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Weather Bureau
CHARLES F. MARVIN, Chief
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HONOLULU, HAWAII, JANUARY 1924

No. 1

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VOLCANIC CONDITIONS IN JANUARY.

Activity of Halemaumau.

The rapid fluctuations in the highest of the molten lava that marked December 1923 continued into January 1924. The weekly period of great flooding or remarkable cascading that started on the first Friday in December was continued during the first three weeks of January. After the flood on January 18, however, the lava did not fall back but continued high until January 31 when there was another spectacular cascade into the north pool. On January 4-5 the southeast cone locality was the main sink hole. This followed a time when the north pool had been higher than and overflowing into the main pool. The range in the highest of the lava between January 1 and January 31, 219 feet to 177 feet below rim was less than the fluctuation on some days of rapid flooding. On January 18th the lava rose 65 feet in less than 16 hours. On January 21 the lava lake was some 45 acres in extent with no islands visible. On this day tumultuous fountains, the largest observed since March 1921, often hurled the spray over 100 feet high. The general arrangement of the source wells has continued much the same since last October.

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January 1. The lava was at about the same level at 9 p. m. as it was on December 31. There was no activity at the south source. The cascade from the north pool continued. The stream turned south at the foot of the cascade and passed directly across the south source locality. There were three or four fountains at all times in the north pool.

January 2. At 5 p. m. there was radial streaming from the south source

with a perceptible rise in progress though the level of the lava was much the same as on January 1. The streaming from the north pool had stopped though that pool was nearly bank full.

January 3. The north pool had overflowed southeast into the east pool since the afternoon of the 2nd. At 3 p. m., however, the north pool was depressed within its banks 8-10 feet. The main pool was 3-4 feet higher than on the 2nd. All islands were still visible. The south source was active with radial streaming and continuous fountaining.

January 4. It was found at 9:45 a. m. that there had been another great rise and that the lava was slowly subsiding. The rate of fall increased and many extremely powerful fountains were in action. Fountains played over the two sink holes, the inner southeast cone and the north pool. The south source was marked by thin skins and bubble fountaining. By 10:30 a. m. the fountaining had become weaker.

January 5. At 11:00 a. m. the pit appeared much as it did before the rise with three large islands in south bay and smaller ones in north bay. The westernmost of the large islands in the south bay looked like the old island of November and had three beaches, each one of which showed increased titling to the southwest. There was sluggish streaming from the south source to the north bay. The north pool was higher than the main pool and cascaded for a short time into it. There were occasional fountains at each end of the north pool.

January 6. The appearance of the pit was much the same as on the 5th. The north pool was a little higher.

January 7. Both pools were higher than on the 6th and the north pool was overflowing rapidly in four large streams. Some of the streams appeared very fluid. There was outward streaming from the south source. Several of the smaller islands in the main pool were drowned. There was but little fountaining. The old southeast cone discharged gas through a crack near its base several times during the morning.

January 8. At 10 a. m. the north pool was overflowing more vigorously than on the 7th though the general appearance of pit was the same. The heat was almost unbearable at many places on the rim. There was radial streaming from and fountaining at the southwest source. The south source was quiet. The fume was thin.

January 9. At 10 a. m. the north pool was slightly sunk in its cup but later it rose and overflowed voluminously to the north. After the overflow it sank back with vigorous fountaining to 15 feet below its rim. By 11:30 a. m. another rise was in progress. The size of the main pool was greatly reduced by the growth of inner benches. The southeast promontory was connected with the south island and the southwest island had joined the west bank. There were small fountains at and sluggish streaming away from the southwest source.

At about 10 p. m. there was another sharp rise. Both southeast cones were marked by dome fountains. At midnight there was no sign of subsidence.

January 10. At 10 a. m. the main pool was at about the same level as on the 9th while the north pool was depressed within its cup. There was sluggish streaming from the southwest source and for a short time a pasty flow from the old southeast cone. There were ten fountaining patches in the northeast bay.

January 11. The pit was quiet and the lava level was much the same as on the 10th. There was an occasional dome fountain at the south source though there was no streaming. Considerable fume arose from the north pool region.

January 12. The size of the main pool was reduced by new islands

and by growth of southwest island. Weak fountains at and sluggish streaming away from the south and southwest sources. There was a puffing crack at base of southeast cone. The north pool was quiet and low. The bench in center of pit was rising and tilted shore lines were prominent.

January 13. The general appearance of pit was unchanged, though the north pool was higher. The fountaining and streaming away from south and southwest cones was more active. There was a new small cone on south side of old southeast cone.

January 14. Both pools had risen and the main pool had formed ramparts in several places. The north pool was smaller. South and southwest sources were much the same as on the 13th. The old southeast cone was belching, sometimes throwing spatter 60-75 feet high, and also pouring out a small flow of viscous lava.

January 15. Both pools were higher than on the 14th and the main pool ramparts were more pronounced. At 2 p. m. the main pool overflowed for a short time. There was considerable fountaining and sinking of crusts in the main lake. The fountaining at and streaming away from the south source had increased.

January 16. The north pool had risen and was overflowing vigorously on the north and south sides. The south source was also active in the main pool. There were ten fountains in the main pool.

January 17. The north pool was down though the adjacent bench was still high. Spatter ramparts on southwest side of north pool appeared to be as high as the recent black ledge. The east and west pools were depressed within their banks 4-8 feet and were separated by an isthmus. A portion of the northeast bench fell into the east pool. There was slight streaming away from the vigorous fountain at south source. Gas was hissing through cracks in the crusts.

January 18. At 10 a. m. the lava had risen so that there was one great lake that extended into the southwest chasm and covered up the June 1923 bench. A vigorous cascade into the north pool that had started about 7:45 a. m. continued all day. There was radial streaming from the south source well. Fountains played over the southeast cones with about four others in different parts of the lake. The level of the flood lowered slightly in the afternoon.

January 19. During the forenoon the pit was much the same as on the 18th. At 2:20 p. m. the north pool started to fountain vigorously and within two minutes the pool was full. This was followed by a rapid rise that drowned the southeast cones. A number of whirlwinds tossed about pieces of crust.

January 20. The lava was down 10-15 feet at 10 a. m. though no crags had appeared. Large fountains played from time to time in various parts of the pit.

January 21. The pit was much the same as on the 20th except that the lava was higher. The vigorous southeast fountain was elongated. A powerful fountain played over the north pool locality. The fume was entirely from the fountains.

January 22. At 10 a. m. the lake was down about 15 feet. The noise from the several vigorous fountains sounded like heavy surf. There was rapid streaming from the south source. The heat was very strong.

January 23. The pit was much the same as on the 22nd. There were four vigorous fountains.

January 24. The lake had fallen slightly since the 23rd. As many as eight vigorous fountains were in action at 10 a. m. The top of the southeast cone was reappearing.

January 25. At 10:30 a. m. the lake had risen and the number of foun-

tains had decreased. Fume rose from various parts of the lake surface. Rapid streaming continued. At 8 p. m. a fountain over the north pool locality hurled molten lava over 125 feet high.

January 26. Conditions same as on the 24th. Fountains played at the southeast and over north pool locality. There was no island in the great lake.

January 27. At 10 a. m. the lava level was the same as on the 26th. It was reported to have risen and then subsided. The fountains and streaming had changed but little.

January 28. At 11 a. m. the lava was materially lower than on the 27th and the top of southeast cone stood 10 feet above the lake. The south source was less active and streaming from it slower than for several days. There were six active fountains in north part of the lake and an occasional one at south source.

January 29. At 10 a. m. the lava appeared to have fallen slightly. There was but little fountaining. There was moderate streaming from the south source. At 11:30 a. m. the lake had fallen further and a cascade was pouring into the southeast cone.

January 31. At 10:45 a. m. the end of a period of sharp subsidence was observed. Numerous fountains were playing and the banks showed hot pahoehoe paste. A weak cascade poured into the north pool. Shortly thereafter the fountaining stopped and a rapid rise commenced that was accompanied by a cascade into the north pool. By noon the cascade was vigorous, being fed by rapid streaming from the south source. The southeast cones were quiet.

LAVA MEASUREMENTS

Measurements of the depression of the mobile lava column below the northeast rim station of Halemaumau, 3716 feet above sea level, for the month of January 1924, were as follows:

	Day	Time	Main lake level
January	4	10 a. m.	160 feet.
"	5	11 a. m.	215 "
"	7	11 a. m.	200 "
"	9	10 a. m.	190 "
"	12	10 a. m.	192 "
"	13	10 a. m.	194 "
"	14	2 p. m.	189 "
"	15	2 p. m.	190 "
"	16	10 a. m.	180 "
"	21	10 a. m.	114 "
"	22	10 a. m.	118 "
"	23	9 a. m.	136 "
"	24	10 a. m.	135 "
"	25	10 a. m.	120 "
"	26	9 a. m.	124 "
"	27	10 a. m.	121 "
"	28	11 a. m.	149 "
"	31	12 noon.	177 "

SEISMOMETRIC RECORD

During the month ended midnight January 31, 1924, twenty-one local earthquakes and one teleseism were registered at the Observatory. These and other earth movements are exhibited below. Time is Hawaiian Standard, 10 h. 30 m. slower than Greenwich.



Fig. No. 1, January 8, 1924. Flood for the north pool. Photo Emerson.

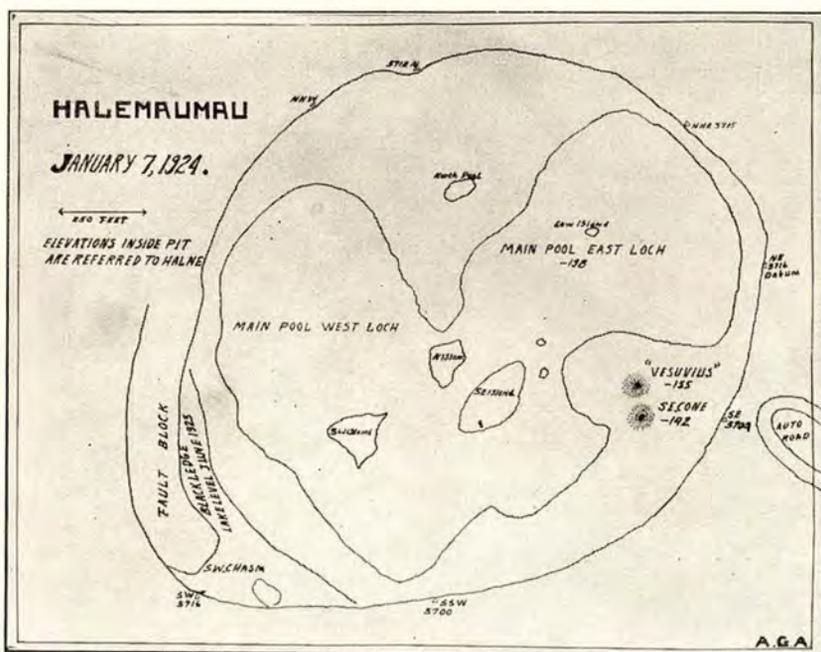


Fig. No. 2. Map showing general relation of islands and pools from November to February 19 inclusive. From survey by O. H. Emerson.

Local Earthquaks.

January 2	1:49 a. m.	Very feeble.
4	9:31 p. m.	Slight, distance 15 miles.
6	12:58 p. m.	Very feeble.
7	12:33 p. m.	" "
8	10:46 a. m.	Slight, felt in Kona.
9	9:58 p. m.	Feeble.
11	5:55 a. m.	Very feeble.
14	2:12 a. m.	" "
16	10:05 a. m.	" "
18	1:01 p. m.	Feeble.
19	3:18 p. m.	" "
21	2:15 a. m.	Slight, distance 8 miles.
	3:01 p. m.	Very feeble.
23	3:05 p. m.	" "
25	3:58 a. m.	" "
26	2:51 p. m.	" "
	3:54 p. m.	Feeble, distance 8 miles.
27	6:22 p. m.	Slight.
28	9:20 a. m.	Very feeble.
	7:29 p. m.	" "
	7:45 p. m.	" "

Teleseism.

January 24..... 7:52 p. m. Slight.

Spasmodic Microtremor.

This type of tremor was slight until January 22nd and moderate from January 23rd on.

Harmonic Microtremor.

This type of tremor was slight during the first 14 days and moderate the last 17 days of the month.

Microseismic Motion.

The amplitude of microseisms was moderate on the 14th and slight on other days.

Tilting of the Ground.

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

December 30-Jan. 5	3.5	seconds NNW.
6-12	4.0	" W.
13-19	4.4	" SSW.
20-26	1.2	" S.
27-Feb. 2	1.3	" ESE.

R. H. FINCH,
Meteorologist.

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VOLCANIC CONDITIONS IN FEBRUARY

Activity of Halemaumau.

Rapid fluctuations in the height of the molten lava that were noted in December and January continued in February until the lava disappeared from view on February 21st. At the beginning of the month the lava was 170 feet below rim. By the 9th the depression was 130 feet. From the 12th on the level lowered gradually and by the 21st the floor was about 380 feet below rim. A fall of 35 feet in one hour, following a rise that was almost as rapid, was reported on February 1. On February 11 some of the fountains were over 150 feet high. On the 15th, 17th, and 18th cascades, sometimes with a drop of 40 feet, poured into the north pool. The main source of the floods was the south feeding well from which distinct and persistent bright lines radiated. As the fall progressed the old topography which had been buried in the January floods reappeared almost unchanged.

During February there were several earthquakes along the volcano end of the northeastern Kilauea rift.

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February 1. Since January 31 the lava rose to about 130 feet below the rim and then sank back so that at 11 a. m. it was about 170 feet down. At 10:20 a. m. there were a series of tumultuous fountains around rim of pit with but few in the center. By 11 a. m. practically all fountains had stopped. Between 10:20 a. m. and 11 the lava must have fallen 10 feet so that islands appeared around the southeast cone and north pool area. The southeast cone stood about 30 feet above the lake but at 11 a. m. its top fell off. There was a moderate discharge of lava from a crack on the south-

west side of the southeast cone. The fume from the fountains was dense and the heat strong. There appeared to be a decided tendency to build up the southwest bench and reduce the size of the pit.

February 2. At 2:30 p. m. the lava had risen to about 140 feet below rim and the lake was quiet. There was weak fountaining at south source and at southeast cone. Streaming was generally slow. The lava was reported to have been much lower during the forenoon.

February 3. At 11 a. m. the lava was down to about 175 feet below rim. The lake was quiet save for occasional fountains at southeast and sluggish streaming from south source. There were no islands except for the southeast cone. A small flow was again issuing from southwest side of this cone.

February 4. At 11 a. m. the lava was higher than on the 3rd, about 150 feet below rim. There was much fume from the five fountaining patches around edge of lake. The sluggish streaming from south source continued. Fresh overflows showed that the lava had fallen recently. Shoals appeared along southwest bank.

February 5. The lava was from 5-10 feet higher than on the 4th. The streaming from the south source was quite vigorous. During the forenoon fountains threw spatter over the rim which was fully 130 feet above lake level. The southeast cone was cracked in an east-west direction.

February 6. The pit was much the same as on the 5th. The rapid streaming from the south source continued and there was a sluggish stream northward from southeast cone.

February 7. At 2 p. m. the lava was about 140 feet below rim and apparently rising. The source of the rising was the south well and a dome fountain at the southeast cone. A small fountain was playing under the east bank. The bench was growing wider.

February 8. At 11 a. m. the lake was about 5 feet higher than on the 7th. The south source was the main feeder. The southeast was a moderate sink hole. The streaming was directed to two vigorous border fountains at the north. Occasionally there were vigorous fountains elsewhere.

February 9. At 10 a. m. the lava was about 130 feet down and rising. There was moderate streaming from the south source to fountains at the north and to the newly formed slab rampart at the northeast bank.

February 10. The lake level was about 150 feet below rim. Most of the fountains, which were tumultuous at times, were in the north side of the lake. Both the south and southeast sources were feeding the lake, the south one being the most active.

February 11. At 11 a. m. the lava was about 145 feet down. Some of the violent fountaining patches under the west, north and northeast rim had a tendency to form grottoes. There were small bubble fountains at and streaming away from the south and southeast sources. Fresh hot spatter was collected along the northeast and north rim. Some of the pieces were six inches long and over an inch wide.

February 12. At 10:30 a. m. the lava was about 145 feet down with no fountains at all. The south and southeast sources were marked by thin skins and bubble fountaining. Streaming was very slow.

February 13. At 11 a. m. the lava was about 175 feet below rim and very quiet. Except for the difference in level the pit was much the same as on the 12th. The fume was thinner.

February 14. At 11:30 a. m. the lava was about 180 feet down. It was reported to have been 50 feet lower at 8 a. m. A rapid rise was observed in the morning. Streaming from the south source was slow. At noon there

was a slight increase in the fountaining under the north rim. There was an occasional fountain near southeast island.

February 15. At 10 a. m. the lava was notably lower than on 14th and a cascade poured into the north pool. There was slow streaming from south source and from west side of southeast island. The heat was strong. Size of lake was materially reduced by growth of benches especially at the south and southwest. At 5 p. m. the lake had risen about 15-20 feet. Aa paste was dripping from the bank at the south where a large section of the bench had fallen away.

February 16. At 9:30 a. m. the lake was sinking with a number of fountaining patches in action. The fountaining died down and at 10 a. m. the lake was perfectly quiet. Avalanches from the inner benches were frequent.

At 5 p. m. the lake level was about the same as in the morning, then vigorous fountaining started in and the lake subsided about 5 feet. Sometimes the spray from the fountains went up over 100 feet.

February 17. At 11 a. m. the lake was slightly lower than on the 16th. Intermittent fountains were in action. Streaming was slow. The heat was less than at any time since January 20th. At 4:30 p. m. the lake was 10-15 lower than in the morning and cascading into the north pool. There was slow streaming from south and southeast sources. A large island had appeared just north of the cascade. There was some peeling off of the veneer from the north wall. The retention of the size shape and position of the north cascade channel after being submerged for a long time under molten lava shows the inability of the molten lava to melt solidified lava.

February 18. The lava was rising with moderate streaming from the south source. The north island was just barely visible. There was no fountaining. At 3 p. m. a cascade into the north pool began and the lake lowered 10-15 feet.

February 19. The cascade into the north pool was reported to have stopped at 12:20 p. m. owing to the lowering of the lake. The marked subsidence with many fountains noted at 2:30 p. m. gradually diminished and at 3:50 p. m. the pit was quiet. The general topography suggested that of December, with a high crag about north pool. There was a highland about the southeast source that was broken up. There were two main bays of main pool, one southwest, and the other northeast. Both of these had small islands in them. About 3:50 p. m. the lava started to flow from the southwest source to the northeast. When this flow stopped suddenly at 4 p. m. a voluminous flow started from the southeast cone and continued for ten minutes. There was occasional cracking and foundering of crusts. A few small avalanches of veneer were noticed. The fume was thin and the heat radiation moderate.

February 20. The lava was 50 feet lower than on the 19th. The north pool was dry with only a small bright patch showing. The main pool was an irregular shaped pond about 225 feet wide by 300 feet long, and was fed by the south source. During the afternoon the lava rose considerably with streaming away from south source. Two constant fountains, similar to those of October, marked the source wells. As they were only about 30 feet apart it appeared as though the south source had split. Considerable fume rose from the southeast source area though no fire was visible there. There were frequent small avalanches from the pit walls. The old crack at north side of pit had widened several inches just west of the north station.

During the forenoon the 1923 outbreak near Makaopuhi was visited. Fumes, probably still rich in SO₃ were still issuing from cracks in and near the flow area. In several places, judging from the appearance of rocks and sand along cracks great quantities of SO₃ had been exhaled. The

cracks west of Makaopuhi were much hotter than they had been in 1922. The 1923 earthquake cracks cross the Kalapana trail parallel to the 1922 cracks and extend about one half mile farther west. There was no good evidence of any movement since August 1923.

February 21. The puddles of lava in south and southwest parts of the pit were lower than on the 20th. The fume was thinner. Pit was dull at night. Only small avalanches noted.

February 22. Conditions at pit were much the same as on the 21st. The only glow to be seen was a small patch in north pool, the banks of which had collapsed considerably since the day before. Dense fume clouds rose from old south source locality.

February 23. The north, south, and southwest source wall localities were marked by small pits. A small amount of aa paste was visible in each of them. No apparent change in the level of the bench. A small flow poured into the south source depression. The north and south pits were the chief sources of fume. Many small avalanches were noted. Cracks back of the rim at the south, west, and north were widening.

February 24. Conditions were but little changed since the 23rd, except for the large volume of fume which was arising from the southeast. The bench around north pit had collapsed a little more. There were few avalanches though the rim cracks continued to widen.

February 27. Conditions had changed but little. Dense fume rose from the southeast area, the south and southwest pits. The solfatara at northeast rim of pit was giving off SO₂.

February 3-5. An ascent of Mauna Loa was made by O. H. Emerson. No changes were observed in Mokuaweoweo. Small patches of snow afforded plenty of water though the usual water holes were dry.

LAVA MEASUREMENTS

Measurements of the depression of the mobile lava column below northeast rim station of Halemaumau for the month ended February 29 were as follows:

	Day	Time	Main lake level
February	1	11 a. m.....	*170 feet.
"	2	2 p. m.....	*140 "
"	3	11 a. m.....	*175 "
"	4	11 a. m.....	*150 "
"	7	2 p. m.....	*140 "
"	8	11 a. m.....	*135 "
"	9	10 a. m.....	*130 "
"	11	11 a. m.....	*145 "
"	15	11 a. m.....	*175 "
"	14	8 a. m.....	*225 "
"	14	11 a. m.....	*180 "
"	15	10 a. m.....	205 "
"	16	10 a. m.....	210 "
"	17	11 a. m.....	216 "
"	19	3 p. m.....	300 "
"	21	10 a. m.....	380 "

SEISMOMETRIC RECORD

During the month ended midnight February 29, 1924, 36 local earthquakes were registered at the Observatory. These and other earth movements are exhibited as follows:

* Estimated.



Fig. No. 3, February 21, 1924. North part of pit from north-northeast rim. Photo Emerson.

Feb. 1.....	6:41 a. m.	Felt locally, NW-SE., origin very close
" 3.....	2:40 a. m.	Feeble, distance 4 miles.
" 9.....	5:31 a. m.	Very feeble.
	7:54 a. m.	" "
" 11.....	2:25 a. m.	" "
" 13.....	12:13 p. m.	" "
	5:20 p. m.	" "
	9:45 p. m.	" "
" 14.....	2:22 a. m.	" "
	5:02 a. m.	Moderate, 2.5 miles, SE-NW., instru- ments dismantled.
	9:34 a. m.	Very feeble.
	1:45 p. m.	" "
	8:16 p. m.	Slight, felt locally.
	11:56 p. m.	Very feeble.
" 15.....	2:59 p. m.	" "
	4:00 p. m.	Slight, distance 2.5 miles, SE-NW., felt locally.
" 17.....	12:36 a. m.	Very feeble.
" 18.....	11:27 p. m.	" "
	11:44 p. m.	" "
" 19.....	12:14 a. m.	" "
	1:57 a. m.	Feeble, distance 2 miles.
" 20.....	1:14 a. m.	Very feeble.
	1:23 a. m.	" "
	1:29 a. m.	" "
	2:20 p. m.	Feeble.
	8:30 p. m.	" "
	11:30 p. m.	Very feeble.
" 23.....	1:55 a. m.	Feeble.
	6:30 a. m.	Very feeble.
	8:01 a. m.	" "
" 24.....	7:45 a. m.	" "
	12:10 p. m.	" "
" 28.....	12:30 a. m.	" "
	9:18 p. m.	" "
" 29.....	1:44 p. m.	" "
	1:45 p. m.	" "

Spasmodic Microtremor.

This type of tremor was moderate until February 14th and slight thereafter.

Harmonic Microtremor.

This type of tremor was moderate on February 2, 7, 11, 12, 16, 17, and 18 and slight on other days.

Microseismic Motion.

The amplitude of microseisms was moderate on February 19, 21 and 24 and slight on other days.

Tilting of the Ground.

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

February 3-9.....	0.9 second S.
10-16.....	3.1 seconds ESE.
17-23.....	0.7 second NNE.
24-Mar. 1.....	1.5 seconds WSW.

R. H. FINCH,
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THE FORMATION OF SULPHATE STALACTITES IN LAVA TUBES

(By R. H. FINCH and O. H. EMERSON)

In December 1919, about a month after the lava ceased to flow in the Postal Rift tube on the floor of Kilauea crater considerable quantities of sulphate stalactites were found in the tube. In some portions of the tube the walls and floor as well as the roof were covered and in other places even where water was dripping the coating was entirely lacking. Localized deposits were found in the fall of 1920 in a tube in Kau Desert through which lava had been flowing in the summer. In a tube formed in 1823 in the Kau Desert considerable quantities of gypsum can be found*. The soluble salts persisted in the Postal Rift tube for about eight months and in the Kau Desert tube for over a year.

Some of the salts from the Kau Desert tube of 1920 were found by J. C. Ripperton of the Federal Experiment Station in Honolulu to contain kieserite. The presence of gypsum and kieserite together with the localization of the deposits added weight to the theory that the salts were not the product of leaching by rain water but due to the action of steam bearing sulphur dioxide and sulphur trioxide on the rock lining the walls of the tube. Such an action would form sulphates of the various bases and liberate silicic acid.

