	iS	16:55:40	
D	Z	eP	21:24:12.4	d	U	PEZ	iR	17:02:04	
U	PEE	eS	21:34:24		Magnitude 6.3 (HVO).				
U	PEZ	eG	21:46:08		C&GS card 99-61: 49.4° N., 155.2° E. 16:39:31.5. Kurile Islands. h about 22 km. Magnitude 6 to 6.25 (Pas), 6.25 (Berk).				

Table 6.--Distant earthquakes--Continued

<u>Dec. 9</u>				<u>Dec. 9--Continued</u>			
U	PEN	eL	02:31:02	D	Z	eP	19:57:27.4 c
Ha	Z	Tmax	02:59:45.0	Ha	Z	iP	19:57:32.3 d
Hi	Z	Tmax	03:00:58.4	Ka	Z	eP	19:57:29.3 d
U	Z	Tmax	03:01:20.6	Hi	Z	iP	19:57:29.5 d
M	Z	Tmax	03:01:23.2	Pa	Z	iP	19:57:29.1 c
Pa	Z	Tmax	03:01:27.2	Na	Z	iP	19:57:23.4 c
D	Z	Tmax	03:01:33.5	C&GS card 99-61: 21.7° S., 179.9° E. 19:49:41.3. Fiji Islands. h about 620 km.			
A	Z	Tmax	03:01:41.5	<u>Dec. 20</u>			
C&GS card 99-61: 56.3° N., 153.9° W. 02:15:22.0. Kodiak Island, Alaska region. h about 31 km. Magnitude 5.5 to 5.75 (Berk), 5.5 (Pal).				M	Z	eP	13:37:20.8 d
<u>Dec. 9</u>				M	Z	ipP	13:38:06.6 c
U	PEZ	ePS	11:44:20	A	Z	eP	13:37:20.1 d
U	PEZ	eSS	11:49:40	A	Z	ipP	13:38:06.5 c
U	PEZ	iR	12:02:48	D	Z	eP	13:37:21.0 d
Magnitude 6.5 (HVO).				D	Z	ipP	13:38:05.8 c
C&GS card 99-61: 43.7° S., 75.2° W. 11:18:08.9. Near coast of southern Chile. Magnitude 6.75 (Pas), 6.5 (Berk), 5.75 to 6.0 (Pal). h about 34 km.				Pa	Z	eP	13:37:18.6 c
<u>Dec. 9</u>				Hi	Z	iP	13:37:19.7 d
M	Z	eP	19:57:26.8 d	Hi	Z	ipP	13:38:09.2 c
U	Z	iP	19:57:26.9 d	Na	Z	eP	13:37:19.0 c
A	Z	eP	19:57:27.1 d	Ka	Z	eP	13:37:22.5 c
				Ka	Z	epP	13:38:12.8 c
				Ha	Z	eP	13:37:26.4 d
				Ha	Z	ipP	13:38:15.4 c
				U	PEZ	iP	13:37:20.1 d
				U	PEZ	ipP	13:38:05.8 c

Table 6.--Distant earthquakes--Continued

Dec. 20--Continued

U PEZ eS 13:46:47

U PEN iG 13:58:20

C&GS card 102-61:

4.6° N., 75.6° W.

13:25:34.4.

West-central Colombia.

h about 176 km.

 Magnitude 6.75 (Pas), 6.0
(Pal).

Dec. 22

M Z iP 22:55:48.0 c

A Z iP 22:55:48.5 c

D Z eP 22:55:47.3 c

N Z iP 22:55:48.1 c

U Z iP 22:55:48.3 c

Ka Z eP 22:55:50.8 d

C&GS card 104-61:

18.6° N., 145.6° E.

22:46:24.6.

Mariana Islands.

h about 155 km.

Dec. 24

M Z iP 02:51:03.4

N Z eP 02:51:11.7

U Z iP 02:51:19.3

U PEZ eL 03:09:05

C&GS card 104-61:

3.4° S., 140.3° E.

02:40:07.6.

New Guinea.

h about 29 km.

Dec. 25

U PEZ eL 00:27:49

Dec. 25--Continued

C&GS card 107-61:

3.4° S., 140.3° E.

00:01:52.1.

New Guinea.

h about 22 km.

Dec. 25

M Z iP 08:13:05.3 c

C&GS card 104-61:

3.7° S., 127.7° E.

08:00:59.3.

Ceram.

h about 47 km.

Dec. 25

M Z iP 08:25:13.1 d

C&GS card 106-61:

1.1° S., 126.7° E.

08:13:07.2.

Spice Islands.

h about 25 km.

Dec. 27

M Z eP 23:59:52.1 d

A Z eP 23:59:49.8 d

D Z eP 23:59:48.8 c

N Z eP 23:59:51.3 c

U Z eP 23:59:50.0 c

Ka Z eP 23:59:49.9 d

Ha Z eP 00:00:04.5 c

U PEE iS 00:07:44

U PEN iSS 00:11:56

U PEN iSSS 00:15:16

Table 6.--Distant earthquakes--Continued

Dec. 27--Continued

Magnitude 6.5 (HVO).
 C&GS card 105-61:
 41.2° S., 175.7° E.
 23:48:01.3.
 North Island, New Zealand.
 h about 57 km.
 Magnitude 6.75 (Pas), 6 to
 6.25 (Pal).

Dec. 29

U PEE eR 00:16:15

C&GS card 105-61:
 12.4° S., 166.3° E.
 23:55:57.6 (Dec. 28).
 Santa Cruz Islands.
 h about 100 km.

Dec. 30

M	Z	eP	00:46:48.7 d
A	Z	eP	00:46:50.0 c
N	Z	eP	00:46:51.2 c
U	Z	eP	00:46:50.8 d
Pa	Z	iP	00:46:52.3 c
Hi	Z	eP	00:46:49.8 d
Na	Z	iP	00:46:52.5 c
Ha	Z	eP	00:46:36.8 c
U	PEZ	iP	00:46:50.2 d
U	PEZ	iS	00:52:52
U	PEZ	iR	00:57:02
Ha	Z	Tmax	01:27:35.0

Dec. 30--Continued

Magnitude 6.8 (HVO).
 C&GS card 105-61:
 52.3° N., 177.7° E.
 00:39:24.1.
 Rat Islands.
 h about 52 km.
 Magnitude 6.75 (Pas), 6.5
 (Berk), 7 (Pal).

Dec. 30

M	Z	eP	11:46:59.5 d
A	Z	eP	11:47:00.4 d
D	Z	eP	11:46:59.9 c
N	Z	eP	11:46:59.6 c
Hi	Z	eP	11:46:57.4 d
Ha	Z	Tmax	12:21:53.6

Off Oregon coast.

No preliminary C&GS listing.

Dec. 30

M	Z	eP	11:48:19.5 c
A	Z	eP	11:48:21.4 d
D	Z	eP	11:48:22.2 c
N	Z	eP	11:48:21.2 c
Hi	Z	eP	11:48:17.4 d

From northeast source.

No preliminary C&GS listing.

Table 6.--Distant earthquakes--Continued

<u>Dec. 30</u>				<u>Dec. 31</u>			
M	Z	eP	16:49:21.0 c	M	Z	eP	13:57:44.4
M	Z	Tmax	17:27:42	A	Z	eP	13:57:44.6
A	Z	Tmax	17:27:46	N	Z	eP	13:57:44.6
D	Z	Tmax	17:27:58	U	Z	eP	13:57:44.5
N	Z	Tmax	17:27:45	C&GS card 107-61: 1.6° N., 127.3° E. 13:46:01.8. Halmahera, h about 140 km.			
U	Z	Tmax	17:27:46				
Off coast of Oregon.							
No preliminary C&GS listing.							

The following bibliography is furnished to provide references to recent publications by the staff at the Hawaiian Volcano Observatory. Many of the publications are either based upon, or supplementary to, data presented in these Summaries.

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