To determine whether there was a sufficient amount of soluble sulphates in the lava to account for the deposits in the tubes we collected several kilograms of coarse spatter thrown out of Halemaumau during the violent

*. This bulletin. Vol. 8, No. 2 pp 19 and 29, and No. 6

fountaining of February 1924 before any rain had fallen on it. Material thrown out by fountains should be more likely to contain appreciable amounts of sulphates than lava that was quietly extruded.

A sample of the collected spatter was ground to a very fine powder first in a steel mortar and then in an agate one. 5.222 grams of this powder in 100 ml. of distilled water was heated over a steam bath for several hours and then allowed to stand over night. After another heating it was filtered off as far as possible. Owing to the fineness of the powder it was impossible to get an absolutely clear solution. To 10 ml. of the solution 5 ml. of barium chloride dissolved in dilute hydrochloric acid were added. This was compared with a 10 ml. sample to which 5 ml. of distilled water were added. The difference, if any, in turbidity was very slight. 1/10 milligram of KHSO_4 dissolved in 10 ml. of distilled water gave with 5 ml. of the barium chloride solution a turbidity heavier than the first two. Hence the lava spatter contained less than 0.02 per cent of leachable sulphates.

As a further check two determinations of the total sulphur in the lava spatter were made by fusion with sodium carbonate and precipitation of sulphur as barium sulphate**. In the first determination, 1.1281 grams of the rock powder gave 3.5 milligrams of barium sulphate, or contained 0.04 per cent of sulphur. In the second 1.1784 grams of rock powder gave 2.7 milligrams of barium sulphate or 0.03 per cent sulphur.

All the above determinations indicate that the leaching theory is not compatible with the observed amounts of sulphates and that they are due to the action of gases on the linings of the tubes.

VOLCANO CONDITIONS IN MARCH

Activity of Halemaumau.

During March no molten lava was to be seen though glow persisted most of the month at the southeast cone locality. The floor of the pit remained practically unchanged during the entire month. The former source wells at southeast, south, and southwest emitted considerable fume that at times prevented seeing the broken and tumbled bottom of pit.

Seventy-eight earthquakes occurred in March a great many of which had their origin along the northeastern Kilauea rift at distances varying from 6 to 27 miles from the Observatory.

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March 5. A fairly good view of the pit was obtained from the west side. There was no visible change in the bottom of Halemaumau nor in the cracks around the rim. The chief sources of fume were the south and southwest pits. There was no glow visible from the observatory though faint glow was discernible at pit's edge.

March 8. Conditions were unchanged.

March 14. At 1 p. m. the fume was much thinner. A glowing cavern could be seen at the southeast cone locality. General appearance of bench unchanged.

March 15. Fume was denser than on the 14th. Considerable fume from the southeast prevented seeing the glowing cavern under the southeast station. Occasional avalanches were heard.

A sample from the south-southwest solfatara showed a small amount of chlorine.

March 17. The general appearance of the pit had changed but little. The southeast cavern appeared cold and there was no glow visible elsewhere.

March 20. There was no noticeable change in the bottom of the pit. The southwest and south areas were emitting dense fume while the northern part of the pit was quite clear. Some fume was rising from the southwest crag locality.

** Washington Chemical Analysis of Rocks 3rd Ed. p. 225.

March 24. The fume was thinner, especially at southeast area. Considerable talus had accumulated at the north and northeast walls. A dull glow was visible at times at southeast cone locality. The fume from this place was warm and sulphurous.

March 30. There were no noteworthy changes in pit. A bright orange glow was visible at times at the old southeast source locality.

A sample collected from the west solfatara was found to be rich in chlorine though it did not contain as much chlorine as sample from northeast solfatara.

LAVA MEASUREMENTS

The bottom of Halemaumau was very irregular and remained at from 375 to 400 feet below the northeast rim during the month of March 1924.

SEISMOMETRIC RECORD

During the month ended midnight March 31, 1924, 78 local earthquakes and one teleseism were registered at the Observatory. These and other earth movements are exhibited below:

Local Earthquaks.

Abbreviations have meanings as follows: Vf-very feeble; f-feeble; s-slight; m-moderate; d-instruments dismantled; fl-felt locally; and *-indicated distance in miles.

Mar. 1,	8:52 p. f.	17,	6:02 p. vf.
2,	3:57 a. vf.		11:45 p. vf.
3,	6:31 a. vf.	18,	1:53 a. vf.
5,	6:42 p. vf.		7:51 a. vf.
	6:54 p. vf.		7:54 a. vf.
	9:57 p. vf.		8:00 a. f.
6,	6:02 p. vf.		12:39 p. f.
	7:02 p. vf.		1:59 p. f. *11.
7,	2:56 a. f. *6	19,	5:20 p. vf.
	5:31 a. vf.	21,	1:01 a. s. *13.
	5:47 a. vf.		1:03 a. s. *13
	2:57 p. vf.		8:06 a. vf.
	4:12 p. vf.		11:32 a. s. *10
	4:45 p. vf.	21,	7:32 p. vf.
8,	7:17 p. vf.	22,	2:38 a. vf.
10,	3:50 p. vf.		4:28 a. vf.
	5:14 p. vf.		2:34 p. s. *13.
	5:22 p. vf.	23,	3:29 a. vf.
	5:45 p. s. *18		3:56 a. vf.
	7:16 p. vf.		4:18 a. vf.
	7:22 p. vf.		5:51 a. vf.
	9:49 p. s. fl.	24,	12:04 p. vf.
	10:09 p. f.	26,	1:20 a. vf.
	11:01 p. vf.		3:36 a. vf.
	11:14 p. f.	27,	10:18 a. vf.
	11:29 p. vf.		10:42 a. vf.
11,	1:53 a. vf.		11:11 a. vf.
	2:01 a. vf.		11:32 a. vf.
	11:30 a. f.	28,	6:09 p. fl. d. *13.
12,	8:03 p. vf.		8:00 p. f.
13,	5:15 p. vf.	29,	1:27 a. s. *27, felt Hilo.
	6:49 p. vf.		6:03 a. vf.
14,	1:15 a. vf.		6:38 a. s.
	6:14 a. vf.		10:44 p. vf.
15,	6:00 a. vf.	30	9:21 a. vf.
	9:30 a. vf.		9:49 p. vf.
17,	3:16 a. vf.		10:27 p. vf.
	9:05 a. f.		10:32 p. vf.
	4:26 p. vf.	31,	8:01 a. vf.

Teleseism.

March 29.....1:56 p. m. Slight.

Spasmodic Microtremor.

This type of tremor was slight throughout the month.

Harmonic Microtremor.

This type of tremor was very slight during March.

Microseismic Motion.

The amplitude of microseisms was slight during March.

Tilting of the Ground.

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

March 2- 8.....	3.3	seconds	SSW.
“ 9-15.....	1.7	“	WNW.
“ 16-22.....	5.7	“	SSW.
“ 23-29.....	3.1	“	SSE.

R. H. FINCH,
Meteorologist.

U. S. DEPARTMENT OF AGRICULTURE
Weather Bureau
CHARLES F. MARVIN, Chief
MONTHLY BULLETIN
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VOLCANIC CONDITIONS IN APRIL

Subsidence and Earthquakes in Puna.

After the numerous earthquakes recorded by the seismographs in March, with indication of their location on the Puna rift line southeast of Kilauea, the seismologist was led to forecast stronger earthquakes that might be felt in Puna early in April. The indicated distances of the seismographic earthquakes, were progressively growing longer, as though the rift in the Puna direction were slowly cracking open. This gave new interest to the line of cones and pits extending from Kilauea in the direction of Kapoho. This region was doubly interesting because lava had come up to the surface in Makaopuhi pit in 1922 and the upland near that pit in 1923. The elevation of these outbreaks was near the 2500-foot contour or about 1200 feet below the rim of Halemaumau pit. The workers at the Observatory had discussed the possibility of more outbreaks farther down the rift as in 1840, and Kapoho residents were repeatedly called by telephone in 1922 and 1923 to inquire about earthquakes, but no unusual number of shocks occurred there during those years.

On April 10, 1924, at 10:46 p. m. there was a strongish earthquake in Puna, felt in Hilo, and reported quite severe in some districts. This and other registered shocks early in April led Mr. Finch, then in charge of the Observatory, to make a trip to Kalapana from Kilauea by way of the old trail. The Twin Craters were passed at 9 a. m. and Kalapana was reached at 4 p. m. No signs of recent movement were observed anywhere other than the previously known cracks near Makaopuhi developed during the eruptions of 1922 and 1923.

On April 16 another excursion was made from Pahoa in Puna southeastward to the Malama homesteads crossing the upper parts of the 1840 flow. The Puulena pit craters and Puu Aa cone were visited, but no new cracks were found and the natives living in that district were not yet alarmed. A slight steam jet was visible at the northern margin of the larger Puulena pit, but this is not a new feature.

During the second week in April the number of seismographic earthquakes increased at the Observatory and as time went on the indicated distance of origin of these earthquakes also increased. It was evident that a seismic disturbance was migrating in a northeasterly direction towards the east point of Hawaii.

April 21 and thereabouts was a time when prolonged mild quaking of the ground began in the Kapoho district. In the region of the Malama homesteads inland from Opihikao, shakings and subterranean noises had been reported as alarming from April 17 to April 20. During the twenty-four hours prior to 11 a. m., April 22, Mr. Henry J. Lyman of Kapoho counted eighty-eight felt earthquakes. At that place during the night of April 22-23 the earth was quaking almost continuously.

An Observatory party visited Kapoho April 22 and at that time noises and increasing earthquakes had been perceived in that region for five days, but as yet there were no signs anywhere of cracking of the ground.

Puulena crater was again visited and the steaming was more pronounced apparently, jets showing in two places at the neck between the two pits, of which this double crater is composed. The hill beside Kahuwai pit was climbed, but no fresh breaks were observed. There was however the debris slope of a small comparatively recent landslide at the west end of Puulena pit. No cracks were discovered in the region between Puu Aa and Honuaula, a larger hill containing a pit crater three-quarters of a mile to the north.

A geophone was tested on the ground at Kapoho and elsewhere in the attempt to detect underground noises. The results were unsatisfactory, though possibly some sounds were perceived at Lyman's east of Green Lake. With regard to the cone of Honuaula, fiery glow was said to have been seen in its crater about October of 1923, but the interior was inspected April 23 and no trace was visible of any lava, scorching or fresh caving in.

The night April 22-23 inaugurated the opening of extensive cracks in the Kapoho district. About twenty pronounced chasms were mapped crossing the roads northeast and southwest from Kapoho village about two miles in each direction throughout a zone about a mile wide extending from the east point to Puu Ki. The gaping of the cracks gradually increased for several days after April 23, and general settlement of the region continued for several weeks. Most of the cracks trend N.60°E., a direction parallel to the lines of cones and old fissures.

The biggest movements of actual faulting extended from the quarry on an old fracture cliff where the railroad crosses the Kula land along the northern boundary of that land northeastward to the sea, the boundary following a

pronounced fault scarp that faces southeast. All along this fault the ground south of the cliff sank eight to twelve feet, the break crossing and destroying the shore road of the old Puna trail near Eldart's. At a place called Kapele at the seaward end of this fault chasm the sunken ground created a new salt lagoon back of the beach where cocoanut and pandanus trees were submerged seven feet or more in sea water. These had stood some five feet above sea-level before the earthquakes. The chasm across the Puna trail made by gaping and caving was fifteen feet wide.

Other conspicuous yawning chasms developed near the road junction and pavilion at the southern base of Kukii hill. Here a block of ground twenty feet wide sank six feet carrying down trees and sugar cane, and revealing deep clefts on both sides of the downsunken block. The walls bounding the breaks exhibited old beds of cinder. The roads were crossed by many cracks, some opened as much as three feet. Some cracks continued opening and caving until April 29, but most of the crisis was over April 27.

Several hundred earthquake shocks were felt at Kapoho April 22 to 23, and some rumbling was heard. The shocks were mild, either vertical or in the northeasterly direction of the cracks. After the 23rd the frequency of earthquakes diminished. An observer at the quarry house situated directly over the main fault fissure, counted 238 earthquakes between 5 p. m. and 9 p. m. April 22. That night appears to have been the culmination of quaking and the time when a new scarp was developing on the Kula fault plane. It was the time when the cracking appeared all over the country.

April 23, moreover, was clearly the culmination of this spasm of subsidence at the eastern extremity of the Puna rift zone, for the seismographs at the Kilauea observatory and at St. Mary's School in Hilo both exhibited a maximum of frequency on that day. The number of earthquakes registered at these two places are exhibited in the following table:

Earthquakes Registered at Hilo and Kilauea.

	Hilo	Kilauea
April 21	1 shock	28 shocks
" 22	16 "	48 "
" 23	32 "	133 "
" 24	15 "	44 "
" 25	5 "	11 "

The Kapoho district on April 23 showed many cracks and every evidence that the block of country between the cinder hills of Kapoho and the Kula fault cliff was sinking so that the maximum downthrow was at the foot of the cliff, and on the Kapoho side cracks yawned open along a hinge line between the eastern cape and the cinder hills. Apparently the country north of the fault cliff remained comparatively stationary. The block that moved hence tilted down on the north side as it subsided sliding downward on the fault plane at the quarry, and consequently the quarry buildings and the railway, (which crosses the fault plane at that point) were displaced. The railroad track was left hanging in places, its extension thrown down from three to four feet and sideways about four feet. A large tank was carried down bodily with the quarry building and only slightly tilted. The total downthrow of the land on the southeast side of the cliff at the quarry eventually amounted to about 11 feet, and this involved all the open fields for a distance of three quarters of a mile between the quarry and Kapoho village.

A preliminary leveling survey along the railroad from the quarry to Kapoho station was kindly run by Mr. Thomas Boles. Referred to a datum point 900 feet north of the fault plane at the quarry, this showed a new profile 9 feet

lower than before south of the quarry, and 1 foot lower than before at Kapoho station. This checks the theory of a hinge line of downbreak at the Kapoho cinder hills and a maximum slump along the Kula fault. The fact of subsidence of the shoreline at the northeastern end of the fault block shows that the net effect is a sinking relative to sea-level. Whether there was any elevation outside of this fault block along the shores north and south can only be proved by extensive precise levelling. No definite shoreline evidence of such elevation has been reported, but it was suspected south of the east cape, through the presence of a bar and elevated sea moss.

The highly localized character of the Kapoho movements was shown by the fact that the earthquakes were not felt at Kalapana twelve miles to the southwest, and were only slightly felt at Eldart's, a few hundred feet north of the Kula fault.

The continuity of the quaking rather than its violence caused a temporary evacuation of the Kapoho district by most of the inhabitants. Telephone wires, pipes, roadways and some foundations were damaged by the cracking of the ground. Some cattle fell into cracks and were buried.

April 24 excessive quaking in Puna had stopped, but a strongish earthquake was felt at the fault plane, sufficiently powerful to produce swaying of the trees. Cracks across the roads had widened. During the next few days the trembling decreased but cracks continued to widen. Other cracks caved in so as to develop large holes. Throughout this cracking open of the country along the rift zone nothing like steam or sulphurous gas was reported anywhere.

By April 30 at Kapele, the ocean end of the sunken block of country, the new lagoon extended 200 feet inland where on April 23 only a small new pool of water had been noticed. The new lagoon is from 6 to 8 feet deep. Three cocoanut trees 175 feet inland from the ocean now stand in 8 feet of water. A rocky beach forms a causeway separating the lagoon from the sea. Farther east along the beach are partially submerged clumps of pandanus trees.

Activity of Halemaumau.

During the Puna crisis nothing very remarkable happened at Halemaumau pit. The bottom of the pit was smoky and from 375 to 400 feet below the rim, with a little glow occasionally visible in the southeast chimney and in cracks.

On the 20th there was much avalanching, sulphurous fume was strong and no glow could be seen.

April 23, the day of culmination in Puna, glow was seen at Halemaumau, and the next night there was brilliant glow at the pit for a few minutes followed by duller flaring that continued at the southern source wells in the bottom of the pit. Noise of splashing lava was heard.

At the end of the month marked subsidence of the bottom of Halemaumau was renewed beginning on the 29th, fume was thinner and the northeastern part of the bottom became a funnel 500 feet below the rim. There was a constant rattle of small avalanches, and red hot matter that appeared to be aa lava was peeling off the side of a former vent and tumbling into the void. As a northern concrete station on the rim of the pit had been undermined and fallen in by avalanching prior to April 20 it appears probable that there was slow subsidence in Halemaumau throughout the last half of April, which became rapid the last two days of the month. This inaugurated the great collapse which followed in May.

DISCUSSION OF SPECIAL FEATURES

Relation of Puna Subsidence to Halemaumau.

The sequence by months of volcanic events in Hawaii prior to April had been high lava level in Halemaumau January, moderate subsidence February, Halemaumau stationary and remarkable south tilt at Observatory accompanied by Puna earthquakes March, all leading to April collapse in Puna and collapse in Halemaumau thereafter.

It should be remembered that the Puna rift zone extending east and north-east from Kilauea is part of the great fracture system parallel with the south-east fault cliffs of the island of Hawaii, that is breaking down the Kilauea flank of the island through the ages. Kilauea crater is a large volcanic sink at a corner or bend in the fracture system. From Kilauea the system extends on to the southwest where it is marked by big shoreward downbreakings in the Mauna Loa flank all the way to Waiohinu. Out of the breaks from time immemorial lava flows have poured forth, showing that the fractures underground are charged with the volcanic fluid.

Two kinds of proof of the presence of hot lava filling the fissures southwest and east from Halemaumau between 1919 and 1924 have been afforded by the sequence of events. One proof was the emission of lava flows and spurts from the fissures, in the Kau desert southwest of Kilauea and twice near Makaopuhi southeast. The second proof was the uplift of the whole mountain during the time of rising lava, suggested by both levelling and tilt measurement between 1912 and 1922. Levelling surveys showed the summit raised two to three feet in the ten years, and this checked with the observed northeasterly tilts measured with pendulums at the observatory.

Pulsations of Subsidence.

For the cycle 1914-1924 the culmination of lava activity of the Hawaiian system was 1919-20 and this was the time when the cracks underground were full of lava so that the mountain was in tension against the action of gravitation, which otherwise would close all the fissures. The culmination of the lava cycle was the culmination of uplift. If the lava by extravasation and loss of gas and heat shrinks and sinks inside the mountain at the end of a cycle, then it may sink faster than elsewhere under the central vents, so that the lava occupying lateral fracture systems drains inward toward the center.

That the lava in the whole Mauna Loa-Kilauea system was subsiding in the course of the decade was evidenced by progressively lower vents: eruptions from the summit of Mauna Loa 1914, high flank of Mauna Loa 1916 and 1919, Kilauea level 1920, lower flank of Kilauea near Makaopuhi 1922 and 1923. The Makaopuhi fractures are those that extend to Kapoho in Puna and on beneath the sea. It was to be expected in the natural order of things, that if gravitative compression were now closing the cracks in the tops of the mountains, the place where lava movement would next show could only be low down near sea-level.

The fissure in the flank of a dome gravitation closes more easily than a round pit in its summit. Hence the last voluminous fissure eruption was in the Kau desert in 1920, and the intense lava outpouring of 1921 was achieved through the round pit of Halemaumau. The Kau desert cracks were sealed and after the 1921 relief of pressure came downrush of the lava in the central pit, followed by recoveries and more Halemaumau risings, with weak fissure escapades of lava frothing on the Puna rift during the two succeeding years.

After each outflow there were subsidences at Halemaumau, and since 1919 the subsidences have been destructive of the pit, enlarging its rim. Before that the overflows had filled niches and finally almost obliterated the

former pit by construction of a dome over it. The three great destructive lava sinkings were in November 1919, May 1922 and May 1924. All of these showed the undermining effects of steeper inner walls than before, faulting down concentric inner blocks of the pit rim, and along with this in 1919 a crack appeared across the pit, gaping open downward, and this gave the lava a vent to the flank of the mountain six miles away.

Accordant with the evidence of collapse at Kilauea is the evidence of southward tilting at the Observatory on the northern Kilauea slope. This would mean that the Observatory sector of the mountain is tipping toward the center and that the center is going down. The tilting has been progressively increasing since 1920, with spasms of increase during the Halemaumau collapses, amounting to 33 seconds in a month and a half during the crisis of May, 1922, and 35 seconds in southerly directions January to April, 1924. As will appear in the May Bulletin, this tilting to the south was destined to become colossal in the succeeding months.

Sectoral Downbreak.

The Hawaiian mechanism of downbreaking in decadent volcanoes is by the slipping down of fault blocks as sectors of the round mountain domes. These sectors may be very open affairs or they may be bounded by right angles as in the eastern block that created Haleakala crater by subsiding eastward. Both Kilauea and Mauna Loa are ruptured by rifts that meet at an open angle at the summit. This open downbreaking sector forms for Kilauea the S.SE flank of the mountain. Through the ages at Keauhou the fault-blocks are slipping down toward the sea in steps, by the 1868 earthquake that shoreline was submerged as an incident of the grand progress, the Kilauea crater corner is merely another higher tread in the flight of steps, and the crater itself is a caved-in triangular block at the top of the sector.

Kapoho Fault Block Over Subsiding Lava.

The April crisis at Kapoho, far down the northeastern rift of Kilauea, appears to have been another stage in the breaking down of the mountain, and probably a final stage in the lava subsidence of the decade. The rift zones are made up of many cracks with broken blocks of country rock between them. What inflation of the underground cracks with gas and lava remained from 1923, took effect at Halemaumau in the revival of December, 1923 and the big lava lake of January, 1924. At those times there was probably lava in the cracks under Kapoho, just as we know there was in the same rift higher up near Makaopuhi five months before; this was still making hot sulphur gases.

The culmination of swarms of earthquakes, subsidence at the Kula fault block and cracking open of the rock at the Kapoho hinge-line April 23rd, was followed by a survey that indicated the whole block of rift ground south of the fault cliff had subsided all the way to the sea and with reference to sea-level. The motion had been felt most right in the fault block, and was notably little felt north and south of it. The fault block for four or five miles along its length had gone down ten or twelve feet on its north side and a foot or two on its south side a mile away. This was one of the broken blocks of country rock between rift cracks. It was the eastern extremity of the rift zone where it passes under the sea. Immediately after the Kapoho subsidence Halemaumau renewed its subsidence also. This developed into a big explosive eruption, with more subsidence.

As there was no heat or fume or lava at Kapoho, and no swelling up, all the evidence seems to point to a draining inward of the underground lava occupying the rift, from Puna towards Halemaumau. This was begun by set-



Figure 4. April 23, 1924, from hill at Cinder Quarry, Kapoho, looking across sunken belt to the north. Kula fault cliff crosses picture from side to side, with the field of subsided land in front of it. Only a fraction of the subsidence shown happened in 1924. Photo Emerson.

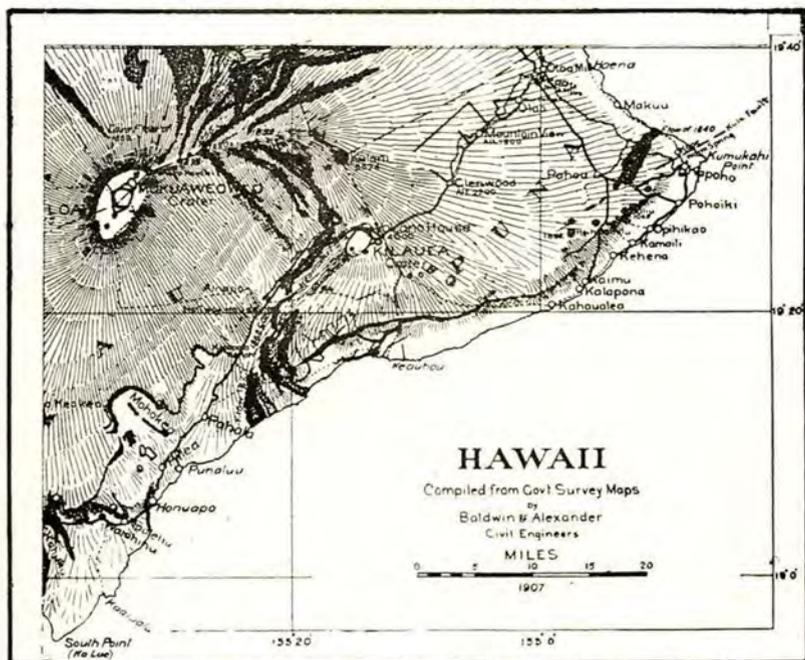


Figure 5. Map of Southeastern Hawaii showing Kilauea and the Puna fault cliffs extending northeast to the Kula fault which moved in April, 1924. Makaopuhi is near the letter P of Puna. Malama and Puulena are near Opihikao.



Figure 6. June 19, 1924, Kapele lagoon, with drowned palms, formed by the subsidence of April, 1924, on the east end of the Kula fault block. The butts of the cocoanuts were lowered about twelve feet. Photo Finch.



Figure 7. Looking northeast along new cracks at Kapoho. One of the cones on the rift zone shown. This is the hinge line of the subsided block, which lies to the left. Photo Maehara.



Figure 8. April 23, 1924, the great fracture on the Kula fault while motion was in progress. The road crossing the fault near Koahe, (Eldart's). Down throw is on the left. Photo Emerson.



Figure 9. April 23, 1924, the great Kula fracture at the railroad crossing where the drop was eight feet in April, 1924. Downthrow in foreground, new break on the left. The railroad track was left suspended. Photo Maehara.

tlement of the Puna country along the rift zone in March, with earthquake epicenters progressively farther northeast. The lava inside was lowering. The tilting evidence made the settlement of May greater than April, April greater than March, March greater than either February or January. The Kapoho incident appears to be one additional proof that the fractures of the rift systems fill themselves with subterranean lava, and this lava from the central shafts may suddenly drain into or out of the fissures without appearing outside as a flow. Many of the sudden drainages of Halemaumau may have been occasioned by rapid opening and filling of these rifts underground, with a net increase in the bulk of the mountain above, but without any show of lava at the surface.

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April 5. At 5 p. m. there was no appreciable change in the volume of fume rising from the southern, southwestern and northern fumeroles but there was increase at the southeast and a very decided increase in fumes from the crags at the southwest chasm.

In the floor of Halemaumau there were few positive changes, but some rock falls were seen and additional talus had been accumulating at the foot of the northern wall. Glow was visible in a crack at the north-northeast side of the bottom area.

April 20. At 5 p. m. the general appearance of the pit remained as before, with moderately thick and strongly sulphurous fume being emitted from the southwest chasm and southeast, south and southwest vents. The northern source vent was not fuming. No fire could be detected through the smoke of the southeastern chimney.

Many avalanches were falling from the northern and western walls and during the term of inspection of the pit there was a constant pattering of small stones from many places. Much new talus had accumulated at the foot of the walls. A concrete bench mark at the northern rim known as the north station had been carried away by the avalanches where the whole rim had caved in.

April 24. Glow from the pit had been reported on the evening of the 23rd and at 8:10 p. m. of the 24th there was brilliant glow for a few minutes followed by duller glow thereafter.

From the rim the southeast and south source vents were glowing brilliantly, the southeastern one light pink in color inside the well where splashing lava could be heard. The flaring of the glow coincided with increased noises of splashing.

April 30. At 9 a. m. the fume from Halemaumau was notably thinner than on the 28th, especially from the southeast vents which were now almost clear. Marked increase of subsidence had begun on the 29th and was now in progress in the northeast part of the floor just east of the north pool sink. This whole section had dropped in funnel shape, its bottom lying about 500 feet below rim of pit. The eastern part of the north pool sink had merged with the greater funnel. During the whole forenoon there was a constant rattle of small avalanches. Occasionally matter could be seen peeling off the eastern side of the depression near the southeast vent, leaving a glowing paste of what appeared to be aa lava.

LAVA MEASUREMENTS

The smoky bottom of Halemaumau was not measured in April but remained at from 375 to a little over 400 feet below the northeast rim until the last few days of the month, when the great subsidence began which carried its lowest point on April 30 to about 500 feet below this station.

SEISMOMETRIC RECORD

During the month ended midnight April 30, 1924, 358 local earthquakes and one teleseism were registered at the Observatory. These and other earth movements are exhibited below. Time is Hawaiian Standard, 10 h. 30 min. slower than Greenwich.

Local Earthquakes.

Abbreviations have meanings as follows: vf=very feeble; f=feeble; s=slight; m=moderate; d=instruments dismantled; fl=felt locally; and * =indicated distance in miles.

April 2—	7:45 a. m., vf		2:07 p. m., vf
3—	7:01 p. m., vf		4:24 p. m., vf
5—	1:44 a. m., vf		7:19 p. m., vf
	8:39 p. m., vf		8:00 p. m., vf
6—	11:04 p. m., vf		8:36 p. m., vf
7—	12:14 a. m., vf		9:07 p. m., vf
	1:23 p. m., vf		9:30 p. m., vf
8—	11:17 p. m., vf		9:36 p. m., vf
	11:58 p. m., vf		9:57 p. m., vf
10—	10:46 p. m., s, *9 fl, and		10:06 p. m., vf
	in Hilo.		10:12 p. m., vf
11—	11:24 a. m., *9, felt in		10:16 p. m., vf
	Hilo.		10:29 p. m., vf
12—	11:34 a. m., vf		10:40 p. m., vf
	11:49 p. m., vf		11:17 p. m., vf
14—	11:59 a. m., vf		11:27 p. m., vf
	11:40 p. m., vf		11:44 p. m., vf
16—	6:46 a. m., vf		11:57 p. m., vf
17—	1:53 a. m., vf	22—	12:18 a. m., vf
	2:14 a. m., vf		12:30 a. m., vf
	3:51 a. m., vf	•	12:36 a. m., vf
	6:04 a. m., vf		12:45 a. m., vf
18—	2:17 p. m., vf		12:49 a. m., vf
	2:18 p. m., vf		1:34 a. m., vf
	10:52 p. m., s, *9 fl.		1:53 a. m., vf
19—	12:16 a. m., vf		2:10 a. m., vf
	4:35 a. m., vf		2:54 a. m., vf
	6:02 a. m., vf		3:11 a. m., vf
	7:23 a. m., s		3:15 a. m., vf
	8:05 a. m., vf		3:29 a. m., vf
	6:28 p. m., vf		4:09 a. m., vf
20—	11:37 a. m., vf		5:01 a. m., vf
	11:42 a. m., vf		5:16 a. m., vf
	2:13 p. m., vf		1:06 p. m., vf
	4:12 p. m., vf		2:02 p. m., vf
	4:13 p. m., vf		2:25 p. m., vf
	9:10 p. m., vf		3:27 p. m., vf
21—	1:18 a. m., vf		3:56 p. m., vf
	2:03 a. m., vf		4:23 p. m., vf
	2:23 a. m., vf		4:34 p. m., vf
	2:57 a. m., vf		5:34 p. m., vf
	3:36 a. m., vf		5:42 p. m., vf
	5:52 a. m., vf		6:21 p. m., vf
	8:18 a. m., vf		6:23 p. m., vf
	9:03 a. m., vf		6:45 p. m., vf
	9:58 a. m., vf		6:59 p. m., vf
	11:48 a. m., vf		7:04 p. m., vf

April 22— 7:06 p. m., vf

7:13 p. m., vf

7:42 p. m., vf

7:47 p. m., vf

7:58 p. m., vf

8:01 p. m., vf

8:03 p. m., vf

8:28 p. m., vf

8:40 p. m., vf

8:50 p. m., vf

9:00 p. m., vf

9:02 p. m., vf

10:07 p. m., f, ♣27

10:10 p. m., vf

10:31 p. m., f

10:50 p. m., vf

11:46 p. m., vf

11:48 p. m., vf

11:54 p. m., vf

23—12:25 a. m., vf

12:34 a. m., vf

12:53 a. m., vf

1:09 a. m., vf

1:11 a. m., f

1:56 a. m., vf

2:16 a. m., vf

2:19 a. m., vf

2:21 a. m., vf

2:43 a. m., vf

2:44 a. m., vf

3:01 a. m., f

3:05 a. m., vf

3:09 a. m., vf

3:13 a. m., vf

3:43 a. m., vf

3:45 a. m., vf

3:47 a. m., vf

3:59 a. m., vf

4:24 a. m., vf

4:25 a. m., vf

4:28 a. m., vf

5:00 a. m., f

5:04 a. m., vf

5:21 a. m., vf

5:23 a. m., vf

5:34 a. m., vf

5:37 a. m., vf

6:00 a. m., vf

6:05 a. m., vf

6:20 a. m., vf

6:41 a. m., vf

6:43 a. m., vf

6:47 a. m., vf

6:54 a. m., vf

7:39 a. m., vf

7:40 a. m., vf

7:49 a. m., vf

8:05 a. m., vf

8:10 a. m., vf

8:18 a. m., vf

8:20 a. m., vf

8:27 a. m., vf

8:40 a. m., vf

8:44 a. m., vf

9:03 a. m., vf

9:06 a. m., vf

9:54 a. m., vf

9:57 a. m., vf

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11:56 a. m., f

12:12 p. m., vf

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12:22 p. m., vf

12:32 p. m., vf

12:44 p. m., vf

12:50 p. m., vf

1:04 p. m., vf

1:08 p. m., vf

1:20 p. m., vf

1:22 p. m., vf

1:24 p. m., vf

1:28 p. m., vf

2:05 p. m., vf

2:09 p. m., vf

2:11 p. m., vf

2:29 p. m., f, ♣30

2:40 p. m., vf

3:03 p. m., vf

3:04 p. m., vf

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3:42 p. m., vf

3:48 p. m., vf

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4:07 p. m., f

4:17 p. m., vf

4:23 p. m., vf

4:37 p. m., vf

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5:03 p. m., vf

5:15 p. m., vf

5:27 p. m., vf

5:31 p. m., f

5:36 p. m., vf

April 23— 5:57 p. m., f
6:00 p. m., f
6:14 p. m., f
6:27 p. m., vf
6:36 p. m., vf
6:48 p. m., vf
6:51 p. m., vf
6:58 p. m., vf
7:05 p. m., vf
7:14 p. m., vf
7:17 p. m., vf
7:27 p. m., f
7:37 p. m., f
7:56 p. m., vf
8:04 p. m., vf
8:13 p. m., vf
8:20 p. m., vf
8:22 p. m., vf
8:26 p. m., vf
8:28 p. m., vf
8:54 p. m., vf
9:06 p. m., vf
9:07 p. m., vf
9:33 p. m., f
10:05 p. m., f
10:20 p. m., vf
10:21 p. m., vf
10:27 p. m., vf
10:38 p. m., f
10:52 p. m., vf
10:57 p. m., vf
11:14 p. m., vf
11:22 p. m., f
11:46 p. m., f
24—12:49 a. m., vf
1:11 a. m., f
1:29 a. m., vf
1:44 a. m., vf
1:52 a. m., vf
3:34 a. m., vf
3:40 a. m., vf
3:50 a. m., vf
6:14 a. m., f
6:31 a. m., vf
7:18 a. m., vf
7:29 a. m., vf
7:34 a. m., f, ✧30
8:04 a. m., f
9:04 a. m., f
9:36 a. m., f
10:27 a. m., f
10:36 a. m., vf
11:09 a. m., vf
11:27 a. m., vf
12:03 p. m., vf
12:09 p. m., vf
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12:49 p. m., vf
1:07 p. m., vf

1:10 p. m., vf
1:59 p. m., vf
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2:33 p. m., vf
3:08 p. m., f
3:45 p. m., vf
3:52 p. m., vf
4:16 p. m., vf
4:18 p. m., vf
4:26 p. m., vf
4:47 p. m., vf
5:25 p. m., vf
6:20 p. m., vf
6:21 p. m., f
7:00 p. m., f, ✧30
7:54 p. m., f
11:05 p. m., vf
11:08 p. m., vf
11:13 p. m., vf
25— 4:22 a. m., vf
5:29 a. m., vf
8:10 a. m., vf
10:22 a. m., f
11:47 a. m., vf
1:10 p. m., f
3:29 p. m., vf
5:51 p. m., vf
6:59 p. m., f
8:02 p. m., f
10:53 p. m., vf
26—12:31 a. m., f, ✧30
2:25 a. m., vf
27— 1:52 p. m., s, ✧9
28— 3:53 a. m., vf
4:01 a. m., vf
5:57 a. m., vf
6:00 a. m., vf
8:36 a. m., f
9:12 a. m., vf
9:28 a. m., vf
10:14 a. m., vf
10:44 a. m., vf
10:53 a. m., f
10:55 a. m., f
10:57 a. m., vf
11:01 a. m., vf
11:35 a. m., s, ✧27
11:45 a. m., vf
11:48 a. m., f
2:01 p. m., vf
2:49 p. m., vf
3:00 p. m., vf
5:24 p. m., vf
6:58 p. m., vf
7:54 p. m., vf
9:28 p. m., vf
10:31 p. m., vf
11:10 p. m., vf
11:33 p. m., vf, ✧2

April 28—11:47 p. m., vf	9:06 a. m., vf
29—12:07 a. m., f	9:46 a. m., vf
4:38 a. m., f	10:00 a. m., vf
9:55 p. m., f	10:41 a. m., vf
30—12:42 a. m., f, ✧2	4:25 p. m., vf
12:43 a. m., f, ✧2	5:03 p. m., vf
2:57 a. m., vf	5:18 p. m., vf
3:29 a. m., vf	6:27 p. m., vf
3:30 a. m., f	6:30 p. m., vf
3:31 a. m., f	10:14 p. m., vf
3:32 a. m., f	10:50 p. m., vf
3:43 a. m., vf	10:53 p. m., vf
4:05 a. m., vf	10:56 p. m., vf
4:30 a. m., vf	10:58 p. m., vf
7:43 a. m., vf	11:22 p. m., vf

Teleseism.

April 14, 1924.....6:02 a. m., s. 5930 mi.

Spasmodic Microtremor.

This type of tremor was slight throughout the month.

Harmonic Microtremor.

This type of tremor was slight on the 29th and 30th and scarcely detectable on other days.

Microseismic Motion.

The amplitude of microseisms was moderate to strong on the 6th, 7th, and 8th and slight on other days.

Tilting of the Ground.

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

March 30-April 5.....	0.3 second NW.
April 6-12.....	5.9 seconds SSW.
13-19.....	2.8 " SSE.
20-26.....	1.0 second S.
27-May 3.....	3.8 seconds SSW.

T. A. JAGGAR,
Volcanologist.

U. S. DEPARTMENT OF AGRICULTURE
Weather Bureau
CHARLES F. MARVIN, Chief
MONTHLY BULLETIN
OF THE
HAWAIIAN VOLCANO OBSERVATORY

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FOREWORD

The Director of the Observatory takes this opportunity to express keen appreciation and gratitude to the workers who made this record in face of danger. He was summoned back by telegraph from work in New York, arriving in Hawaii May 28. The burden of responsibility fell on Mr. R. H. Finch, seismologist at the station and acting director, assisted by Mr. O. H. Emerson, research fellow of the Hawaiian Volcano Research Association.

I have to thank also the following visitors and residents for assistance in taking notes during the night and day watches at the Observatory during the time of crisis: W. J. Belknap, Superintendent Thomas Boles, Allen Burdick, W. O. Clark, Theodore Dranga, Jr., F. L. Durning, Mrs. R. H. Finch,

Vern Hinkley, Dr. P. H. Kirkpatrick, Lieutenant C. S. Lawrence, Professor Harold Palmer, Captain Charles H. Perkins, Samuel S. Rolph, W. B. Stoddard, Dr. C. K. Wentworth.

VOLCANIC CONDITIONS IN MAY

Activity of Halemaumau.

An increase of glow had occurred in Halemaumau pit while the swarm of earthquakes at Kapoho in Puna was in progress, and on April 28 there was a second small spasm of quaking at Kapoho, without any indication, however, of a subterranean lava flow. At the beginning of May the subsidence of the bottom of Halemaumau that had commenced April 29 continued so that the lowest point was over 600 feet below the rim, with avalanche material from the former floor and from the walls continually rolling into a funnel at the northeast part of the bottom. The instrumental frequency of earthquakes increased early in May and the tremor suggested underground lava surging from April 29 to May 4. This coupled with the subsidence in the pit implied lava drainage, but no outflow was anywhere reported.

During the second week of May Kilauea volcano entered upon an explosive phase, Halemaumau throwing out broken rock fragments during the early morning of May 11. This happened in the midst of uprush of dust clouds from avalanching such as had been observed here many times. The explosive activity was distinctly a function of subsidence and the rocks thrown out were wholly talus fragments of all sorts. The explosions increased in frequency, large rocks being hurled half a mile into the air and falling over a thousand feet from the pit, the debris of each explosion being largely confined to one sector of the ground encircling Halemaumau. Large segments of the rim fell in, including the long fault bench southwest. Numerous earthquakes were felt at the Observatory and still more were perceptible at Uwekahuna Bluff. Large quantities of dust and sand were deposited around Halemaumau and in the Kau Desert.

The eruption reached a maximum May 18 and the seismic maximum was reached May 24. The only loss of life occurred on May 18. There were two to eight principal explosions each day, with a surf-like roaring noise and great cauliflower clouds. Excessive tremor as distinct from earthquakes was recorded during the first few days only. The earthquakes were numerous and those accompanying the explosions tended to wax gradually to a maximum of vibration and then die away. Big black cauliflower clouds rose from the pit and developed electrical storms and pisolitic mud rain. Air concussion was felt with the larger explosions one to two seconds before the dust cloud cleared rim of pit, and several seconds before rocks were ejected. Avalanches continually enlarged the pit. The upper dust column reached a counter current and produced falls of sand or mud to windward with reference to the northeast trade wind, one of these sand falls at noon of the 17th lasting twenty-five minutes and carrying some lapilli. Rocks ejected were seen to be incandescent. Some boulders fell on the lower Uwekahuna terrace and others on the gravel flat near Keanakakoi. The circle of debris around Halemaumau had a radius of half a mile. The rocks ejected were without a trace of new lava. Many were crystalline, and some showed signs of surface heating. Cracks concentric and radial to the pit were developed on the Kilauea floor with much steaming. Noxious fume was absent. Hydrogen sulphide was perceptible as a new feature in the vapor, and as the explosions declined, rushing white steam apparently replaced the dust-charged clouds.

Toward the end of the month the explosive eruption was gradually replaced by intense seismicity, strong avalanches and development of steam clouds.

Avalanching was very pronounced May 21, rock showers signifying deep explosion were seen May 22, 23, and 24. Thunder and lightning developed in the eruption cloud twice on May 22, twice May 23, once May 24 and a last time May 25. The eruption 9:14 a. m. May 24 made trajectories of broken rocks 3000 feet high, the dust cloud was over 6000 feet high and after four or five major explosions lasting twenty minutes a heavy deposit of ash had been added to the country north and south of the pit.

Inspection at night May 27 revealed no glowing matter. Luminous flashes were seen over the pit May 21, suggesting gas combustion, but usually such flashes could be traced to lightning. Earthquake frequency declined rapidly at the end of the month. Southward tilting seismographically measured was intense throughout the eruption, conforming to the evidence at the eruption center of inward breaking and subsidence.

DISCUSSION OF SPECIAL FEATURES

Volcanic Phenomena of the Eruption

By T. A. Jaggar

Comparison with Kilauea Eruption 1790

In a lecture by T. A. Jaggar published in this Bulletin, January 1918, page 15, occur the following sentences: "Hawaii has had explosion and volcanic blast, in 1790, from Kilauea crater, when the soldiers of Keoua and their families and cattle were suffocated and burned. In a repetition of that event the damage would extend further to leeward than to windward, fine sand would fall at Glenwood, and dust would fall at Hilo. During trade winds the heavy ash fall would be in the Kau direction."

"In considering the menace of volcanic disaster, common intervals between great crises are in multiples of 65 years. One hundred and thirty years is a common interval. 1920 will be 65 years since the tremendous activity of 1855 for both Kilauea and Mauna Loa, 1920 will be 130 years since Kilauea exploded and threw all the great rocks which one sees near Keanakakoi. And we know nothing of the duration of that series of explosions, nor of the lava flows and earthquakes of the period, nor of the activity of Mauna Loa."

"I do not pretend to predict anything portentous for the year 1920, but merely call attention to the sequence, the 65-year cycle having interested us, as discussed in Mr. Wood's paper on "Cyclical variations of Kilauea activity," the second report of the Observatory. (Cambridge, Mass. 1917.)"

"Danger means (1) Explosion and suffocation, destruction by burial of houses under sand and stones, destruction by tornado blasts from a crater, or loss of life by direct bombardment from flying or falling stones. Falling in of roofs may be occasioned by gradual accumulation of dust or sand at some distance from the volcano."

Other dangers to be expected from volcanoes are mentioned as (2) lava flows, (3) earthquakes and (4) tidal waves. In this Bulletin for June, July (page 114), and October, 1921, will be found accounts of the explosive eruption of 1790 and the ash and footprints left therefrom. There were numerous explosive eruptions from Kilauea before 1790 as shown by numerous ash beds with layers of vegetation in between and in some cases with thick strata of lava in between. There was ash fall in Hilo in 1924.

In the article cited above the writer expressed the view that great damage to the country roundabout might be done by a repetition of eruption on the scale of 1790. He is still of that view and all the results of the eruption of May, 1924, indicate that the intensity of explosion, height of dust

clouds, distance of rock throwing, overwhelming power of lateral blasts, size of rocks for the same distance, and thickness of deposits are much less in 1924 than they were in 1790.

Our ignorance of the context in the unwritten history of the last decade of the eighteenth century in Hawaii is unfortunate, and we can build up an hypothesis of what were the phenomena precedent to the 1790 eruption only by comparing what preceded 1924. The quality of the explosive phenomena of 1924 was undoubtedly the same, violent gas rushes carrying dust, sand and boulders, accompanied by thunder, lightning and mud rain, (the latter falling as pisolites or pea-like semi-solid droplets,) black clouds that shut out the light of day, earthquakes, and the killing of people by volleys of stones.

Both the descriptions and the effects of the 1790 phenomena present three happenings that did not occur in 1924. (1) There rose a column of dense black smoke, "followed by the most brilliant flames, and streams of lava spouted up in fountains." (2) Bombs fell in 1790 and may now be collected 2000 to 4000 feet from the eruptive center, which are characterized by coatings of black lava encasing rock fragments. These corroborate the lava fountain story, and neither lava-coated bombs nor lava fountains occurred in May, 1924. There were incandescent stones in 1924, but the fragments that show glazed and heat-cracked surfaces are crystalline intrusive types of rock; a large red hot intrusive body not ordinary lava was left showing in the wall of the pit; and it seems likely that the glowing stones were pieces of such intrusive bodies exposed by the eruption and the collapsing pit. (3) A third phenomenon that did not happen in 1924 was the overwhelming of people by ash suffocation and scorching heat some miles away. This is what happened to Keoua's party, just as it happened at Tarawera in New Zealand, at Pele' in Martinique, and at Taal in Luzon.

These volcanoes, notably Pele', produced outrushing lateral blasts, an effect that is probably coupled with vortical phenomena of tornado intensity, like the avalanche blasts of the Tyrol. The most common-sense explanation of these blasts is that the millions of tons of heavy debris falling back on a slope displace the air in an outward-rushing whirl of tremendous violence, added to by incalculable heat effects. The element of slope is possibly important. The 1790 eruption was so much more violent than the 1924 that the heavy backfall of rocks overtopped the Uwekahuna Bluff and may have sent a blast downward to the southwest. The stones barely reached the lower terrace of Uwekahuna in 1924.

The year 1919-1920 duly produced a culmination of big eruption in both Mauna Loa and Kilauea for the current cycle, with the explosive fountaining of the Alike flow source, the building of the big lava hill of Mauna Iki, and the pouring of lava floods across country on both Kilauea and Mauna Loa, the last named for six weeks, and the former pushing across the Kau Desert for several months. All of this accompanied other lava floods of the decade in immense volume in the two big craters and in Puna and Kau, in 1914, 1916, 1918-21, 1922 and 1923. The curve of rising activity (see Monthly Weather Review, March 1924, page 145, diagram) culminated in 1918-20, beginning in 1913 for the current cycle, and declined after 1921 in a series of collapses of Halemaumau pit, whereby the pit was enlarged and the lava sank away to lower and lower levels.

And the pit itself more than doubled the depression reached in 1913 and the enlargement of the pit to 3400 feet for its longer dimension and 1330 feet of depth exceeded anything on record for the innermost cup now called Halemaumau. We have no clear record, however, identifying Halemaumau prior to 1840. Before that time the inner pit of Kilauea meant a very large area with certain lakes and cones inside of it and a black ledge outside of

it. This area after the drainage of 1823 was according to Dana 1500 or 1700 feet below the Uwekahuna summit. The present bottom of Halemaumau is over 1700 feet below that summit. If there was a second innermost pit in 1823 or thereabouts, its bottom may have been still lower at times. It is probable that the large low-lying inner area of Kilauea was what was left by a very big collapse in the explosions of the 1790 cycle. The most significant fact of the comparison with 1924 is that 1790 must have been a time of collapse after constructive activity that preceded, and not as hitherto imagined (this Bulletin July, 1921, top page 115) following a long spell of quiescence.

The forecast for 1920 then was satisfactory in justifying the sixty-five year interval. The date "1790" is only an approximation arrived at by native memories, but we know that 1855 was the middle of a cycle of strong building up of the Kilauea floor alternating with the longest Mauna Loa flows of the nineteenth century. The collapses of Halemaumau between 1920 and 1924 ending to date with the May explosions are doubtless the equivalent of what happened before the 1790 crisis, and if the latter was a great slumping of Kilauea crater as seems probable, then there must have been strong lava outpouring in the decade preceding.

Were there lava flows about the 1790 period? Hitchcock (Hawaii and its Volcanoes, page 80) concludes that Mokuaweoweo the summit crater of Mauna Loa showed less activity after 1780 and before 1832 than in the decades since. This statement appears to me unsupported in view of the remoteness of Mauna Loa, the imperfect records even today, and the fact that there are some records even for that unrecorded time. For the whole system Hualalai-Mokuaweoweo-Kilauea there were certainly lava flows between 1780 and 1801. Hitchcock on the same page says the natives told Wilkes in 1840 that the northern Mokuaweoweo pit had been active about 1780, that another authority had reported a Mauna Loa eruption shortly after the death of Captain Cook (1779), and that Turnbull had seen eruptions from the west side of Hawaii in 1803. There was an abundant flood of lava from several sources northwest from Hualalai in 1800-01. Ellis in his "Narrative of a tour through Hawaii" (Honolulu, 1917, Advertiser Publishing Co. pages 214 and 217) describes volcanic eruptions in the Malama district of Puna in two different portions of his text, possibly the same, but disagreeing in date, and Hitchcock arrives at still a third date for Puna lava flow. Hitchcock's reference to 1788, thirty-five years before the missionary party with Ellis was at Kilauea, disagrees with Ellis who refers to the Malama country overflowed with lava "about thirty years since". He was writing in 1823. In Ellis' second reference he describes an immense torrent of lava obstructed by the Honuaula, Malama and Maliu cones, which inundated the country in the days of Kalaniopuu, who died in 1782.

If we put all these references in series we get the following:

- (1) Puna lava flow before 1782.
- (2) Lava north of Mokuaweoweo about 1780.
- (3) Puna lava flow 1788.
- (4) Kilauea explosive eruption about 1789-90.
- (5) Puna lava flow 1793.
- (6) Hualalai lava flows 1800-01.
- (7) "Eruptions" seen from west of Hawaii 1803.
- (8) Big Kapapala lava flow 1823.

As the omissions for this period are unquestionably more numerous than the records, everything indicates that the Hawaiian volcanic system was quite as much a producer of continuous activity in the early days as at present.

In this connection, and with the explosions of May, 1924, in mind a new interest is given to the exact words of the careful paragraph written by Ellis (page 184) summarizing what he gathered from the natives, seated

around the camp-fire on the Kilauea rim in 1823. "The volcano had been burning from time immemorial and had overflowed some part of the country during the reign of every king that had governed Hawaii: in earlier ages it used to boil up, overflow its banks, and inundate the adjacent country; but for many kings' reigns past, it had kept below the level of the surrounding plain, continually extending its surface and increasing its depth, and occasionally throwing up, with violent explosion, huge rocks or red hot stones. These eruptions they said were always accompanied by dreadful earthquakes, loud claps of thunder, with vivid and quick-succeeding lightning. No great explosion, they added, had taken place since the days of Keoua; but many places near the sea had since been overflowed, on which occasions they supposed Pele went by a road underground from her house in the crater to the shore." This appears to hint at a prolonged widening and deepening of Kilauea crater, at repeated explosive eruptions, and at repeated rift flows near the sea after the big explosion of Keoua's time.

The idea that the 1790 crisis was an eruption after dormancy may as well be abandoned, and I think that the same thing is true in a measure of Vesuvius in the year 79 A. D. The Pompeian eruption may have found the Vesuvian cone quiet, but Epomeo volcano in Ischia had been active, and all a part of the same system. Probably Kilauea and Mauna Loa and Hualalai had shifted their activities back and forth, Kilauea had been enlarging and collapsing at the end of a long period of construction and upbuilding, flows poured out in the districts of Hilo, Puna, Kau and Kona, and the internal lava at the end of a final vigorous cycle of activity that had begun at Mokuaweoweo about 1780, had now lowered to sea-level in Puna and below the internal ground-water level in Halemaumau. This would couple superficial steam-chamber action with a plugged pit above and hot lava below and bring about a secondary series of explosions after the primary lava-and-gas effervescences had declined. Such has probably been the action in 1924.

It is of interest to note that an interval of about thirty-three years (one half of sixty-five) elapsed between 1790 and the tremendous activity of 1823, when also there was explosion along the Keaiwa crack whence came the great Kapapala flow of that year. The topographers of the United States Geological Survey have mapped a locality three miles east-southeast of Pahala where about 280 feet above the sea broken talus fragments of all sorts are strewn around the crack grading off to gravel, sand and dust a few hundred feet from the opening. There is another similar place along the crack farther north about 700 feet above the sea. The broken material is not piled high, some of it is embedded in contemporaneous lava sputter, it looks almost exactly like the fields of debris ejected by Halemaumau this year, 1924, except for the contemporaneous lava, and its relation to the underground lava is perfectly exhibited. This lava emerged from the crack in large volumes all along a continuous fissure for six miles to the north, the volume diminishing to the south, the lava there being replaced by these explosion holes along the crack. The indication is that the crack, forced open by the lava above, broke down by block faulting along parallel fissures, the lava supply gave out in this direction above ground but continued for a short distance underground, and when the lava withdrew at the end of the eruptive period it here formed an underground steam-chamber between the plugged crack and the subterranean water level which is very close to sea level. The underground water closed in over the hot lava, boiled, and forced an exit through the cracks, carrying rock debris with it.

Many such places are beginning to be discovered in Hawaii near pits, cones and eruptive cracks, and indeed the explosion cones, formed where lava flows entered the sea are not very different, except that there the fragments and sand are mostly made of the hot lava itself.

The year 1823, then, yielded a big Kilauea "eruption" in the sense in which Dana used this term, meaning a drainage and collapse after a time of accumulation in the summit crater. Strong earthquake with sulphurous gases and cracking in lower Puna occurred. Thirty-two years later brings us to 1855, and thirty-two years after that to 1887, a time of immense crisis after great upbuilding at Kilauea followed by collapse, along with earthquake and a big lava flow from Mauna Loa. The next thirty-three years takes us to 1920, the culminating year of the present cycle. For Vesuvius about thirty-three years is a common interval between great crises (1872-1906). It would appear then, and this agrees with Omori's work in Japan, that 130, 65 and $32\frac{1}{2}$ years are intervals significant in volcanism.

The feature characteristic of a great "eruption" is the final sinking away of the lava fluids into the depths after a prolonged rising which has occupied many years. That this sinking produces violent phenomena is due to the lava itself only to such extent as the first releases of pressure induce gas effervescence and intense heat. The big earthquakes, breakdown of crater walls, avalanches, dust clouds, ejection of broken rocks and outrush of powerful steam jets may all be due to meteoric waters and gravity asserting themselves after both have been opposed and resisted for years by an upward and outward lava pressure.

The notion that sea-water gets into a volcanic pocket and creates explosion in a volcano on land is opposed by all the principles of hydrostatics. However low the groundwater level in a land that is rained on, its level is higher than sea-level. All around southern Hawaii fresh water seepage is found along the shores. If faulting mechanism opened a fissure, fresh water would pour out, not sea-water in. The fresh water is in adjustment to the heat of the underground lava most of the time, doubtless driven back by that heat from the enclosing shells of lava around the conduit shaft, or from the sides of the dykes, to a distance determined by the conductivity of the rock and by the temperature. Diffusion of the steam into the magma gas is possible according to the balance of pressures. But even supposing an accident that would suddenly admit cold water against live lava by the opening of a fissure, the fact of the opening would send the water back whence it came if steam were developed, and on the other hand the chill of the water would solidify the lava.

To produce explosion from the crater with outside water, the mechanism must import the water, confine it, and heat it too rapidly for quiet escape. These conditions appear to be fulfilled when a lava column sinks suddenly with intense effervescence and gas-heating of its shaft. Crater collapse plugs the upper vent with a tremendous weight of talus. The same collapse opens water-ways to the shaft above the lava and below the plug. The water rushes in because it is under a high groundwater head. Possibly mud, with continued settlement of the mountain, closes off the waterways, or some seismic pumping, partially closing them, sets in.

An enormous pressure develops under the talus plug, the vapor rushes up around the borders of the plug, and a certain rhythmic process is produced for weeks, a geyser of earth and stones and dust and sand. The lava keeps the furnace going as long as releases of pressure supply it with gases. The water keeps replenished as long as steam makes and escapes. The eruption keeps going as long as lava and water keep up the steam pressure. Water and lava finally enter upon their old adjustment, possibly by lava cooling, becoming viscous and rising sluggishly into the boiler, making a watertight shell about itself. For the time its heat supply is depleted. The lava pressure, however, is again apportioned through the fissure-system to some support of the country above. Collapse declines gradually, and everything is ready for the next application of "ascensive force," to use Dana's term.

The writer suggests this explanation with all diffidence and without prejudice. His own preference by previous experience would have been for explaining paroxysmal explosion by hydrogen and deep gasses. He was surprised on reviewing the evidence to find Kilauea which is notably a lava-gas volcano, in May, 1924, blasting out broken rocks in a succession of steam rushes without any lava, with practically no lava-gas and behaving much like Bandaisan in Japan. He was further surprised to see this explosion come at the extreme end of collapse after a lava cycle, instead of inaugurating the collapse and final lava flow as in Vesuvius in 1906. The Keaiwa crack explosions of 1823 and other similar purely dynamic happenings shown in the old exposures were now explained. The analogy with what a lava flow does when it enters the sea and confines itself by an encasing shell was close, and as in this case the underground water is an extraneous agent superficially encountered, and its work is no more volcanism in the deep sense than is the splash of the mud rains. Such explosive work and release of pressure, however, directly affecting a volcanic edifice at its very core, give new meaning to the relationship of the boiling spring mechanism of Waimangu Geyser in New Zealand to the long dormant Tarawera, or of the hot springs and underground water circulation of Japan to Bandaisan. The eruptions of Waimangu since 1887 have been semi-volcanic. One can easily imagine gradations in gas release to explosive fountaining through such stages as

- (1) Kilauea without bombs or lava in 1924.
- (2) Kilauea with bombs and lava in 1790.
- (3) Sakurajima with explosion, many bombs and stiff lava flows in 1914.
- (4) Mauna Loa with gas rushes, gas fountains and frothy lava flows in 1919.
- (5) Kilauea with quiet viscous fountaining lava.

The most fundamental contribution which this explanation of the action of Kilauea would make to volcanology if true is that it sharply divides paroxysmal explosive eruption from true volcanism. By true volcanism is meant that process which is inherited from the pristine earth and its gases without the intervention of atmospheric processes. This of course is carrying the analogy between Kilauea explosions as observed and all other great explosive eruptions to its extreme value. I can see no reason whatever for making an exception of it. It has been fashionable in some teaching to make an exception of it on account of its liquid lavas, on the supposition that Kilauea is not explosive at all. Now that it is proved explosive, there is certainly no reason for making an exception of its explosions.

In the series above outlined of gradations in gas release, there is implied a gas potential in the lava itself of different volcanoes, for which a casual explosion due to meteoric waters acts as trigger. In this case we get a geyser effect mixed with gas-lava fountaining effect. This is precisely what might be expected in any locality where the normal lava is rarely in the habit of exuding at the surface, but is much in the habit of intruding because of superjacent deposits. Volcanic eruption in such a place would be permitted to take the place of intrusion only when the underground accident of confined water and volcanic heat brought about destructive pressures under old craters. It seems likely that exactly this condition is prevalent under most of the andesitic volcanoes.

Sequence Leading to the May Crisis.

There has been mentioned above the possibility of various intervals controlling crises in volcanism dependent upon some astronomic cause. A nine year cycle for the Hawaiian system has been repeatedly mentioned and found useful since the days of William Lowthian Green. A discussion of the current cycle with diagram will be found in the Monthly Weather Review (March, 1924) article above mentioned, and my discussion in the April Bulletin re-

views the sequence which led to the Puna subsidence of that month. For the current cycle there was rising lava in the system from 1914 to 1919 and subsiding lava from 1920 to 1924. The southerly tilt discussed in April increased at the Observatory in May to 59 seconds for the month, an enormous bend in the tilt curve much greater than what happened during the collapse of May, 1922. The earthquakes also of May, 1924, numbering 3961, were much more frequent than in the 1922 crisis (690 shocks May-June). Sudden subsidences have always been times of maximum earthquakeing at the Kilauea station, indicating that gravity slips on fault planes are the main causes of the local shocks.

The parallelism to the events of May, 1922, was very striking, both crises exhibiting

- (1) Sinking of lava column.
- (2) Caving in and enlargement of Halemaumau.
- (3) Southerly tilting and many earthquakes at Observatory.
- (4) Avalanches and big cauliflower dust clouds.

Then as now a period of repose began with continued subsidence and adjustments during succeeding months.

The marked differences in May, 1924, only began after the cauliflower clouds had been rising for several days and there was added to the convectional uprush an uprush of gas accompanied by concussion on the ears, and where sand and dust had been rising before a force was demonstrated, capable of throwing out stones. These stones had every appearance of being subangular talus in large part, the early dust was reddish from oxidized upper lavas, the later dust grayish from fresh intrusive bodies revealed after the walls had broken down. That the force which hurled up boulders was largely attributable to steam was shown by rushing steam jets appearing in the closing stages of the eruption where they had been blackened by debris before, and by the entire absence of gas odors or gas effects, either far or near to leeward. The officers of the Observatory staff repeatedly made circuit of the pit during the eruptive period, at first with gas masks, which they found entirely unnecessary. Slight odor of sulphuretted hydrogen was perceived, and after the eruption some free sulphur of spicy smell, but even the usual sulphur dioxide of the Kilauea lava was absent, and persons who were caught in the dust clouds occasionally, reported no oppressive gases. These facts accord perfectly with what was observed by Perret on Vesuvius in the downrushing clouds of the paroxysmal eruption of 1906, the bad gas products of the crater being perceived chiefly during later stages after the lava flows had started.

We have no assurance that there was not some steam explosion entirely inside the Halemaumau cauldron, and on a small scale, in 1922. The after effects thunder and lightning, however, were not then observed. The difference in 1924 began when the arch or plug of fallen crushed ledges at a depth of a thousand feet or more in the pit impeded the egress of confined vapor that was generating somewhere below. In 1922 apparently no such vapor was generated or confined in any great amount.

Comparing what happened in April at the subsiding fault block near Kapoho in Puna with what succeeded in May at Halemaumau, we can do nothing more than make a guess. Possibly the hot lava in the fissure system was held up under Halemaumau until the opening of the rift zone at Puna by a yielding of the mountain. The Puna block dropped down and wedged open the crack. The center of the mountain at Halemaumau started to drop down in similar fashion. The lava column below poured back from Puna into the central void which had been created by the wedging open, the Halemaumau debris plugged that void above, deep frothing and surging of the lava far down released heat and the sea of ground water found innumerable earthquake cracks that had opened a way whereon it exerted its pressure to flow inward and downward on top of the receding lava.

Seismic Sequences of the Eruption

By R. H. Finch

The events leading up to the explosions of Kilauea caused no unusual apprehension as many of the happenings, southerly tilting, harmonic tremor indicating underground lava surging, numerous earthquakes, many of which were along the northeastern rift of Kilauea, where underground lava movement was suspected, and the subsidence of the Halemaumau floor, seemed closely to parallel events in May 1922.

Superficial examination of the seismograms up to and including the time of the first explosion that threw rocks seemed but to strengthen the analogy between May, 1922 and May, 1924. A closer examination of the seismograms showed a peculiar continuous tremor that was soon to be recognized as the characteristic graph of an explosion.

Harmonic tremor had been noticeably slight or absent since the disappearance of the molten lava in February. On April 29, just after the Puna earthquakes, when the possibility of a lava flow was still being considered, harmonic tremor became noticeable on the seismograms and continued until May 5th. During the subsidence of May, 1922, the harmonic tremor visibly increased on May 25th three days before the lava broke out in Makaopuhi.

On May 6th this year the harmonic tremor increased again later on, becoming moderate to strong and accompanied the explosions until May 16 on which date this type of tremor became very slight. If the harmonic tremor is due to lava surging, as seems probable, then possibly the molten lava had receded so far by May 17th that it failed to produce marked harmonic tremors at the Volcano Observatory two miles from the pit. Coincidental with the decrease in harmonic tremor the intensity of the explosions increased.

The tilt repeated on a grander scale the tilt of May, 1922. In 1922 the tilt started on May 20th and continued until June 6th, amounting to 19.8 seconds south-southwest, though the lava had started to fall on May 14. In 1924 the southerly tilt started in January and continued with only occasional slight north tilt until June 19th amounting to 88 seconds of arc. 69 seconds of this amount occurred from April 29 to June 19th. It is common to have southerly tilt here between January and some time in April. The direction of the tilt was again south-southwesterly as the westerly tilt that started on February 26 and stopped on June 17th amounted to 32 seconds of arc. Most of this amount, 27 seconds, occurred from April 23 to June 17th. The tilt here during spring and early summer months is normally westerly and much less than the amounts given above. The most rapid westerly tilt occurred on the same days as the most rapid southerly, just preceding, during, and immediately following the explosions.

The daily variation in the number of earthquakes does not show good correlation with the number of explosions. The maximum number of earthquakes on one day, 467 on May 24th, was well after the maximum of explosive activity. There was a distinct lull in the activity of Halemaumau on May 12th and the number of earthquakes correspondingly decreased. (See table in Seismometric Record.) An hour to hour plot does not show any striking correlation between number of earthquakes and individual explosions. If a shorter time interval is used the correlation is better as frequently most of the warning quakes occurred within the half hour preceding an explosion. The quakes accompanying the explosions gave long drawn out records that built up gradually, continued for a half a minute or so with a nearly uniform period of 0.4 to 0.5 second and then died down gradually. The record of individual earthquakes accompanying the larger explosions was usually masked by continuous tremor with a period of 0.4 to 0.5 seconds. The duration of this continuous tremor was usually a few minutes longer than the total duration of visible explosive activity.

None of the larger explosions occurred unheralded by the seismograph. Even the small puffs and explosion roars that threw but little or no dust above the pit rim left their records. The earthquake warnings, commencing in seismic lulls were from 10 to 15 minutes to two hours preceding explosions. The continuous tremor afforded a 2 to 5 minutes warning. The continuous tremor evidence, often without felt earthquakes, became so positive that observers in the seismograph room frequently called out that an explosion was coming 2 or 3 minutes before anything could be seen at the pit.

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May 1. At 10:30 a. m. the lowest point of the funnel of talus at the bottom of the pit was something over 500 feet below northeast station and continuous small avalanches rolled down the sides of the pit. Several red hot cracks were visible on the floor. Small clouds of smoke rose near the south source well and dense smoke at the southwest chasm, but no odor of fumes was noticeable at the eastern rim.

May 5. At 10 a. m. the subsidence of the bottom of Halemaumau continued, accompanied by frequent small avalanches. The northeastern funnel had now engulfed the sites of the north pool and the southeast well and was encroaching upon the south and southwest source wells. The bottom of the depression had become a trough tending west-northwest. Moderately thick fume rose from various vents.

May 6. The early afternoon was marked by a pronounced spasm of seismic disturbances with distances indicated by the seismograms corresponding with that of the Halemaumau center.

At 3 p. m. there were continuous avalanches into the big depression at the bottom of the pit, and this inner funnel was now enlarged to the southwest. Cracks around the pit rim were widening on the north, west, and southwestern sides. A large avalanche had just fallen from the west wall. The southwest fault bench, which merged with the upland towards the west, was now extended several hundred feet in that direction by slumping down bodily more than a foot along the fissure bounding it. At its eastern end this bench had tilted outward toward the pit leaving a small wedge block faulted down between it and the main wall.

Most of the fume in the pit rose from the south and southeast sides and was not specially dense but filled the cauldron owing to the eddy of a southerly wind. Cracks south-southwest of the pit were giving off much steam and some sulphur dioxide with formation of a yellow deposit. Fume had increased from the southwest pinnacles, a portion of the rim standing as towering crags opposite the southwest chasm left by the collapse of 1922.

May 7. At 11 a. m. the subsidence and avalanching continued unabated, including the whole center of the pit, the only important section of the original floor remaining being a sector some 300 feet wide along the west side. Bottom of funnel was now visible only from the northeast and appeared well over 600 feet deep. The southwest pinnacles were the main source of fume and vapor.

May 9. Subsidence was more rapid with continuous avalanches. During the morning bottom was visible but after noon pit was so full of smoke that nothing could be seen. Cracks back of rim appeared unchanged. During the forenoon heat at the rim was very noticeable and much glowing aa paste was visible where avalanches tore away large surfaces of the cliff faces remnant from the recent lava fill.

May 10. At 6:30 a. m. the volume of dust clouds rising from the pit had increased tremendously and made an impressive spectacle. At the edge of Halemaumau nothing was visible because of incessant rising of dust. Generally the outline of the dust cloud was soft, but occasionally it was very

hard. There was continuous roar from the avalanches, but no collapse of the outer walls.

May 11.. During the night preceding this date an explosion in the pit blew out rock fragments, so that in the morning a 400-pound block was found 200 feet from the rim, a 100-pound fragment 750 feet back, and a 20-pound boulder 900 feet back. The main deposits were on the north and northeast, a few fragments fell on all sides, and the minimum fall was west-northwest. Judging from evidence of bouncing, the trajectories had been nearly vertical, though some boulders showed horizontal plowing. The stones showed great variation in mineral content and structure, some were crystalline, some contained much hematite, and others were fine grained and flinty.

Avalanching continued all day with increased vigor, the top of the dust clouds reaching a height of 6000 feet. Inspection at 11 a. m. showed that the southwest fault bench was still in place, this being a high remnant of the upper rim dating from May, 1922. All the black floor from the January-February floods of 1924 was gone. Talus was observed some 700 feet down the western wall. On an iron stake at the southeastern trig station a mud of ash 1.5 inch thick was plastered and more or less cemented.

During the forenoon the thunderous noise of the avalanches was plainly audible at the northern bluff of Kilauea crater and the dust cloud made the whole sky to the south of Kilauea a deep purple amounting almost to blackness.

At 2:15 p. m. the whole southwest fault bench had fallen in but the pinnacles persisted about 300 feet high. Along the west side avalanches had carried back the rim about 100 feet. A crack 100 feet back of the southwest rim was visibly yawning open, sometimes as much as an inch in fifteen minutes. Earthquakes of quick period and decided vertical component were frequent and plainly felt, often lasting several seconds.

Observatory party spent night at Halemaumau. At 10 p. m. small quakes with faint rumbling were felt at northeast solfatara, part of the old encircling "Postal Rift."

May 12. At 2:10 a. m. there was very loud noise from avalanche. At 3:20 a. m. there were numerous earthquakes with loud rumbling at the road terminus. Party left the terminus at 3:40 a. m. and at Keanakakoi a noise like the puff of an explosion was heard at 3:55 a. m. and an earthquake felt at 4:05 a. m. Returning to the road terminus the noise from avalanches had increased but there was marked decrease in the dust column. There was no perceptible change in the rim. An earthquake was felt at 7 a. m. followed for a time by a dense dust cloud.

On this day the evolution of dust had lessened. A circuit of pit at 8:45 a. m. showed no further caving in of upper rim, but the two southwest pinnacles were greatly reduced in size. Avalanching was less, dust clouds had softer outlines but bottom of pit was not visible. Southwest crack seen in motion the previous day at 3 p. m., had widened only one half inch.

At 2 p. m. observers made circuit of pit equipped with gas masks and encountered several whirlwinds along south and southwest sides. There were some new notches of the rim south-southwest and southwest, but the greatest recession had been west-southwest. All the leeward rocks were plastered with dust solidified to a hard though friable mass.

May 13. Heavy cauliflower clouds rose from the pit in spasms at about the following times: 5:30 a. m., 7:10 a. m., 8 a. m., 9:35 a. m., 12:15 p. m., 1 p. m., 2:30 p. m. The last was accompanied by a report like distant blasting heard at the Observatory

At 10:15 a. m. a circuit of pit showed that further avalanching had carried away the south-southwest trig station and the nearby hot solfatara. The

southwest crack had widened one half inch in twenty-four hours. There had been some further ejection of rocks north and east, but a great series had been thrown out southwest. The falls covered a belt over 200 yards wide from rim of pit and in places the stones were so numerous that one could not walk without stepping on them. Most of them were small, but some weighed over 200 pounds. One was seen still hot with a temperature of about 60° C. A number of sharp reports were heard which may have been small explosions or avalanches.

2:30 p. m. came a cauliflower explosion cloud, accompanied with a clap of thunder and lightning, and at 2:35 p. m. south rim of pit was observed with telemeter telescope to have fallen in.

There now began a series of violent explosions for ten days and observations were maintained at Uwekahuna Bluff and at the Observatory almost continuously, and the region of the crater floor was visited every day except the 19th, 20, 21st and 24th.

At 4 p. m. there was a double explosion, first near center of pit and second near east side. Rocks were seen rising above the cloud, one fragment going to a height over 2500 feet. Many rocks were visible above the clouds and beside them. The noise of rocks falling on the floor of the greater crater was plainly heard at Uwekahuna, and a roaring noise inside of the pit was heard for several seconds before the appearance of the dust column and the rock fragments. The dust cloud rose very rapidly. A smart earthquake was felt at 4:48 p. m. and three more shocks occurred within two minutes.

At 4:57 p. m. occurred a small explosion without visible rocks. An earthquake with rumble came at 5:16 p. m. and a stronger one at 5:18. Small explosions occurred at 5:20 and 5:33 p. m. At 6:52 p. m. an explosion cloud shot up to a great height and small explosions occurred during the evening. Earthquakes were frequent between 10 and 11 p. m. During the rest of the night a heavy dust cloud stood over the pit without marked explosions.

May 14. At 4:50 a. m. at Uwekahuna an earthquake with slow swaying motion occurred followed a minute later by one with very rapid motion. A strong quake occurred at 5:24 a. m. followed a minute later by a small explosion making a patter of falling rocks which nearly all appeared to go back into the pit. Steam was rising from north side of pit.

At 9:05 a. m. a heavy explosion occurred followed by dense cauliflower clouds for more than an hour estimated at 9:25 to be rising 25 feet per second.

At 10:30 a. m. the pit was visited and the southern rim, a piece of high ground with large cracks back of it, was found to have been carried away for a width of over 100 feet. The northeast rim appeared little changed. The explosion blocks of the previous afternoon of 4 p. m. were for the most part large but not numerous. They landed with great force as shown by holes they punched in the lava. A rock weighing 300 pounds landed 1400 feet from the rim and bounced 150 feet to its present position. Smaller boulders fell 1800 feet from the rim. During the afternoon there was a continuous steady moaning roar from the pit sounding like heavy surf. An exploration of the southern rim of the greater crater discovered no evidence of new cracking.

At 3:37 p. m. a big explosion cloud shot up which scattered rocks on the southwest rim of Halemaumau. The roaring noise diminished thereafter. Several avalanches occurred after the explosion, a notable one at 4:42 p. m. Heavy clouds rose for more than an hour. In the course of the day however, the dust clouds decreased and white vapor increased. During the evening the rear increased and at 10:25 p. m. occurred an earthquake, avalanches, and explosion cloud and there after the roar was reduced. For about four minutes a glow was seen in the western part of Halemaumau.

May 15. At Uwekahuna Bluff at 3:38 a. m. a strong earthquake was experienced (Rossi-Forel VI) that caused avalanches at both Uwekahuna and Halemaumau. From the pit a tremendous dust cloud arose. At 9:30 a. m. with easterly wind a heavy downpour of yellow rain on the depressed bench of Uwekahuna made a yellow cascade over the cliff.

At 11 a. m. an explosion threw hot rocks to the southeast which were sizzling at 11:20. During part of the early morning there had been little steam and no dust. After 11 an attempt to see into the pit discovered nothing owing to avalanches. From the rim a small cloud was seen in southwest part of pit without evident ejection of rocks.

During the afternoon there were moaning noises and roars heard at the station on Uwekahuna and light earthquakes were felt. In spasms the noise increased, there was a small explosion at 5:44 p. m., the roar was very loud at 8:30 p. m. and at 10:25 p. m. an explosion occurred followed by intermittent roar during the night.

An estimate of depth of pit in the early morning of May 15 gave 1350 feet plus. This was done with telemeter telescope and stop watch, given the distance of pit rim, (2.1 miles from Observatory) rate of travel of avalanche sound, measuring ascensional rate of avalanche cloud, and measuring difference in time between first roar and first appearance of cloud above rim. The data thus gave the vertical distance travelled by the avalanche cloud before it appeared above the rim, which would be the approximate depth of the funnel.

May 16. From Uwekahuna at 9 a. m. loud continuous roar was heard. A continuous thin stream of dust rose from the pit which was steadily falling at Uwekahuna. The fume was thin changing to a convection cumulus 2000 feet above Kilauea floor and sometimes much lower. There were several earthquakes which did not correlate with any change in the noise. At 9:50 a. m. roar became louder. At 10:20 a. m. there was a lull in the noise. After a perceptible quake the noise was resumed.

At 11:06 a. m. and for seven minutes thereafter, a series of gas discharges with rumbling noise threw out rock fragments, and a black cloud rose to a great height. At first a few big rocks came at intervals of one to two seconds, then a barrage of small ones heard rattling down continuously with a noise like a machine gun. An earthquake was felt during the discharge. The dust cloud appeared one minute after the rumble; the first rocks were heard falling two and a half minutes after the rumble.

At 11:33 a. m. came a loud roar followed by the dust cloud in sixty seconds. The cloud was estimated to rise 25 feet per second. Depth of pit was estimated at 1700 feet. After the spasm the roaring stopped for a few minutes. Prior to the explosion the dust was rising from the southeast part of the pit, later it came from the west.

At 1:59 p. m. a small explosion was followed by its dust cloud in one minute. At 2:20 p. m. occurred a heavier explosion followed by small discharges at 2-minute intervals for a quarter of an hour with falls of rock. Clouds were estimated to rise at 30 feet per second.

The pit region was visited in the afternoon. Two small parallel cracks lay across the road on the Kilauea floor 2000 feet from the rim of pit. These cracks are parallel to the rim as though the whole floor were weakening that far back.

At 5:05 and 5:10 p. m. came explosions with ejected rocks, roaring and some rumbling, the second discharge accompanied by an earthquake, and then heavy clouds arose continuing until 6 p. m. As this was watched from near Keanakakoi at 5:15 p. m. a swishing noise in the sky like a whirlwind was heard that gradually became louder while the descending dust cloud to

leeward of the pit became denser. By 5:18 the noise was found to be due to a pisolitic mud rain which fell in thick viscous drops over one-eighth inch in diameter. This continued to fall on the observers in their car travelling north beyond Kilauea Iki.

There were more dust clouds from the pit at 6 p. m., 8:10 p. m., and between 11 p. m. and midnight. At 8:59 p. m. occurred the largest explosion to date. Owing to a brisk southwest wind current aloft small lapilli fell at the Observatory and at the settlement one mile in the Hilo direction. Incandescent rocks were thrown southward from the pit. There were thunder and lightning thereafter, mud rains fell, and stones falling were heard again at 10:17 p. m. Quiet ensued a half hour after midnight.

May 17. A station was occupied during the night on the gravel spit southwest of Keanakakoi. There were explosions at 1:20 and 1:27 a. m., a continuous roar from 2 a. m. on, an avalanche cloud at 2:28 a. m., increased roar 3:19 a. m., and at 3:20 a. m. the noise increased, an explosion occurred, a few red hot rocks were thrown out southeast of the pit and one minute later a few came out from the east side. There was another small explosion at 3:38 a. m. During this eruption, at the Observatory a very black straight cloud was seen to be shot up from the pit and rocks other than the glowing ones were heard falling. At 3:32 a. m. the cloud had become enormous, the roar was continuous, pisolitic mud began to fall and at 3:35 flashes were seen in the cloud over the pit. At 3:42 there was a roar lasting four seconds accompanied by a slight earthquake, and by now the cloud had spread out like a fan over almost the entire sky. At 3:45 a. m. a noise like an avalanche lasted two seconds, at 3:47 there was a roar for six seconds and the mud rain ceased falling.

This sort of record was now maintained for many days at the Observatory, and we have to thank numerous volunteer observers for their assistance. The seismographs showed tilts, prolonged tremblings, and numerous earthquakes, and required incessant attention restoring the pens to the drums. This Observatory record is summarized hereafter in tabular form.

The pit was visited after 9 a. m. May 17 and a circuit was made beginning southeast and east. Pit was greatly enlarged, especially northeast-southwest, and rim southeast, east and northeast had gone back 200 feet. Depth appeared much over 1000 feet and bottom appeared nearly flat, covered with talus material, with small irregularities, including a low dome-shaped elevation under the southeast wall, and steam was rising without pressure and creeping across the floor irregularly in small continuous cottony clouds. The southwest rift tunnel was plainly visible and there was another tube on the east side with what appeared to be a large and irregular dyke near it extending diagonally southward with branches. The upper walls of the pit appeared to slope inward at 60°, approaching verticality farther down, so that the avalanches had a free fall to land with a tremendous crash at the bottom. Often the rocks fell with a pattering sound. There were debris slopes around the bottom, covering most of the floor area.

The cracks across road 2000 feet southeast of Halemaumau had widened and there were numerous other cracks concentric to the rim between there and the pit. There were no new radial cracks away from the pit to the northeast but there was a zone of them extending south-southwest about 100 yards wide from a recess in the pit wall, with individual cracks several feet across showing settling on one side. There were strata of cracked lava in the south wall and others dipping in V shape southeast.

The Kilauea floor near the pit was now covered with boulders in large numbers, locally extending a half mile from the pit and in places there was at least one fallen fragment to every square foot. Some boulders weighed several thousand pounds. There were pieces of dunite consisting of friable olivine almost exclusively.

With a booming noise at 9:07 a. m. a cloud rose rapidly at the northeast rim. An earthquake was felt at 9:45 a. m., with rumbling. At 10 a. m. a stronger quake occurred followed by rapid rise of a steam cloud carrying blue fume with it over the northeast rim.

At noon came one of the big impressive explosions of the eruptive series causing great consternation among visitors. At 12:02 p. m. came a roaring noise and a big dust cloud, accompanied by a moderate earthquake. At 12:32 p. m. there was a roar with sharp crashing noise lasting fifty seconds and a very heavy black cauliflower cloud rose, much bigger than the one of the early morning hours. At 12:35 p. m. fifteen explosive outbursts rose in the course of eleven minutes, accompanied by continuous roaring, loud crashes of thunder and frequent lightning flashes very low over the Observatory and toward the east and the west. Showers of rocks were heard falling heavily. At 12:45 p. m. dust and sand fell for twenty-five minutes. At 1:05 p. m. was heard the roar of an avalanche.

A visit to the pit after this explosion revealed nothing of the interior owing to steam and dust. New fallen hot dust had accumulated in a thick layer near the rim of the pit and had singed grass farther away, 2000 feet from the rim.

The only gas noticed in the steam exhaled from the pit up to this time was a small amount of sulphur dioxide, indented as blue fume. In the early morning of May 17 yellow fume was seen rising for a few minutes from the northeast part of the pit at a time when no dust was coming up.

At 6:09 p. m. a fresh explosive eruption began and at 6:10 five lightning flashes were seen and a heavy fall of rock fragments was heard. Short lightning strokes became abundant in the cloud over the pit and at 6:13 there was a large fall of red hot rock mostly to the north.

At 7:30 p. m. falling rocks were again heard, lightning flashes were seen and at 7:39 there was hissing and a thunder storm was in progress. A roar for thirty seconds was heard at 8:05 p. m., thunder and rain continued, at 9 o'clock the clouds over the pit were thinner and at 9:55 the rain stopped and a slight continuous hissing was audible.

For the rest of the night there were alternations of roaring, hissing, dust clouds, steam clouds and a little rain. The air was very calm.

May 18. This was the day of culminating intensity in the explosive eruptions, but the maximum of earthquake frequency was reached on the 24th. Earthquakes and prolonged spasms of shaking were now being registered continuously on the seismographs.

At 1:48 a. m. after a light rain there was a faint sound of falling rocks and dust clouds rose thickly from the pit without any noise, followed by ordinary steam clouds at 2:10 a. m.

Beginning at 2:11 a. m. there was more rain, slight roaring and a small dust cloud followed at 2:20 by a flash, three cauliflower puffs that shot up to the same height, dull red glow above the pit and then red hot rock fragments which fell outside the pit for two and a half minutes. At 2:25 there was a small explosion of red hot rocks which rose to the level of the rim of the pit and a hard edged fume column rose rapidly with very short lightning flashes, the top of the cloud drifting west of the Observatory. Sand fell at 2:30 a. m. Dull roaring continued.

At 3:35 a. m. there was a straight rapid fume column with lightning and thunder. At 4:38 a. m. there was a straight slender cloud, lightning flashes near the mouth of the pit, a very rapid rush of gas apparently without explosive violence and sounds of falling rock for one and one half minutes. By 5:19 the fume was very thin. After this there were avalanche clouds with occasional noises from different sides of the pit, and at 7:50 a. m. there

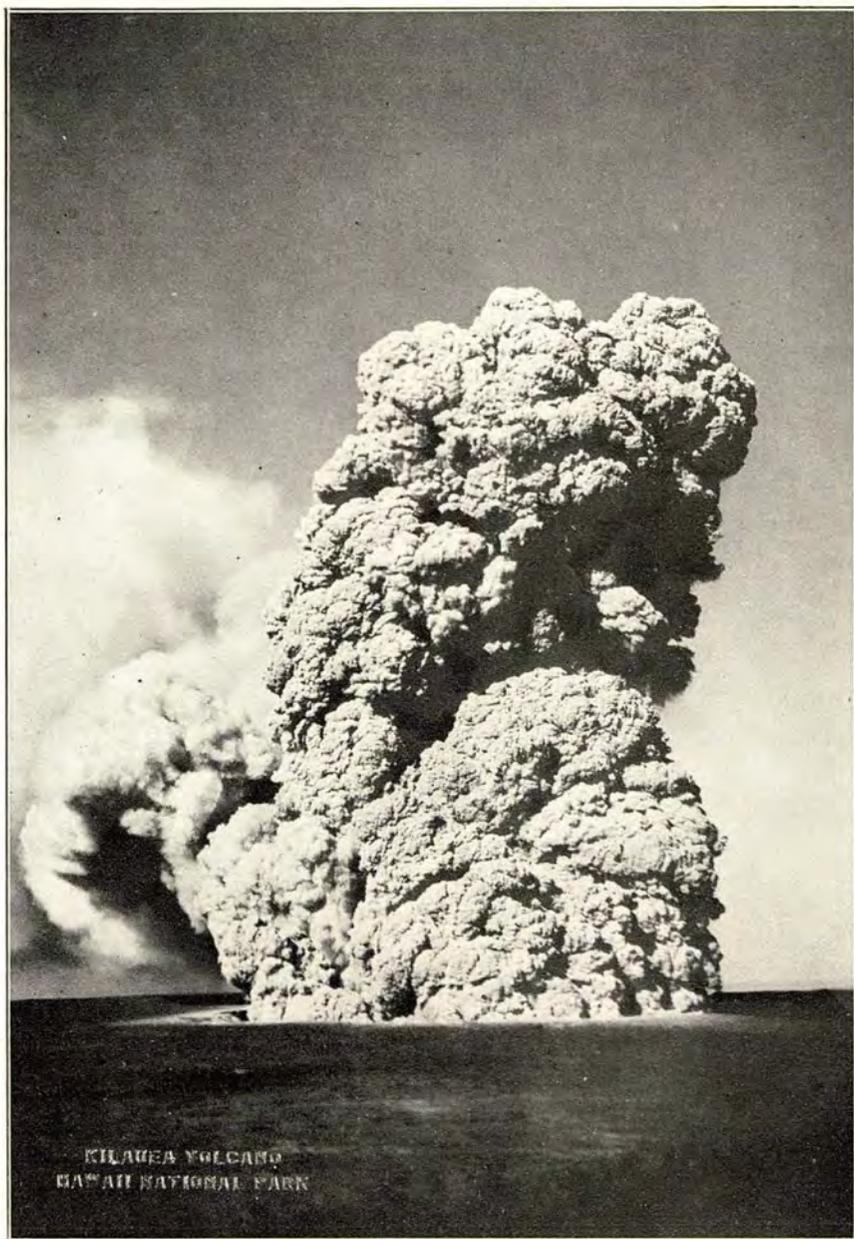


Figure 10. May 24, 1924, explosions of 9:15 a. m., initial "hard" cauliflower cloud rising rapidly from Halemaumau. Taken from Volcano House. Photo Maehara.



Figure 11. May 24, second stage, a few minutes after time of Figure 10, taken from north end of Uwekahuna bluff. Boulders were falling near the pit and lightning was flashing in the cloud. Top is over 6000 feet high. Photo Maehara.

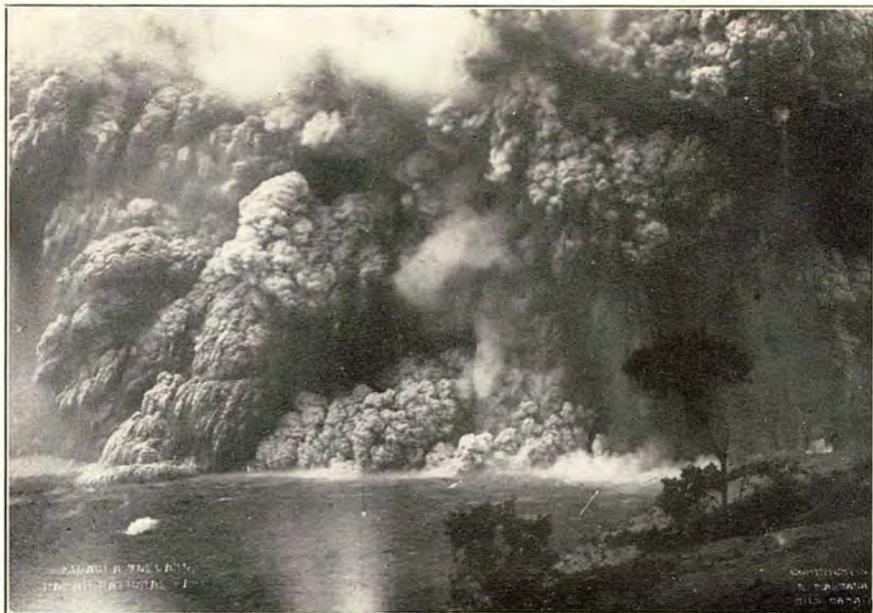


Figure 12. May 18, 11:15 a. m. Detail of the maximum explosion taken from Uwekahuna. Note uprush on the right, impact puffs on the Kilauea floor, cascade trajectories of falling showers of rock on the left. Note the vortical roll where these strike the floor. This is the action that destroyed St. Pierre. Photo Maehara.

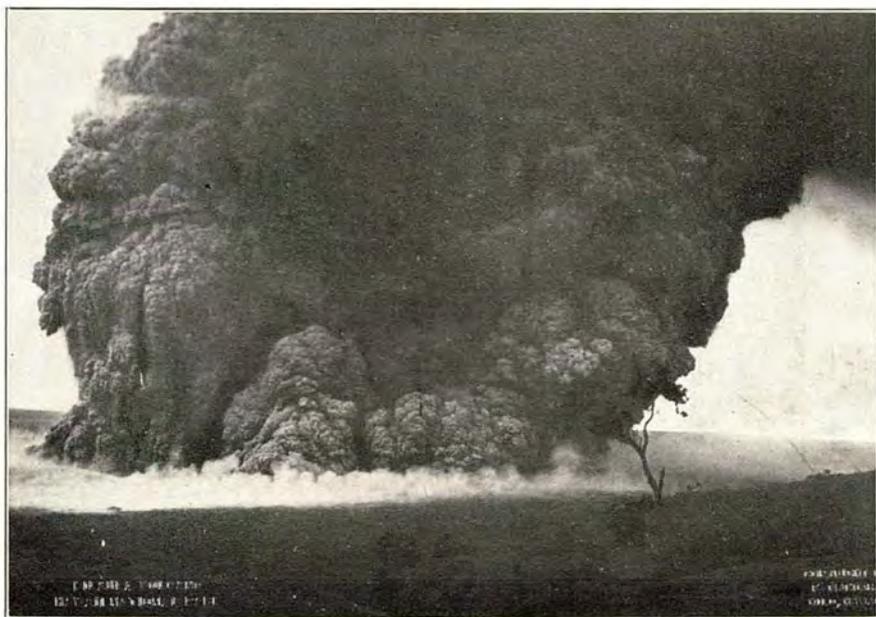


Figure 13. May 18, a few seconds after time of Figure 12. The cascade trajectories on the left have lifted, the "worsted" rolls of cauliflower action are well shown, and immense showers of boulders are raising white dust. Distance one mile. At this time Mr. Truman Taylor was being overwhelmed in the background at the left, the only fatality of the eruption. Photo Maehara.

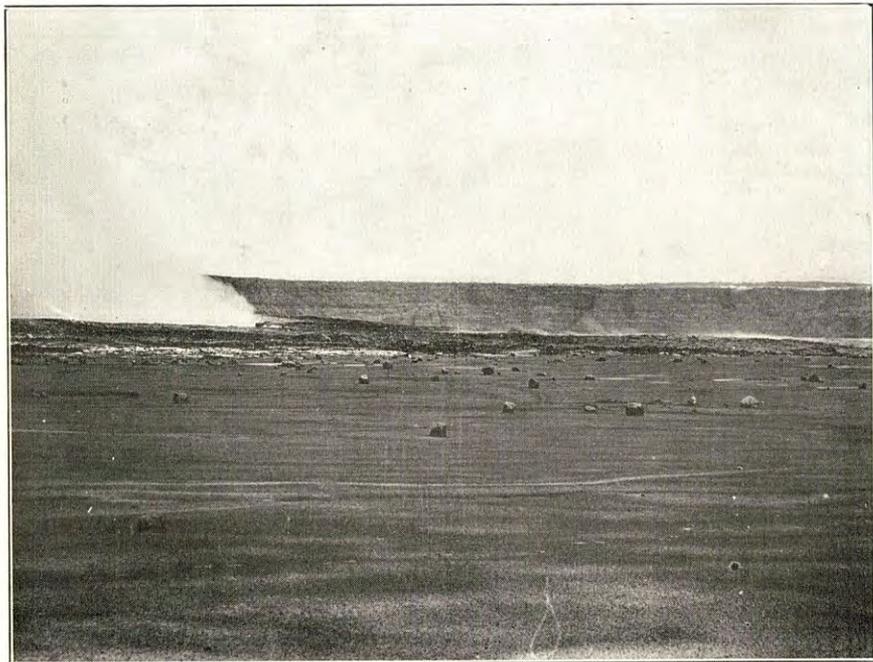


Figure 14. May 22, looking from the gravel flat northwest toward the north rim of Halemaumau. Foreground strewn with new boulders and sand. Photo Emerson.



Figure 15. May 29, 1924. Rill-marked new ash, south margin of Kilauea crater. The gullies trench the old ash beneath. Photo Emerson.

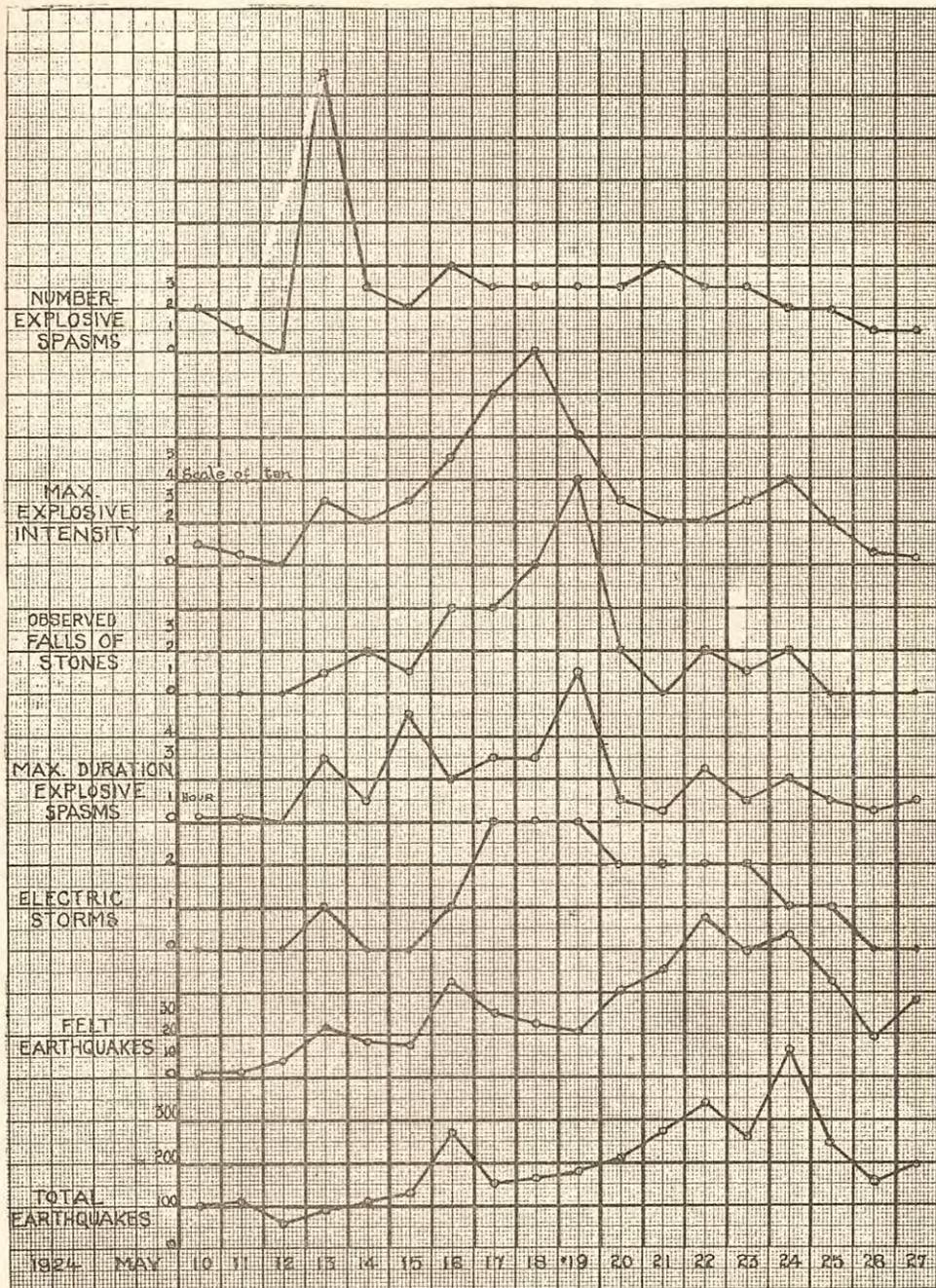


Figure 16. Diagram showing curves of the different activities illustrated in the tabular summary of the eruption, May 10 to 27, 1924.

was increased roar with a heavy dust cloud rising at a rate slower than that due to explosions, and hence believed due to avalanching.

Several earthquakes were felt and rumbles heard of a quality distinct from the avalanche roar during the forenoon. At the Observatory these earthquakes were numerous between 10 and 11 a. m. At 10:09 a. m. a steam cloud was rising and at 10:45 a small cauliflower cloud of dust appeared. At 10:54 a. m. came a roar for ten seconds and a slight dust cloud from the southeast side of the pit. At 11:01 a. m. a sharp earthquake occurred. At 11:02 came a roar with an explosion cloud.

At 11:07 a. m. began a great culminating explosion with a tremendous dust cloud and ejected rocks. At 11:09 there was a second explosion throwing out rocks and plastering the area northeast of the pit with hot sand for several hundred yards. At 11:12 a. m. came a much smaller explosion throwing rocks. At 11:20 a. m. there was a steady loud roar and a fall of pisolitic mud at the Observatory. At 11:21 came a small explosion to the southeast. At 11:55 there was another followed by a fall of fragments and some thunder. At 12:15 p. m. hard black cauliflower clouds were still rising when mist intervened, cutting off the view of the pit.

During the great eruption of 11:09 a. m. there was an Observatory party near the pit, and numerous other persons were in the vicinity. It was on this occasion that Mr. Truman Taylor was fatally stricken down by a barrage of boulders and sand on the Kilauea floor about 1800 feet southeast of Halemaumau. He was rescued, but died after being removed to a hospital. The observers were on the sand flat farther southeast where there is a cliff of ash facing away from the pit (the Italian Cliff where blue-green algae were formerly abundant). Large puffs of steam were rising and when sitting on the ground one could feel numerous quakes and rumbling was heard. At 11:09 came a wave of increased air pressure that was painful to the ear drums. Big rocks shot high into the air toward the southeast and one of these weighing over 300 pounds cleared the Italian Cliff and landed on the 1921 lava of the south embayment of Kilauea crater. One large boulder weighing 8 tons fell on the gravel flat 3500 feet from the Halemaumau center, made a deep impact cavity and broke, the fragments bouncing and partially burying themselves on the side remote from the trajectory. Heavy showers of broken rock fell on the Kilauea floor accompanied with masses of sand and gravel.

An observer sitting on the ground at the roadway by Keanakakoi crater reported as follows:

At 10:16 a. m. three earthquakes were felt within five minutes. Between 10:30 and 11 a. m. quakes were decidedly sharper and of very rapid vibration. Roar from pit was almost continuous. At 11:09 a. m. big explosion cloud rose from center of pit, followed by others to northeast of pit. Enormous rocks were seen about 3000 feet in the air and slightly in advance of the explosion cloud. Stones were thrown a great distance toward the southeast. The northeast part of the pit was practically clear. At 11:14 a. m. there was a second smaller explosion and rocks were thrown out. At 11:20 a. m. came a rain of mud balls as large as peas. At 11:54 a. m. an explosion cloud rose from the northeast part of the pit followed by others in the central part. Rocks were thrown out chiefly northeast and east. The mud rain continued over three-quarters of an hour.

An intense electrical storm followed about noon and thereafter, so that one received a shock even by touching a motor car. About four miles toward Hilo twenty-one telephone poles in a line were destroyed by lightning. The thunder and lightning at the volcano, however, were not so strong as on the 17th.

At 2 p. m. the east and north parts of rim of pit were visited. There was much sand covering everything which thinned out a half mile back

from the rim. The section northeast of the pit was plastered with small rocks to a distance of 700 yards and some large rocks went much farther. Fresh cracks were observed extending northeast from the pit in the direction of the northern end of Byron's Ledge, but not so well developed as those to the south-southwest.

The afternoon of May 18 was comparatively quiet and at 6:30 p. m. the crater was clear except for light steam clouds. These increased in density becoming a black cloud at 6:40 p. m.

At 7:14 p. m. began another major eruption with a roaring noise and falling rocks. At 7:17 the explosions were still strong especially toward the southeast. At 7:18 glowing rocks were seen landing on the lower ledges of Uwekahuna Bluff. Most of the ejections were toward the north and the fiery trajectories of rock fragments were over 3000 feet high. At 7:19 the eruption appeared to be dying down. At 7:22 the glow of incandescent rocks that had fallen on the floor of the greater crater was still visible. There was dull glow over Halemaumau. The ground all around the pit was illuminated by the fragments. It was evident that there had been very heavy bombardment to the southeast. A large rock had fallen to the east about 4000 feet from the rim of pit and another toward the north about 5000 feet. The total ejection was estimated about equal to that of the noon eruption of the 17th. At 7:57 there was another spurt or roaring, falling of rock, lightning and cessation, followed by another explosion with a heavy cloud and an earthquake. The first explosion lasted one minute and the second two minutes. At 7:59 the fallen rocks were still glowing. At 8:00 p. m. the eruption was waning but in thirty seconds it started up again, glowing rocks could be seen at 8:01, a minute later there was an earthquake and thunder and lightning occurred, then there was roaring noise which increased at 8:08 and was accompanied by a heavy thunder clap. At 8:10 p. m. an intensely black cloud arose which spread out at 8:12, and at 8:20 there was a continuous roar and a fall of pisolitic mud rain. Mauna Loa was seen to be clear with its whole summit covered with snow. There were avalanches at 8:25, 8:30, 8:48 and so on during the night, but white steam clouds began to replace the dark dust cloud at 8:48, 9:45 and 11:08. There was some hissing noise. Whitish clouds increased and the pit became quiet after 1:00 a. m.

May 19. At 2:57 and 3:58 a. m. earthquakes were felt, and at 4 a. m. there was an explosion at Halemaumau throwing out a very few red hot rocks. This was followed by heavy thunder. Thereafter the pit was quiet with a steam cloud rising rapidly from its eastern part. The morning light revealed heavy sand deposits southeast, northeast and north of the pit.

In the forenoon there were a few avalanches, a sharp earthquake occurred at 10:49 a. m., and steam clouds were dominant over dust clouds.

At 11:44 a. m. a heavy dust cloud appeared which was over 600 feet high by 11:50, and there were small explosions, while the seismograph registered continuous small earthquakes. At 11:51 a. m. a lightning flash appeared in the dense volutes of dust near the pit rim and thunder was heard several times. At 11:53 the lightning was nearly continuous, accompanied with short sharp detonations. At 11:54 the dust descended east and northeast of the pit cutting off the view and there was a heavy roaring noise. The uprush continued and at 12:12 p. m. there were occasional lightning flashes east and west of the fume column and a little later falls of rock occurred northeast and southeast of the pit. After 12:46 p. m. steam clouds replaced the dust clouds. All the afternoon there were alternations of these with occasional avalanche roaring.

At 5:39 p. m. explosions started. At 5:40 explosion clouds rose from south side of pit, there was the usual short lightning at the base of the cloud, noise of falling rocks was heard, and another cauliflower rising from the southeast side ejected visible rocks that could be seen tumbling outside the

pit. The volutes alternated from different parts of the pit and most of the explosions were small. At 5:41 p. m. and at 5:43 came two larger explosions progressively bigger with longer streaks of lightning and appearing higher up the cloud. An avalanche fell from the northeast rim and things became quieter with occasional lightning. At 5:51 there was a new rush of gas and heavy avalanche clouds to the south and southeast, most of the dust descending in the Kau Desert. An avalanche cloud rose at the north side at 5:53 p. m.

Next comes a night record from the Observatory wherein it appears that there were falls of rock either seen glowing or heard falling, at 6:47 p. m. lasting five minutes, at 7:30 p. m., at 7:49 p. m., at 8:20 p. m., at 9:30 p. m., 9:51 p. m. and at 10:32 p. m. There was pisolitic mud rain at 7:15 p. m., lightning, thunder and earthquake phenomena continued all night, pronounced westerly tilt was observed in the behavior of the seismographs and roaring noises waxed and waned.

May 20. Similar phenomena continued during the early morning hours and the instruments were dismantled by sharp earthquake shocks at 12:47, 3:40, 4:02, and 6:17 a. m. Lightning was noted only once at 2:59 a. m. There was a strong earthquake at 7:03 a. m. when the instrument was not operating. The explosions evidently diminished after the preceding midnight and steam clouds were noted in place of dust clouds during the night at 9:11 p. m., 11:08 p. m., at 11:36 p. m., at 1:45 a. m., at 2:12 a. m., at 4:10 a. m., at 4:49 a. m., at 5:10 a. m., at 7:01 a. m. and 7:10 a. m. At 7:39 a. m. a small explosion occurred at the southeast side of the pit and spread very quickly to the north followed by a heavy dust cloud. Avalanche clouds were numerous during the forenoon mixed with the heaviest steam cloud that had yet been seen during the explosive eruption. Puffs of steam were numerous and rapid between 11:45 a. m. and 12:47 p. m.

At 12:49 p. m. began the usual noon-day eruption. A hard dust cloud rose first from the east-northeast side of the pit and next from the north. Rocks fell a short distance northward. At 12:50 and 12:52 there was heavy roaring and more explosions. At 12:59 the dust cloud may have been four miles high and a heavy pall of falling dust lay over the Kau Desert. At 1:02 p. m. there were more small explosions, the dust clouds rolling out over the northeast part of the rim and at 1:54 came a moderate earthquake and a heavy mist shut off the view of the pit. During the early afternoon there were steam and dust clouds with explosive activity at 4:31, 4:40, 4:45 and 4:56 p. m. accompanied by earthquakes, lightning and some ejections of rock fragments. A small explosion was reported by an observer at Keanakakoi at 5:31 p. m. but fifteen minutes later the cloud was steamy without much dust. After this until midnight the white vapor cloud became increasingly dominant, roaring noise had noticeably diminished but seismic disturbances and avalanches occurred from time to time.

At 7:20 p. m. an Observatory party went to the half-way house on the road between Volcano House and Pahala to inspect the Kau Desert, as earthquakes had been recorded at Hilea and felt at Pahala as well as the Observatory. A slight earthquake was felt by this party about 8 p. m. and a dust storm occurred about 3:30 a. m. May 21. At 7 a. m. May 21 Mauna Iki was visited, but no sign of new activity was discovered along the rift zone between Kilauea and Kamakaia. Hot cracks on the summit of Mauna Iki had a temperature about 75° C. (not a new feature).

May 21. Between midnight and 5 a. m. there were earthquakes, dust clouds and steam clouds, and at 2:17 a. m. there were probably explosions. The frequent earthquakes of small amplitude were such as to make the observatory creak, and at 2:16 and 4:47 a. m. there were sharp shocks. At 6 a. m. a newly cracked block of the north rim of the pit was observed with crevasses 35 feet back from the rim. At 7:34 a. m. there was a small explosion and

another at 8:52 a. m. Explosion clouds again appeared at 9:53 and 9:59, followed by puffing steam clouds over the entire pit at 10:01 a. m. Angular measurements at this time showed the rim on the south side to be 600 feet back of where it was on May 5. From Uwekahuna numerous cracks were visible concentric with the pit. Unusually heavy avalanching occurred this day along with seismic disturbances. At 1 p. m. very strong southerly tilt was observed at the seismographs. The numerous avalanches of the afternoon were characterized by red dust clouds. Explosions were noted at 4:54 and 9:01 p. m., a gas rush without explosive violence at 5:18 p. m. and luminous flashes in the steam cloud about 7:50 and 9:05 p. m. The main characteristics of May 21 were increase of steam, of earthquakes, and of avalanches, and decrease of explosions. The rim of pit was moved back 200 to 300 feet by the avalanching of May 21-22.

May 22. Earthquakes, avalanches, steam clouds and roars continued up to 6 a. m. A disturbance at 2:15 a. m. and another at 2:25 had the characteristics of explosion dying away after 3 a. m. Northeast tilt was noted at 3:05 a. m. The earthquakes had produced avalanching from Uwekahuna Bluff.

The following was a typical correlation of seismic movement with explosion that happened at this time. At 8:05 a. m. there was a heavy steam cloud over the pit. At 8:07 a. m. came an earthquake that dismantled both components of the seismograph. At 8:09 a. m. the tremors continued. A half minute later a dense dust cloud arose. At 8:10 a. m. rocks were ejected northward and a half minute later the cauliflower cloud rose from the center of the pit. At 8:11 a. m. lightning appeared in the cloud. At 8:18 there was thunder and the cloud rose rapidly from the north-northeast portion of the pit. Seven minutes later the dust cloud was softer and drifting south-southwest and at 8:30 it was mixed with steam.

There was another small explosion at 8:51 a. m. when dust fell at the Observatory and the rest of the forenoon record deals with avalanches and steam clouds.

At 1:32 p. m. gaseous activity was increasing after a dismantling of the instruments by an earthquake twelve minutes before and at 1:35 a heavy dust cloud rose rapidly for two minutes along the north wall of the pit to a height of 3000 feet. At 1:58 p. m. an explosion cloud from the south side of the pit was accompanied by lightning and thunder, this became central at 2 p. m., there was the usual roaring noise, at 2:02 the explosion clouds were from the north and there was a heavy fall of ash on the Kau Desert and at the south side of Kilauea crater.

At 2:10 p. m. another explosion developed east of the center, the north half of the pit being free from any explosion cloud. There was a heavy roar increasing in loudness, lightning appeared in the upper cloud and rocks fell southeast of the pit. At 2:12 p. m. there was a shower of rocks with lightning on the eastern side of the cloud and nearly continuous explosion. This eruption diminished after 2:30 p. m. Another explosion developed at 2:54 p. m. This was succeeded after 3 o'clock by spurts of steam, earthquakes and avalanches. There was a very small explosion at 3:37 p. m.

During the rest of the evening steam clouds, avalanche clouds, earthquakes, tremblings, roarings, rumbles and the obscuring of the pit by fog occupied the attention of the observers until midnight.

At 10 a. m. on May 22 the area southeast and south of the pit was visited and then an expedition was made across the Kau Desert. The ash on the gravel peninsula south of Keanakakoi was 3 inches thick, and southeast of Kilauea in the Kau Desert it was 1 inch thick. The cracks extending south-southwest from the pit which had been discovered on May 17 were found to

spread out away from Halemaumau and to disappear at the southern edge of Kilauea crater. No new cracks were found in the Kau Desert.

May 23. During the early morning there were numerous earthquakes, avalanche clouds and steam clouds. The noise of a rush of gas was identified at 3:30.

At 7:54 a. m. the steam was replaced by a reddish brown dust cloud rising from two centers rapidly to a great height over the pit and at 7:57 there was a new puff farther north accompanied by lightning. At 8 a. m. there was another puff to the west. At 8:04 another cauliflower of hard outline rose and at 8:08 there was an earthquake.

At 8:52 a. m. a small puff of dust on the southeast side of the pit was accompanied by lightning, at 9 a. m. an explosion cloud rose at the northeast side and at 9:14 there was a heavy fall of ash on the desert.

From 10:20 a. m. to 12:40 p. m. an exploration was made of the northern floor of Kilauea crater. Many earthquakes were felt. The route lay from the foot of the Volcano House trail eastward to Bryan's ledge, then across the floor to Uwekahuna. The whole crater floor seemed to be almost continuously agitated. No rumbling was heard. About forty earthquakes were recorded.

Avalanches and steam clouds continued until 3:06 p. m. when a dust cloud arose that exhibited lightning at 3:07, a cauliflower explosion northeast of the center at 3:08, followed by others until 3:12 with more lightning and rocks falling inside the pit, and others showing dust trails fell to the Kilauea floor north-northeast. Lightning was seen between two cauliflower volutes at 3:12 and a half minute later when there were no clouds across the northeast corner of the pit lightning could be seen inside the pit. There were fresh outbursts at 3:16 and 3:21 with steam clouds in between. By 3:37 a heavy steam cloud stood over the pit.

For the remainder of this day noises and felt earthquakes greatly lessened, and the plume of cloud over the pit was probably mostly steam.

May 24. Earthquakes, steam clouds and occasional avalanches characterized the morning hours. A report from Kapoho in Puna indicated there had been no further movement in that region. At 3:22 a. m. there was a loud cracking detonation from the pit but no lightning was observed.

At 8:09 a. m. a heavy explosion of steam and dust rose from the east side of the pit. This thinned out and at 8:26 a. m. a dense cloud rose from all over the pit probably due to rush of gas. At 8:30 there was another explosion. At 8:43 came an earthquake. At 9:10 heavy dust clouds rose rapidly in puffs. At 9:13 came an explosion northeast of the pit center, with lightning and at 9:14 the most vigorous succession of explosions seen here for several days. Many rock fragments were thrown out and some went 3000 feet above the lip of the pit. At 9:15 there was lightning in the middle of the cloud, accompanied with short cracks of thunder and rocks were falling to the north. At 9:17 a violent explosion rose in the center sending up dense black clouds and hurling boulders northward. At 9:18 the dust of another violent explosion rose over 6000 feet and at 9:25 lightning appeared in the cloud, a tremor was felt and the cauliflowers rose rapidly on the northwest side of the crater. At 9:26 a heavy deposit of ash had been added north and south of the pit and a horizontal jet of cloud shot out laterally on the northwest side of the main column about 700 feet above the lip of the pit. At 9:35 the dust clouds were much thinner, but at 9:37 there was a new rush of gas at the northeast and east which by 9:41 had sent up a cloud 4000 feet high. After this for two hours there were avalanche clouds changing more and more to steam clouds at noon and thereafter. For the rest of the day there were steam and dust clouds with occasional earthquakes, the phenomena about 2 p. m. suggesting a small explosion.

May 25. Felt earthquakes were stronger and more numerous during the night preceding this date than on the previous night. But roaring noises and avalanche clouds were becoming fewer. A visit was made by way of the Volcano House trail to the field of ejecta east of the pit. No new fissures were found. At 7:29 a. m. there was a dust cloud with hard outlines rising from the pit accompanied with roaring noises. Avalanches were numerous during the forenoon. Explosions were identified at 11:21 a. m., 12:18 p. m., 12:24 p. m. and 12:27 p. m., a lightning flash at 12:31., followed by a steady cannonade of thunder, another explosion with thunder and lightning occurred at 12:32 and the heavy clouds at this time were rising at the east and north-east sides of the pit. The thunder storm continued and at 12:39 the country was obscured by mist. At 12:48 the active spell had ceased and ten minutes later the whole pit was visible with steam rising. Most of the afternoon the crater was obscured by mist and the night was foggy.

May 26. There was roaring noise at Halemaumau during the early morning hours, the weather being misty. An inspection from Uwekahuna Bluff at 6:15 a. m. showed that fine pisolitic ash had fallen there. Continuous roar at the pit was heard and an occasional sharp snapping noise. There appeared to be new small radial cracks on the floor between bluff and pit. Roaring and earthquakes and some thumping continued during the day, and steam or dust clouds were occasionally seen when weather permitted.

At 3 p. m. the pit was visited. A series of cracks was found extending southeast to the gravel flat. The cracks across road near the flat had widened and were steaming strongly, temperature about 80° C.

May 27. For three hours after midnight there were numerous avalanche roarings heard at the pit and earthquakes felt and registered at the Observatory.

In order to inspect pit in the dark with a view to discovering glow, Halemaumau was visited at 3:40 a. m. The former road on Kilauea floor was strewn with boulders. At 4:05 a. m. inspection of the interior revealed no glowing places whatever. The crack across road 2000 feet southeast from pit showed evidence of movement since the last dust deposit mantled it. The steam at the surface felt boiling hot. At 4:19 near the pit an earthquake was felt preceded and accompanied by rumbling; at 4:40 came another with louder rumble; in both dominant movement seemed eastwest. Avalanches from southwest side of pit fell at 4:46, 4:48 and 4:49. At 4:55 there was a sound like rushing gas.

From the Observatory between 6:30 and 9 a. m. pronounced roaring was repeatedly heard at the pit followed by rapidly rising clouds of white vapor, sometimes in two columns, from the northeast side and elsewhere, with no avalanche dust whatever sequent upon the roarings.

Beginning at 9:35 a small explosion spasm started with a slight earthquake followed by spurts of steam and avalanche clouds, then small explosion clouds at 9:45 a. m. and 10:13 a. m., ending with clear spells, spurting steam mixed with dust, then at 11:00 a. m. slow rise of steam on the west side followed by a very clear pit.

At 9 a. m. a daylight visit to the pit showed that the gravel peninsula southwest of Keanakakoi was covered with rock fragments and coarse gravel and this was true of the lava floor on both sides of the peninsula, the gravel lying on top of the last ash layer that had fallen. A view into the pit at 10:45 a. m. showed the bottom to be covered with avalanche material as on the 17th and there was a long debris slope southwest. Steam was rising from a vent at the northeast side. The relation of pit diameters was the same as before the outbreak, longer northeast-southwest than in other directions. The odor of hydrogen sulphide was noticeable but there was no steam at the southern margin of the pit though some steam was rising from the foot of the southern talus slope.

For the rest of the day there were numerous earthquakes, some of them moderately heavy after 10 p. m., and the avalanches at the pit continued.

May 28. In the early morning hours there was a slight earthquake at 1:08 and the pit was full of steam clouds. At 8:11 a. m. an explosion cloud spurted over the east rim, then boiled up northwest and southeast, the seismograph showed a prolonged tremor, and at 8:19 the dust cloud boiled up over the entire pit. During the next twenty minutes the cloud softened and became steamy.

At noon the cloud over the pit was very thin. During the remainder of the day there were several light earthquakes and avalanche clouds were seen occasionally at the pit.

From the rim of Kilauea south of Uwekahuna Bluff some cracks could be seen on the Kilauea floor extending southwest from Halemaumau mostly less than half way to the edge of the Kilauea floor. These were tangential to the rim of Halemaumau. No such tangential cracks were identified toward the west or northwest. The fall of boulders to the south and southwest had been much less than on other sides and the main explosive zone appeared to have been at the northeast end of the pit. A preliminary survey that had been made May 27 showed that the pit was now 3400 feet long by 3000 feet wide.

A circuit of the pit the forenoon of May 28 yielded good views from the west-southwest and northeast sides. From the former the floor appeared almost level, but from the latter viewpoint the pit appeared deepest toward the northeast. The 1920 arcade or tunnel on the dyke fissure in the southwest wall was a conspicuous object one-quarter of the way down to the talus on that side. There was much cottony steam pouring up from the bottom so that observation of detail was impossible and an incessant roaring noise came from the pit like an ocean surf on a rocky shore.

Toward the south the Kilauea floor was covered with much mud and small gravel and a few boulders, these increasing in number and size northward on both sides of the pit. A boulder about 150 yards from the rim, west-southwest, measured 8 by 6 by 5 feet. It had struck the ground 75 yards from where it came to rest, suggesting a long trajectory possibly from the northeast part of the pit.

On the northern side everything was covered with small stones weighing from 5 to 25 pounds with large boulders scattered about. The hummocky lava below gave this material the appearance of thick heaps, but it really formed a layer only a foot or two in thickness.

May 29. On this day there were earthquakes and avalanches, the activity slowly declining, and at 10:53 a. m., 11:06 a. m., and at 6:48 p. m. the puffs were believed to contain explosive rushes of gas. Visits were made to the pit and to the northern part of the Kau Desert. The pit was estimated to be close to 1300 feet deep.

May 30. Occasional earthquakes continued and northeasterly tilt was now strong. An unusually strong earthquake occurred at 8:42 a. m. This started a big dust cloud at the pit. The steam cloud was rising higher than on the 29th.

The pit was visited at 9 a. m. and numerous avalanches were seen, notably from the northeast, northwest and southwest corners of the pit, which seemed to be working on certain vertical cracks. The slides would accumulate along these cracks and develop cauliflower clouds at the bottom which rose as big red volutes. There was much steam from cracks on the rim of the pit. The avalanches made roaring noise, and often were started by light earthquakes that could be felt underfoot.

The rocks thrown out during the eruption had made impact pits in the gravel flat southeast and either remained in them or bounced beyond, the line of bounce not always according with the line of the trajectory from the crater. Many of these impact pits were floored with very fine-grained slimy mud of pink color, made by rain washing of the ash. This mud lies in hollows all over the country and in places holds large pools of rain water. Where stones have fallen in the mud they have buried themselves and left impact saucers with raised edges. Footprints in this mud that have dried are hard and resistant to washing of ordinary rain or to the impression made by later walking on the surface. The steaming cracks at the present road terminus, concentric with the pit 2000 feet away, show overlapping fracture en echelon in the new ash. A striking feature of the wall of the pit halfway down the west side was large red boss surrounded by massive platy gray rock that appeared to be some sort of an intrusive body.

This day was marked by further decline in the seismic and volcanic activities, and this was the last day of the hour to hour notes of observed phenomena connected with the explosive eruption.

May 31. Only thirty-five earthquakes were registered on the seismographs for this date in contrast to sixty-four, ninety-two and one hundred and thirty respectively for the three preceding days. The maximum had been 467 for May 24. The phenomena of tilting of the ground had also been extraordinary and intense during the eruption, the northeast rim of Kilauea crater tilting to the south and southwest, for successive weeks beginning April 20, one, four, eleven, twenty, fifteen and twelve seconds.

The pit was visited and observed as before but the phenomena were of the same order as on the previous day, with declining intensity.

TABULAR SUMMARY OF EXPLOSIVE ERUPTION OF KILAUEA, MAY, 1924

May	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
Number explosions	2	1	0	13	3	2	4	3	3	3	3	4	3	3	2	2	1	1	
Intensity 1-10	1	½	0	3	2	3	5	8	10	6	3	2	2	3	4	2	½	¼	
Stone-falls	0	0	0	1	2	1	4	4	6	10	2	0	2	1	2	0	0	0	
Duration explosions (hrs)	¼	¼	0	3	1	5	2	3	3	7	1	½	2½	1	2	1	½	1	
Electric storms	0	0	0	1	0	0	1	3	3	3	2	2	2	2	1	1	0	0	
Felt earthquakes	3	3	8	24	17	15	45	30	25	21	41	50	75	59	67	45	19	36	
All earthquakes	101	111	59	88	113	132	276	150	165	180	210	275	339	257	467	248	156	195	
Mud rains	0	0	0	0	0	1	2	3	3	2	0	0	0	0	0	0	1?	0	
Caving rim direction	0	SWSW	S	S	?	SE	SE	all	all	all	all	N	all	all	max.	?	?	?	?

The Tabular Summary

The foregoing tabular view exhibits zeros which do not mean absence of the phenomena on the days in question, but absence of observations recorded. The figures are those therefore that rise above a more or less uniform minimum, dependent on an approximately uniform system and place of recording. There were some explosions, and falls of at least light stones, every day from the tenth on. Those recorded were seen or heard, mostly from the Observatory as a place of systematic record night and day, and also from Uwekahuna Bluff May 14, 15 and 16.

By "number of explosions" are meant explosive spasms. The table shows that on the thirteenth they averaged two hours apart, and thereafter from 6 to 12 hours apart. The mean was 8 hours, or three spasms a day, from the 14th to the 23rd.

Intensity of explosion is based on an arbitrary scale, making May 18th "grade 10," and the first ejection of the tenth is called "grade 1." In each day the maximum explosive spasm determines the grade for the day.

"Stone-fall" means showers of stones seen either glowing at night or raising dust by day, or heard making a patter on the hard floor of the big crater, or observed boulders making a trajectory with a trail of dust. The figure given is the number of separate times for the day such happenings were recorded.

Duration of explosions refers to number of hours single explosive spasms lasted, often composed of numerous gas rushes repeated at intervals. The figure is for the longest spasm of the day. The evening of the 19th produced continuous explosion and continuous seismographic tremor, but the intensity maximum of concussion and violence had been passed on the eighteenth.

By "electric storms" are meant thunder and lightning, one or both, number of times noted for the day.

Felt earthquakes are those classified as slight, moderate or strong, generally felt at the Observatory by persons on watch. The figure is the number for the day, and the list provides a rough intensity curve of seismicity for the eruptive period.

"All earthquakes" include these, and all the instrumentally registered shocks, in so far as they may be separated out on the seismogram from the prolonged tremblings. Here again numbers per day are shown, producing a frequency curve of seismicity.

The list of mud rains includes a few separately recorded spells of raining with pisolites, sand, dust and lapilli at the Observatory. This list is very incomplete as it takes no account of the large number of showers to leeward of the pit, and the showers were notably local and scattered.

The same imperfection of record attends the caving in of the rim of Halemaumau, seen occasionally with or without field glass, or observed during a visit to the pit. There was unmistakable subsidence of the rim southwest first, this being the side of the Kau desert rift tunnels of 1920, and of the great enlargement of 1922. The collapse after southwest breakdown proceeded in order around the circle to the S, SE, NE, and N: the balancing of the breakdown to the northwest and then evenly all around the previous outline of the pit, (for the new outline is everywhere about 700 feet back from the outline of April, 1924) was accomplished during the times of maximum explosion, maximum duration of spasms, and maximum intensity of earthquakes. On May 21 and 22 the collapsing by incessant avalanches was observed and recorded as the maximum breaking down of the walls.

These figures are of interest when platted as curves as shown in Figure 16. Here the maxima of ejection violence clearly correspond in time to a depression between two maxima respectively of numbers of explosive spasms and of seismic phenomena. The maximum number of spasms comes near the beginning, the violent crisis in the middle, and the earthquake intensity and greatest frequency near the end.

This probably means that the eruption began with 2-hourly rhythmical pulsations of steam release. Collapse of pit blocked the steam, and violent ejection at longer intervals ensued.

By the 19th the throat was cleared and prolonged release was permitted. By the 22nd the pit had collapsed and the greater sink or crater of Kilauea outside was weakened and slipping. By readjustment of the mountain blocks, this produced the seismic maximum.

List of Explosion Spasms

The following is the compilation of explosion spasms on which the tabulation is based:

May 10.....	6 a. m. ?.....	10 p. m.	
11.....	10 a. m. ?.....		avalanches W. and SW.
12.....	?		“ decreased.
13.....	5:30 a. m. —	2:30 p. m.	“ S. rim.
	7:10 a. m.	4:00 p. m.	
	8:00 a. m.	4:57 p. m.	
	9:35 a. m.	5:20 p. m.	
	12:15 p. m.	5:33 p. m.	
	1:00 p. m.	6:32 p. m.	
		10:00 p. m.	about
14.....	9 to 10 a. m.		
	3 to 4 p. m.		
	10 to 11 p. m.		S. rim falling.
15.....	11 a. m.		
	6 to 11 p. m.		
16.....	11 to 12 a. m.		
	2 to 3 p. m.		
	5 to 6 p. m.		
	9 to 11 p. m.		
7.....	1 to 4 a. m.		
	12 to 1 p. m.		Rim back 200 feet SE, E, and NE.
	6 to 9 p. m.		
18.....	2 to 5 a. m.		
	11 a. m. to	1:30 p. m.	
	7 to 9 p. m.		
19.....	4 a. m.		
	11:50 a. m. to	12:50 p. m.	
	5:40 to midnight.....		avalanches 5:45 p. m.
20.....	Diminishing explosion	1 a. m.	
	7:39 a. m.		Small
	12:45 to 2 p. m.		
	4:30 to 5:30 p. m.		
21.....	Probably 2:17 a. m.		6 a. m. crevasses seen N. rim.
	7 to 10 a. m.		rim S. side 600 feet back
	4:54 to 5:18 p. m.		heavy avalanches
	9:01 p. m.		
22.....	Probably 2 to 3 a. m.		
	8 to 9 a. m.		
	1 to 3:30 p. m.		all rim back 200 to 300 feet in two days.

May 23.....	3:30 a. m.
	8 to 9 a. m.
	3:30 p. m.
24.....	8 to 10 a. m.
	2 p. m. Small.
25.....	7:29 a. m.
	11:21 a. m. to 12:32 p. m.
26.....	Early morning.
27.....	9:35 to 10:30 a. m.

SEISMOMETRIC RECORD

During the month ended midnight May 31, 1924, 3961 local earthquakes and one teleseism were registered at the Observatory. The number of earthquakes per day and other earth movements are exhibited below. Time is Hawaiian Standard, 10 h. 30 m. slower than Greenwich. Nearly all of the local earthquakes appeared to have had their origin in the neighborhood of Halemaumau and occurred during the explosive period. Some occurred southeast from the Observatory apparently in the vicinity of Keanakakoi and a few others nearly south along faults roughly parallel to the coast line.

Local Earthquakes

Day	Number of quakes	Day	Number of quakes
May 1.....	15	May 17.....	150
2.....	6	18.....	165
3.....	9	19.....	180
4.....	5	20.....	210
5.....	5	21.....	275
6.....	16	22.....	339
7.....	18	23.....	257
8.....	8	24.....	467
9.....	36	25.....	248
10.....	101	26.....	156
11.....	111	27.....	195
12.....	59	28.....	130
13.....	88	29.....	92
14.....	113	30.....	64
15.....	132	31.....	35
16.....	276		

Teleseism.

May 4..... 6:31 a. m. Slight.

Spasmodic Microtremor.

This type of tremor was moderate on the 4th and slight on other days.

Harmonic Microtremor.

This type of tremor was moderate to strong from the 7th to the 16th inclusive and slight on other days.

Microseismic Motion.

The amplitude of microseisms was slight.

Tilting of the Ground.

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

May 4-10.....	11.0 seconds	SSW.
11-17.....	20.1	" SSW.
18-24.....	15.5	" S.
25-31.....	12.5	" S.

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Volcanologist.

U. S. DEPARTMENT OF AGRICULTURE
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VOLCANIC CONDITIONS IN JUNE

Activity of Halemaumau.

After the explosive eruption there were numerous small quakings recorded to the number of 20 or more per day, increasing somewhat during the second week in June. Three or four moderate earthquakes per day were felt, and many tremblings rattled doors or windows. Some of the earthquakes were felt generally over the island of Hawaii.

The pit had become a cauldron of oval shape floored with broken rocks, 1330 feet deep and in plan 3400 feet long northeast-southwest and 3000 feet wide. The walls showed bedded lavas with numerous large and small intrusive bodies more abundant towards the bottom. A vertical dyke thinning out upward occupied the rift fissure of 1920 and was exposed on opposite sides of the pit with caverns in two places along its course in the southwest wall, leading away underground toward the 1920 flows in the desert. Large platy intrusive bodies of whitish aspect and somewhat lenticular form were conspicuous objects in the north and west walls. Ten or twelve dykes were visible in the lower walls especially northeast and southwest, petering out upward. The bottom area was steaming vigorously, some purring noise could be heard, much of the debris slope was wet and avalanches were frequent.

The floor of Kilauea crater outside Halemaumau showed the most

bowlders east and northwest, while on the south the surface was covered with rill marked sand and muddy pools with few stones. The reddish mud tended to dry up and crack. The cliffs and floor of Kilauea everywhere were dusty with ash or plastered with mud rain.

June 8 to 10 small earthquakes increased in number and there were several puffs of dust laden clouds from Halemaumau. There was a notable puff accompanied by roaring noise and producing dust showers in the Kau Desert on June 8. There was mud rain yielding pisolitic balls of dust. Avalanches increased and some cracks indicated earthquake motion on old fault planes near Keanakakoi. Cracks parallel to the edge of Halemaumau and back from the rim were widening. Slight sulphur patches with blue fume developed on the bottom of Halemaumau. On June 9 there were heavy reddish brown puffs of dust accompanied with deep growling noise and dust fall to the south. In the evening June 12 glow at the pit was identified as coming from the long platy intrusive body in the north wall, the incandescence of which was revealed by powdery avalanches of red hot stones that collected below in a fiery talus. Quiet steam rose from the bottom of the pit and the glow wall appeared to be remnant incandescence, and not new lava in any sense. It exhibited no glow in daylight. The rift dyke of 1920 was seen to cut through this light gray slaty rock of the glowing intrusive.

A strong earthquake on June 13 was coincident with movement on a fault plane north of Kilauea crater.

On days of high wind the new fallen dust was blown in simoon whirls and sent up in clouds continuously over the Kau Desert, along Uwekahuna Bluff and on the Kilauea floor. The whole country was gritty with the new ash clinging like cement on the ground, on foliage and on houses.

Seismic conditions became nearly normal towards the end of June. Inspection of Mauna Iki six miles to leeward of Kilauea in Kau Desert showed that the ash there is less than one-eighth inch thick. At this place in 1790 the ash was several feet thick. At Kapoho in Puna cracking and earthquakes had ceased, but some settlement near the quarry was reported to be still in progress. A visit to the summit of Mauna Loa revealed no changes there. The Postal Rift cavern northwest of Halemaumau was broken in at new places by fallen bowlders of the explosive eruption and much of the upper end of the cavern had been engulfed with the widening of the pit. This widening had been about equal on all sides, amounting to a breaking back of the walls some 750 feet radially. A quarter mile southwest of Kilauea crater the new ash and gravel are eight inches deep and at Makaopuhi six miles east-southeast there is only a film of ash.

All activities at the pit such as volume of steam, number of avalanches and size of avalanche cloud were decreasing at the end of the month and Halemaumau was very clear on sunny days. It had become a huge natural rock quarry with vapor jets on its bottom. The four longer talus heaps were building up along with an accompanying recession of upper rim of pit. Some large pieces of the rim fell in and carried away the survey flags. A fume yellow sulphurous patch appeared on the bottom flat. There was an increase of avalanches on the 28th.

A visit to Pahala June 29 following the road from Kilauea showed the May dust to be thinning from the Volcano southwestward to one half inch at the road camp, one-eighth inch at Kapapala and only a film at Pahala mill. This district had had abundant rain and all the vegetation was fresh and green, though it was estimated that the ash fall had been four tons to the acre.

DISCUSSION OF SPECIAL FEATURES

The month of June was distinctly for Halemaumau a period of quiet after storm. There was a slight seismic spasm culminating on the 13th with renewed avalanches and big cauliflower puffs of dust, but nothing happened really comparable to the May explosions. After that earthquakes and avalanches diminished and at the end of the month there was even a slight reaction from the southerly tilting which had been continuous since April. There was ample evidence that the rim of Kilauea crater continued to adjust its blocks through the action of gravity, and some of the stronger earthquakes of the month were accompanied by displacement of the earth on the cracks between these blocks.

By far the most remarkable subjects for inquiry and discussion were the intrusive bodies left incandescent and exhibited in section in the lower walls of Halemaumau at depths from 400 to 1000 feet down. The rock appears to be a fine grained gabbro which is jointed in platy or thick parallel sided laminae. It forms big bodies some of which disappear beneath the talus of the northern part of the pit. It is cut by the Kau Desert rift dyke that crosses the pit from southwest to northeast. This dyke we saw form as a crack afterwards filled with lava November 28, 1920. The fact that the lava filling cuts across the massive intrusive appears to imply that this intrusive was in place before 1920. If so its heat must be remnant from a time before that, or else it must have heated up since without changing its form.

The shape of these intrusive bodies is either in irregular rounded bosses, or in the case of the long northern lens which is the most conspicuous of them, in elongate "U" shaped sills of subhorizontal habit ending in two horns which give to the cross-section of the whole the shape of a canoe. This pair of horns is prolonged upward as an unconformity between the overlying lava as though it were an intruded mass of lava which had penetrated the bottom layers of an old pit section and sent its upward prolongations up the wall crack between the fill of the pit and its former walls. Immediately over the northern lens there is a section of indefinite reddish beds on one side tending to cave away which look as though they might be talus sections.

The U-shaped sections are apparent in other places of the Halemaumau wall. In one of these an old talus section is very clear. In some places there are veneers of what appear to be old wall crack material emerging around the edges of these U sections. By wall crack material is meant the peculiar scraped lining of hardened lava which has been repeatedly seen in Halemaumau at times of lava subsidence, when it was seen that the bench magma floors and crags were separated from the wall of the pit underground by an encircling dyke of basalt between the fill of the pit and the older wall. This when seen was called the wall crack veneer.

The chief dynamic function of the red hot intrusives in the wall of Halemaumau is to undermine what is above and form the locus of notable avalanching. The northern lens keeps the entire wall above it in uneasy sliding and keeps it almost vertical, the two horns and the unconformities above being the places which develop avalanche gulches. The avalanche debris of the hot intrusives creates intense convection by its high temperature and the cauliflower clouds of avalanche dust are conspicuously hard and full of vortexes.

It is worthy of note that many of the rocks thrown out red hot in the May eruptions were fragments of these gabbroid types of intrusives and in considering the cause of the steam explosions we have to ponder the possibility of large bodies of red hot intrusives suddenly opened for access to the underground waters. This would be more logical as a condition imagined

for the particular results achieved than the explanation given in the May Bulletin, in that the fragments ejected would correspond with the materials of the heated boiler. This would accord with the fact that the fragments are not new lava. But as in a geyser the pressure of the water would have to be sufficient to prevent the steam from forcing the water back by the route of its entrance. Otherwise it would be necessary to confine the water after admitting it to a red hot chamber, which might possibly be achieved by some earthquake mechanism, or by mud, that closed off the water bearing cracks.

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June 1. Made circuit of Halemauap in the forenoon. Top of southwest talus lay about 300 feet below rim and this talus is under a niche or angle in the rim backed by greatly cracked ground and liable to much more avalanching. The talus cone was dry at the sides and wet in an inverted "V" up the middle, with much steaming. The intrusive boss in the western wall of the pit also lay about 300 feet below the rim, with lava beds unconformable above it, showing a rusty red circular body above partly surrounded by a light pink massively jointed and fine grained rock in horseshoe shape with the opening of the horseshoe upward. Against this about the horizontal lava beds right and left.

The eastern wall of the pit falls off less steeply than elsewhere with successive buttresses below, the lowermost one trenched at the southeast by deep gullies of avalanche slides, and except for some small lens-shaped intrusive bodies and some oblique dykes at the bottom, the material is wholly bedded lava. These oblique dykes are more or less parallel to the wall, as all the dykes in the pit seem to trend with the Kau Desert rift system, which is also parallel with the Uwekahuna wall, and with the greatest length of the pit itself.

The southwest wall shows three or four dykes at the bottom which peter out above, and one long dyke which rises to within 100 feet of the upper rim. This is the 1920 rift dyke, interrupted by the rift cavern about 300 feet below the rim, a high arcade, perhaps 60 feet from floor to roof, and leading away into mysterious darkness. Below this the columnar jointing of the dyke may be seen, possibly 15 feet wide, and this is again interrupted farther down by another crooked tunnel. The wall shows some arched beds athwart the dyke towards the top.

The northwest wall of the pit showed at this time what appeared to be a fuming fissure zone, uneasy with the incessant working of avalanches that tumbled into the void beneath, sending up rapid cauliflower clouds as they fell. At the bottom of this wall could be seen the upper portion of a platy, massive, light colored and fine grained intrusive body, the extent of which downward and sideways was obscured by the red talus slopes of the bottom region. A vertical strip of this body which had caved away as a gulch on one side showed horizontal lavas behind it in a northwesterly direction, as though the visible intrusive had a vertical contact on that side. The general quality of the rock appeared similar to the light colored portion of the western boss. A similar large body of massive intrusive rock appeared in the northeast wall two-thirds of the way down and this showed vertical columns of small size and a platy lamination that was very marked. To the west of this small dykes could be seen through the steam, one of them evidently the northeastern continuation of the southwest rift dyke.

In going from the east side of the pit to the southwest side the Kilauea floor showed an even gradation from boulders to gravel, from gravel to sand, and from sand to dust. There were boulders on the southern ash surfaces, but sparsely scattered. The ash was crusted and covered with rain rills.

Toward the west lay a big boulder 400 feet from the pit, twelve feet long and four feet high. The odor of hydrogen sulphide was perceptible but there was no disagreeable fume from the pit anywhere. The west-northwest rim was a boulder field of fresh broken rock of every possible petrographic type of basaltic magma. Here and there lay singular rock fragments of gray-green or red color, that had rotted down in place under some chemical decomposition or heat effect. Some of the light colored olivine rocks of fine grain exhibited slight breadcrust cracking, and others were slightly glazed. There was no trace of lava blobs, Pele's hair, lava droplets, or bombs made of fragments wrapped in lava, like those ejected in 1790. There was no trace of contemporaneous lava at all. All of the material might have come from the talus on the bottom of the bit and from the deep-seated intrusive masses and dykes through the action of a dynamite explosion.

The old lava domes protruding through the layers of new-fallen gravel near the north rim of the pit showed yawning cracks full of wedged rocks that had fallen into them. In many places the thin shells of old lava were punctured by big stones or even large boulders which in some cases broke through to a cavern below. The northern edge of the pit was covered with rocks from 3 inches to 3 feet in diameter and here there were no cracks back from the rim. The eastern and western edges were much cracked and steamy for 50 feet back. A crack concentric to the rim 6 inches wide, but not hot, was found 300 feet back on the west side. The small round spheres of mud raindrops (pisolites) were found plastered on a big boulder. There was notably little sand about the northern edges of the pit, although heavy sand falls were reported to a depth of 2 or 3 feet during some of the big eruptions. This is due to the fact that the sand collected on the immediate edge of the pit at that time, and several hundred feet of that edge, had caved in afterwards. The Postal Rift cavern now emerges at the northwestern rim of the pit as a broken trench, this being a portion of the cavern that was 500 or 600 feet back from the former rim. It is roofed over a few paces back from the present rim and may be traversed as before, but there are several new holes punctured in the roof. The face of Uwekahuna cliff appeared very dusty with the new-fallen ash.

June 2. At 10 a. m. the vapor in the pit was thinner, and a yellow solfataric deposit was visible on the northeastern talus in lines departing radially from the center of the pit. The color was greenish, suggesting ferric sulphate. At 11:30 a. m. the upright fissure at the north side of the pit appeared to be in motion, and at the same time a tremor lasting 30 seconds was registered at the Observatory.

June 3. At 10 a. m. surveys were begun to determine the shape, depth and position of the new pit and to establish new flags. The volume of steam in the pit appeared greater, probably owing to rainy weather and there was more dust flying owing to increased movement of the pit walls with avalanching, recorded as follows:

9:58 a. m. movement along E.NE. crack.
10:13 " " " NW. and E.NE. cracks.
10:25 " " " E.NE. crack, slight.
10:31 " " " E.NE. crack, slight but long continued.
10:43 " " " N. crack.
12:00 m. moderate avalanche.
12:06 p. m. increased steam rising.
12:15 " avalanche.

June 4. Surveys were continued, some of the cracks concentric with rim of pit appeared to be widening and there were frequent small avalanches.

June 5. Steam at the pit seemed thinner and there were a few small rock falls.

June 6. Kapoho in Puna was visited. H. J. Lyman reports that the April earthquakes were hardly felt at all at Eldart's a few hundred yards north of the Kula fault. No proof of raised shoreline north and south of the subsided belt had been brought forward. The stories of dead fish and shells were discredited.

Exploration of the coast from the Kula fault to Cape Kumukahi showed evident submergence all along the line with trees growing under water. In one place there was a grove of pandanus in a lagoon 200 yards back from the beach.

June 7. Steam puffs at Halemaumau seemed bigger but there had been much recent rain. An earthquake was felt in the morning and numerous earthquakes had been perceptible during recent nights.

At 10 a. m. steam in pit was thin and bottom debris appeared very wet. Two or three avalanches occurred during forenoon, the biggest one at 11:50. New talus had fallen on the sulphur patch at the north edge of the bottom area. A patch of steaming vents north of the bottom area appeared less vigorous than before. A geophone used at the steaming cracks at road terminus revealed no underground sounds. Studies were made of the mud drip that had hardened on boulders, of the pitting whereby some boulders had gone through the 1924 ash and disturbed the 1790 ash below, and of the many clay-filled depressions showing geometrical patterns of sundried cracks. For a circular pool of the clay-like ash, the main cracks are radial, and the subordinate ones concentric and irregular. Delicate rill patterns had developed on the ash at the south rim of Kilauea crater. At the Italian Cliff on the east side of the gravel flat falling boulders had hit the top of the cliff and bounced off into the south bay.

A sample of ash collected from a flat roof near Observatory was three-eighths inch thick. The collection was made several days after any ash fall. The last heavy fall was a mud rain May 18 followed by a cloud-burst of clear rain when nearly 2 inches fell in a little over a half hour. This of course washed the deposit on the roofs, and the total accumulation must have been something over one-half inch or 12 millimeters.

An avalanche at 10:44 a. m. on this day observed from the road terminus 2000 feet from the pit rim produced its visible cloud above the rim one minute after the roar was first heard and no tremor of the ground was perceived.

June 8. An Observatory record was kept on this day. There were several quakes during the previous night, slight ones were felt at 10:30 a. m. and 1:25 p. m., and a strong earthquake at 2:20 p. m. dismantled the seismographs, made an avalanche from the southern part of Uwekahuna Bluff, and was followed by dust clouds at the pit for twenty minutes.

At 3:44 p. m. a slight roar came from the pit followed by a heavy spurt of steam cloud. At 3:47 a dark gray cloud rose at the north and northwest sides and became continuous at the west side. At 3:48 there was a slight roar and a new spurt of dust and steam at the north. At 3:50 dust was rising northwest and steam at the east. At 3:52 the cloud was all steam.

At 4:30 p. m. came a roar and a heavy cloud believed due to explosion which filled the pit. A half minute later there was a hard spurt of black

dust on the north side. The cauliflower continued for four minutes becoming lighter at 4:35 p. m. when a pall of dust was falling in the desert to the southwest. At 4:39 another dust cloud rose on the northwest side of the pit. There were roarings at 4:43 and 4:45. At 5:12 p. m. an earthquake was felt. More or less continuous roaring was heard between 5:51 and 6:20 p. m. from a station on Uwekahuna Bluff, and the noise of avalanches was occasionally heard above the continuous roar which appeared to be due to a different cause. At 6:02 p. m. there was another earthquake.

June 9. At 7:30 a. m. the steam column over pit was very slight. There were earthquakes at 10:50 a. m. and 11:41 a. m. followed by dust clouds.

At 11:59 a. m. a sharp earthquake was felt at the roadway in the gulch west of Keanakakoi. Here the cliff faults cross a causeway in the road and small cracks were visible in the road, the stone walls and the hillsides northeast and southwest. It was evident that the fault fissures of the gravel flat were working, and this earthquake was felt by an observer standing on the fault where it crossed the road.

At 1:06 p. m. a puff of dust cloud rose clear of the pit without leaving any veil of dusty air below. At 1:19 red brown puffs filled the whole east section of the pit. At 1:24 dust was falling toward the southwest and a translucent veil of gray color hung over the pit.

At 3:30 p. m. a cauliflower cloud arose and at 3:48 a bigger one preceded by a deep growl. Brown cauliflowers overlapped the northeast edge of the pit. During all of these the west side of the big crater lay in deep shadow from the overhanging cloud. At 3:58 p. m. another pink puff came up the northeast wall of the pit. The upper part of the dust column had now disappeared in low-hanging clouds. At 4:08 another column arose at the northeast edge mixed brown and white. In the quiet intervals these columns became white, steamy and sluggish. Most of the time the west corner of the pit remained clear. The dust columns were very red and when mixed with steam they gave the cloud a salmon color. At 4:15 p. m. a new heavy red column at the northeast boiled up in beautiful soft volutes, white on the west and red on the east. At 4:28 p. m. white steam was boiling up rapidly at the northeast rim.

At the pit in the forenoon of this day surveys were continued, an occasional faint roar was audible in the steam in the bottom of the pit, and what appeared to be a new patch of blue gas was seen on the west side of the bottom flat.

In the above account of cauliflower clouds for this day and the preceding one it is evident that some intense working of the northeast wall of the pit was in progress, and this was probably the development by strong avalanching of the columnar intrusive body, which was destined three days later to appear as a red hot mass in the wall. There were mud rains on June 9. It is impossible to say in the absence of observations at the pit itself just where avalanching ended and a rush of gas took its place in making cauliflowers.

June 10. At 10 a. m. there was hissing in the bottom of Halemaumau, blue and yellow fume in addition to steam came from cracks in the bottom and from the base of the north wall, and avalanches fell along the fissures in that wall. Earthquakes, avalanche clouds and rumbles were noted from time to time at the Observatory during this day.

June 11. Between 10 and 11 a. m. and at 12:28 p. m. heavy dust clouds boiled up from the pit probably produced by hot avalanches from the north-

ern intrusive. Earthquakes were felt at 12:08 p. m. and at 4:13 p. m.

June 12. An earthquake at 4:30 a. m. was preceded by rumbling noise that seemed to progress from south to north. Another occurred at 1:59 p. m. without observed effect at the pit. At 5:54 p. m. a deep booming noise was heard at the Observatory.

About 9 p. m. glow from within the pit was reflected on the cloud above. From the rim it was found that the columnar whitish intrusive body two-thirds of the way down the northeast wall, was all glowing like a patch of aa lava, and powdery trickling small avalanches were falling from the glowing surfaces. These made the talus glow beneath. The area that exhibited more or less glowing in the wall was about 600 feet long east and west, 300 feet high, and its top was more than 600 feet below northeast rim of pit.

Other avalanches fell from the usual places. Quiet steam rose from the bottom of the pit, and no purring or hissing was heard.

June 13. Just after midnight, at 12:40 a. m., came an unusually strong earthquake which at the Kilauea Military Camp back of the north rim of Kilauea crater overturned objects on shelves.

The origin of this earthquake was discovered by officers of the camp to be on the road to the Fern Forest where it crosses the big crack on the 4000-foot contour. This is part of the cliff that extends westward back of the Sulphur Banks, and is one of the main concentric fissures of Kilauea crater. The fresh dirt wet by rain of the previous day was found broken across the road in eight or nine places along about 80 feet of roadway. This is the road that departs from the main Kau road northward just east of the Military Camp. When first visited in the morning the cracks were perfectly fresh. They stood open from one-eighth inch to one-half inch, forking more or less and extending into the country east and west of the road for 30 or 40 yards. The blocks of ground between the cracks had slipped down with downthrow of from one-quarter to three-quarter inch both on north and south sides of different cracks. Predominantly the downthrow appeared to be on the side of Kilauea crater. The biggest cracks were right over the old chasm crossed by the road, and most of the others were south of this chasm.

That the midnight earthquake was contemporaneous with the formation of these cracks was proved by the fact that the shocks were felt most strongly at the Military Camp with intense vertical motion, whereas they were less strong at the hotel to the east and at Keauhou Ranch to the north. The place is almost in the line of Uwekahuna Bluff, and at the north corner of the Kilauea fault blocks. Like the cracks across the road at Keanakakoi gulch, this motion showed the Kilauea sink to be working and settling as result of the great subsidence at Halémaumau.

At 9:15 and 10 a. m. loud roars from the crater were heard at the Observatory. These were identified by the observer at the pit with heavy avalanches over the southwest talus, which sent big boulders rolling down the slope, but made only moderate dust clouds which were sucked down by the trade wind vortex to be dissipated by mixture with the steam at the bottom.

The place seen glowing on the previous evening proved to be a big intrusive mass with platy parting planes and columnar structure of fine grain and light gray color. The glowing talus below is platy and gray. The red of the incandescence represented a temperature of about 750° C., and did not show in daylight. The slides on the intrusive mass, which forms a vertical wall, were sudden and powdery and the dust boiled up with much heat in the resultant cauliflower clouds. All the steam tails of the bottom



Figure 17. June 11, 1924, Halemaumau pit from Uwekahuna Bluff, showing enlargement by May collapse, and ash landscape. Photo Emerson.



Figure 18. May 30, 1924, west wall of Halemaumau, with red boss underlaid by massive intrusive rock which showed incandescence June 18. Upper layers are mostly lava flows. Photo Emerson.



Figure 19. June 5, 1924, northwest wall of Halemaumau, showing upturned horn of a whitish intrusive body, broken across by an avalanche scar. This break shows horizontal flows behind the intrusive, indicating a vertical contact. Photo Emerson.

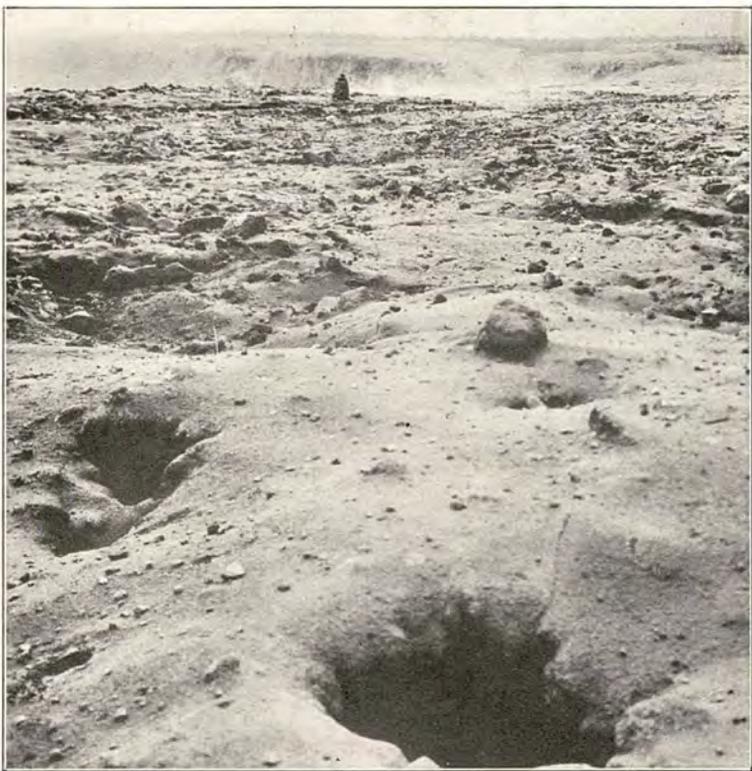


Figure 20. New boulder field from May eruption 2000 feet southeast of Halemaumau. Holes in foreground were punctured in shells of old lava by falling rocks. Monument is present road terminus, near where Mr. Taylor was killed. Looking east. Photo Maehara.



Figure 21. Block thrown four hundred feet west in May. This is twelve feet long and weighs approximately fourteen tons. It lies west-southwest of Halemaumau. Note its isolation. The larger rocks were frequently thrown farther than the gravel. Photo Emerson.

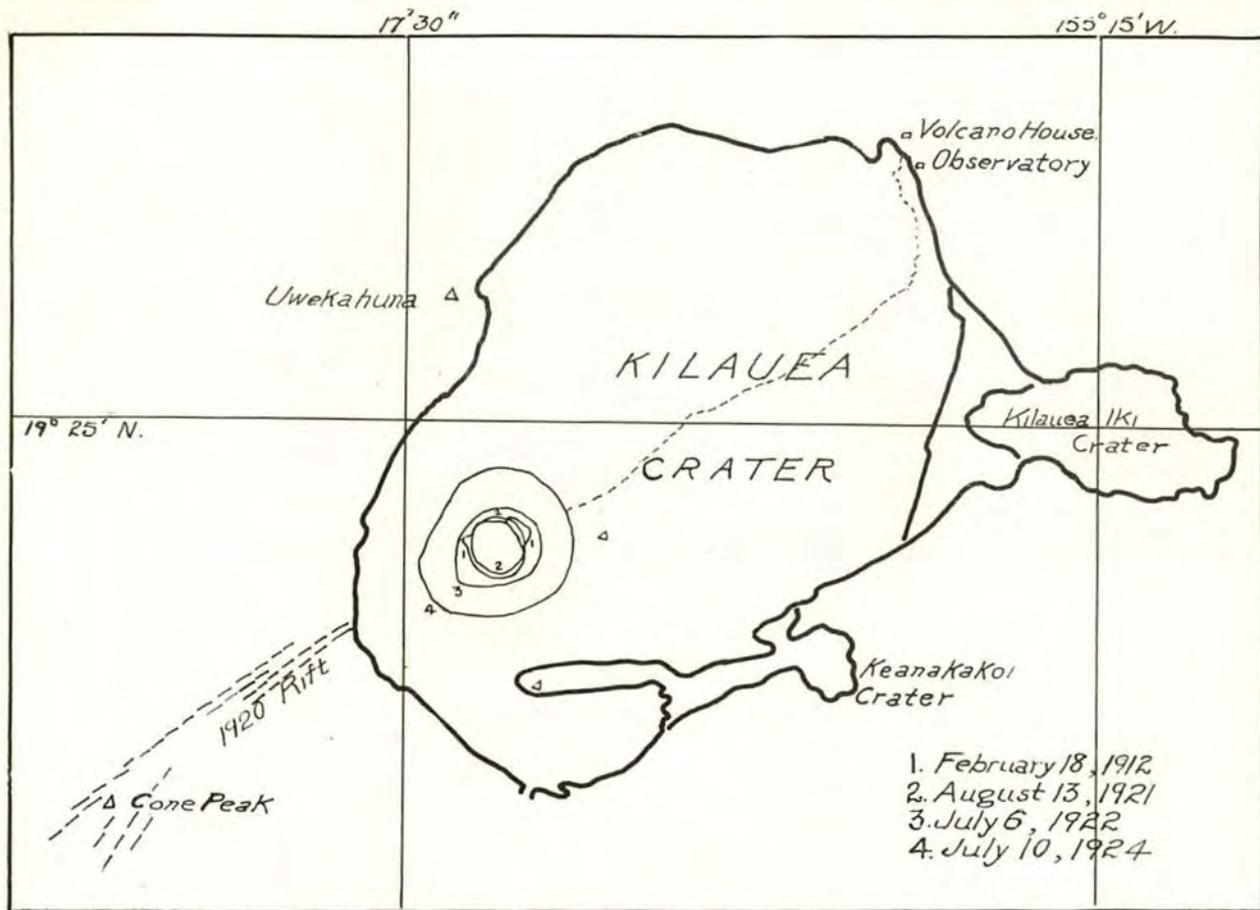


Figure 22. Map of Kilauea showing changes of Halemaumau rim 1912 to 1924. Dimensions in feet: 1912, 1225x1530. 1921, 1235x1210. 1922, 1980x1520. 1924, 3410x2910. Note axis of elongation parallel to 1920 rift.

of the pit were drawn toward this hot wall because of the convection and this effect was increased by the hot avalanches. West of the incandescent body very continuous avalanches rolled down the north chasm that was being formed there. This ended below at the two big massive intrusive bodies at the bottom of the cliff. Most of the intrusives lay where the walls were steepest and the talus slopes shortest. They were thus where the walls are exposed nearest to the bottom of the pit and they are also in that northern region where the biggest explosions originated and where the funnel of collapse began on April 29. Dykes are also most abundant around the bottom area, and what looks like an intrusive sill in one place. The dykes are mostly 2 to 5 feet thick. The big intrusive masses are north-northwest, north and northeast, and there is the problematical pinkish boss in the middle of the west wall.

The big incandescent mass seen in daylight is a flat "U" shaped lenticular body ending in upturned horns east and west, apparently cutting across beds as though it occupied a gash, its columns up and down, its length 2000 feet and its height 400 feet. It looks as though it filled the bottom of an old pit section beneath a pile of lavas above, making a lenticular intrusive of saucer shape, the edges of the saucer tending to push upward between the fill of the old pit and its bordering walls. Its greatest extent is certainly horizontal like a lens, for it has been developed and revealed by the avalanching back of the northeast wall, and its vertical columnar jointing is that of a body filling a horizontal fissure. It is somewhat like Daly's "laccolith" in the west Kilauea wall and its platy jointing is like pieces of laminated crystalline olivine rock found among the explosive debris. At the place that scales off with hottest incandescence the jointing is peculiarly feathery and somewhat like a slaty cleavage. Seen in daylight neither the slides nor the rock bear any resemblance to lava, and the incandescence appears to be remnant, in a body which had crystallized before the explosive eruption began. What the relationship of this heat may be to the recent lava fill of Halemaumau pit, is wholly problematical. No steaming or continuous fuming is seen at the intrusive body.

At 8:53 p. m. another earthquake was strongly felt.

June 14. Earthquakes preceded by rumbling were felt 9:55 a. m. and at 2:43 p. m. At the pit in the forenoon increased cracking was observed at the southwest corner and fresh avalanching had taken place there. Frequent and heavy avalanching was observed towards the northeast.

June 15. In the forenoon at Halemaumau blue fume was observed rising from cracks in the wall about 75 feet below the north-northwest rim. Some hissing was audible in the pit. Hot dry air rose from some of the southwestern fissures back of the rim. Avalanching had diminished.

June 16. In the forenoon there were occasional avalanches and some steady trickling of dust was observed at the top of the northern hot intrusive on its west side.

June 18. At 9 p. m. the north intrusive was found still glowing and a small spot of incandescence in the light colored platy rock of the lower portion of the western intrusive boss. A steady glow hole was seen in the talus at the bottom of the north wall. Blowing noise was audible, waxing and waning in the bottom of the pit. An avalanche which fell from the west end of the north intrusive left a large surface of glowing wall and created a glowing talus below. The wall cooled off rapidly through dark red and purple shades until only a few incandescent cracks remained.

It was now evident that steam, earthquakes and avalanching were all decreasing, and the seismograms had become almost normal.

June 19. In the forenoon a part of the northeast wall above the hot intrusive was found to have fallen off. Cracks along southeast rim of pit had widened. There were frequent avalanches.

June 20. At 3 p. m. some cracks on the southwest side were identified as wider. Small avalanches were frequent and hissing was audible in the bottom. One of the southwestern cracks was caked with a hard white deposit having a salty taste.

The Kilauea floor north and west of Halemaumau was explored and also the Kau Desert in the region of the large chasm of the 1920 rift. The ash and small pebbles north of Halemaumau vary in thickness from a half inch to 2 inches as one travels southward from the northern floor of the great crater. Large stones on the Uwekahuna side are first found about a half mile from the pit. On this side the fragments show broken faces of fresh rock much less masked with mud and ash than on the southeast. A new opening was found in the roof of the Postal Rift cavern farther away from the pit than the other openings. The opening at the big bend of the cavern had been enlarged. Remarkably delicate rill patterns were found in the new ash at the southwest end of Kilauea crater. At the chasm trig station in the desert the new ash was 8 inches thick.

June 21. An exploration was made of the new flow locality near Makaopuhi which had been erupted in August, 1923. In the autumn of that year this place had been full of noxious steam. Now the steam was very hot still in some places, depositing bright yellow sulphur along the fissures but the eruptive cracks were accessible. The main crack was a good type of fissure eruption in a forest. The flame holes were now surrounded with aa spatter and coated with sulphur. The fissure trends southwest and northeast with two main flows from it. The northeastern one was that first explored but the southwestern one was inaccessible in the autumn of 1923. This is a short flow of pahoehoe which has made a large number of tree moulds and covers about 2 acres. The two flows are about a half mile apart. In between the forest has been killed by gas and along the cracks brilliant deposits of sulphur make coatings on dead ferns and logs. There is here no lava but the scalding fume had evidently been intensely active. In the north wall of Makaopuhi pit there is a steaming hole high above the fissure that produces the lava of 1922.

On returning by way of the Kalapana trail twenty-five or more cracks from one inch to one foot wide were found crossing the trail trending northeast-southwest in the region southwest of Makaopuhi. Those were in two principal sets, one group being near Makaopuhi and appearing fresher, the others near Alea crater.

June 23. A slight spicy sulphur smell was perceptible at the Halemaumau rim at 9:30 a. m. There was less steam on the bottom. A small avalanche fell from the northern hot intrusive and there were numerous small rock slides. Occasionally the blowing noise from the bottom region increased distinctly. The flattish bottom area was reddish and muddy, somewhat diamond shaped and nearly in the center of the pit. Almost no steam rose above rim of pit and the inner jets lay chiefly along the east, southeast and northwest edges of the bottom flat. This bottom area was farther north at beginning of June, but the talus heaps under the hot body had gradually increased covering up that part. The principal talus cones lay west, northwest, north, northeast and southeast and they occupy three-quarters of the

bottom area, the central flat occupying the other quarter. The central area is smooth rather than flat and is probably lowest towards the east. There was a very marked difference in the grades of the southwestern and north-eastern inner slopes, the former making a long gentle grade to the bottom, whereas the northeast wall was nearly vertical. Gullies formed by avalanching had formed on the north sides of the east and west prows of the hot intrusive and some of the materials in the cross-section appeared to be remnants of old talus slopes buried in the wall of the pit. There were now seen three caverns along the southwest rift dyke and there was some sign of a massive intrusive body at the base of the southeast wall of the pit.

June 22. When the pit was visited at 10:15 a. m. it was clear that the growth of the talus slopes would be one of the main changes recorded for this month. The southwest talus appeared higher than on the previous day. Small avalanches continued. A new big talus was growing at the south, a moderate one southeast, a high narrow one into a niche that exhibited a curved unconformity at the northwest, and a broad one under the hot body extending from north to northeast. At 10:15 a. m. there was a fall here, and at the south wall rocks were falling all the morning adding to the big southwestern and southern slopes.

One of the features of this gigantic pit that can be traced in many of the walls west, southwest and north is the presence of outlines of old niches or "U" shaped extensions of the pit that were lined in ancient times with wall-crack fills between bench magma and the perilit. These old fills now appear as smooth veneers either hollowed as cups or protruding as curved humps in the walls here and there, showing discordance with the lavas beneath and distinctly hinting at the lining of old funnels. A study of any of the walls reveals puzzles in solid geometry suggesting old pits that have shifted position from time to time about the Halemaumau axis as a center.

June 26. Surveys were being continued in the forenoon. Avalanches were mostly south and north. A flag south-southwest had gone in and big slabs of the south rim were carried away. One fummy sulphurous patch was visible in the bottom amid many tails of steam. Toward noon the steam thinned.

This period showed diminution of steam as a whole and there were very marked changes in apparent vapor between times of warm sunny weather, when it disappeared, and cool moist weather when big clouds were visible. The vapor appeared every evening whereas in the hot noonday no steam whatever as visible above the rim.

June 28. At 3:45 p. m. an avalanche puff was seen to rise from the pit from a viewpoint at gravel flat without any noise whatever, boiling up in a heavy dust cloud of brown color and then clearing the edge of the pit immediately without leaving a veil of dust. There were other numerous avalanches from the north wall, usually noisy. This peculiar dust cloud blew away to leeward as a unit and could be seen over the desert for five or ten minutes. There had been numerous earthquakes during the previous night.

June 29. A study was made of the Pahala and Kapapala districts with reference to the effects of dust fall, etc., produced by the May eruption of Kilauea on these places 4 to 25 miles to leeward. The observed thicknesses of new ash were as follows:

Old prison camp, pisolitic ash	- - - -	8 to 16 millimeters.
Dust on pahoehoe lava Halfway House	- 2 " 7 "	"
Dust on soil Kapapala gate	- - - - 3 " 4 "	"
Dust on soil at lone kukui	- - - - 1/2 "	"
Dust on soil Pahala	- - - -	Mere film.

Rain had been usually abundant since the eruption and vegetation at Pahala was remarkably fresh and green. It was estimated there that an average of four tons of ash fell to the acre. The first week of the eruptions the ash fall was reddish, after that it was gray. The ash falls had been numerous, sometimes obscuring the view and laborers harvesting had occasionally tied wet cloths across their faces. The ash had fallen as a dry flour without rain. On the roofs the ash appeared gray like a coat of paint but heavy rain May 18 washed it off clean; the electrical storms had been distant. The plantation appeared prosperous and this amount of ash appears to have been beneficial rather than otherwise. It was reported that high winds still blew the dust from the desert southward and this drifted in from the sea at Pahala.

At Kapapala darkness had occurred in daytime on some afternoons like May 18 so that the electric lights were turned on. There was a little mud rain but mostly dry ash. Eyes of ranch cattle became sore and for a day or two the cattle did not eat. The dust fall was very heavy in the upper Ohaikea paddocks. Earthquakes had been numerous but not strong enough to knock anything over.

An observer on this day down the Keauhou road reported discovery of two fresh cracks each about a half inch across one mile south of the fork of the Kapapala trail. The trend of the cracks was east and west, toward Alea and Makaopuhi, and it is probable that some of the many fresh cracks in this district were opened in the spring of 1924.

At Halemaumau 10 to 11 a. m. a few small avalanches and falls of individual rocks were noted in the pit and a distinct purring noise due to escaping gas was audible in the bottom.

SEISMOMETRIC RECORD

During the month ended midnight June 30, 1924, 801 local earthquakes and four teleseisms were registered at the Observatory. The number of earthquakes per day and other earth movements are exhibited below. Time is Hawaiian Standard, 10 h. 30 m. slower than Greenwich. The great number of quakes recorded in June accompanied the closing of the explosive period starting in May.

Local Earthquakes.

	Day	Number of quakes		Day	Number of quakes
June	1.....	33	June	16.....	28
	2.....	17		17.....	10
	3.....	29		18.....	7
	4.....	25		19.....	11
	5.....	19		20.....	14
	6.....	27		21.....	3
	7.....	16		22.....	13
	8.....	53		23.....	12
	9.....	47		24.....	4
	10.....	63		25.....	13
	11.....	63		26.....	7
	12.....	75		27.....	4
	13.....	91		28.....	27
	14.....	49		29.....	11
	15.....	29		30.....	1

Teleseisms.

June 7.....	9:20 a. m.	Slight.	
17.....	10:51 a. m.	Feeble.	
25.....	3:19 p. m.	Slight.	Distance 1200 miles.
30.....	5:22 a. m.	Feeble.	

Spasmodic Microtremor.

This type of tremor was moderate for a while on June 25 and slight on other days.

Harmonic Microtremor.

This type of tremor was very slight or absent during June.

Microseismic Motion.

The amplitude of micorseisms was slight throughout the month.

Tilting of the Ground.

By weeks this movement was as follows expressed as angular change and direction of motion of the plumb line:

June 1-7.....	4.3	seconds	SW.
8-14.....	4.7	"	S.
18-21.....	3.2	"	SSW.
22-28.....	2.5	"	NNE.

.....
T. A. Jaggar,
Volcanologist.

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VOLCANIC CONDITIONS IN JULY

Activity of Halemaumau

The month at the lava pit opened with no other changes than occasional avalanches from the walls and a lessening of the bottom vapping.

The cauldron left by the May eruption was at the upper rim, by measurements platted early in July, 3400 feet long northeast-southwest by 3000 feet wide. It remained an irregular oval with edges that had gone back about equally in all directions. The lowest part of the bottom flat was towards the north approximately 1335 feet below a datum station on the eastern rim. This bottom area was diamond shaped and gravelly, of dimensions 1000 by 700 feet. The area of talus slopes including the bottom occupied an ellipse 2800

feet long by 2000 feet wide. The inward funnelling of the rock wall above the talus was least steep on the east side, where the horizontal distance from rim of pit to top of talus was 800 feet, and here the talus was least developed.

Across the north side of the bottom region above the talus and locally passing under it there were revealed intrusive whitish bodies of dense crystalline rock, presumably a gabbro, 1500 feet across. In the walls higher up there were red hot crystalline bodies of similar composition, one a lens at least 1800 feet long in the northeast wall, and another roundish with a red boss in the middle 400 feet in diameter in the west wall.

It thus appeared that the deepest part of the pit where the explosions came from was probably underlaid with big intrusive masses like many of the rocks that the explosions threw out. The site of the center of the new pit was identical with the old Halemaumau, which had merely been enlarged and deepened.

The walls showed discordances in the ancient beds marking old funnel sections, and most of the beds appeared to be lava flows above the big intrusive bodies. Mild blowing noise somewhere in the bottom of the pit became somewhat louder as the 19th of July approached and a deep booming noise was heard the day before that date.

Otherwise there was little forewarning of an outbreak of lava in the midst of the western talus which occurred just after noon on that day and continued for the rest of the month. The lava brought much gas with it and made a spraying fountain like the ones so often seen on Mauna Loa, but otherwise the development of the lava pool from a source in the talus was quite like what has happened here before, and what occurred in Makaopuhi pit at the time of the big subsidence of Halemaumau lava in 1922.

The lava flowed down the talus slope, formed a big cone at its source, developed both aa and pahoehoe form, threw up Pele's hair and light basaltic pumice and finally developed a new fill over 1000 feet across, occupying most of the bottom area.

During the last two weeks of the month the fountaining dwindled, small fountains in the bottom pool disappeared, the flows crusted over and travelled in tunnels and the spraying of the source vent diminished until finally on the 30th no activity could be seen except blue smoke at the cone and glow in the cracks at night. The next day most of the blue smoke had disappeared and all lava motion ceased.

All of this recalled the activity of returning lava in Halemaumau in July of 1922, which also ceased during the month.

For the rest there were occasional avalanches from the walls and some glow remained in the intrusive bodies especially north.

DISCUSSION OF SPECIAL FEATURES

Return of Lava

The return of the lava on the 19th of July to the bottom of Halemaumau pit at an elevation approximately 2400 feet above sea level is of interest in comparing what happened after the May collapse of 1922 and what might be expected on the hypothesis of water explosion discussed in the May and June Bulletins. In 1922 it was estimated that the lava sank 1000 feet and broke out in Makaopuhi and Napau pits at about the level represented by such sinking. In 1924 the sinking is supposed to have reached sea level if the ground water closed in above the lava and brought about the disastrous explosions of the month of May.

If this is what happened then we must suppose that the end of the explosive eruption was marked underground by a rising of the lava, which gradually filled the steam chamber, crusted itself over by cooling on its outer surfaces until it was defended against access of water, and behaved as a stiff black pahoehoe body in the cracks and shafts underlying the pit. In this condition it was forced upward gradually by the expansion of its own gases, which finally

achieved release rather easily owing to the big voids in the pit and beneath it that had been left vacant by the spring blasting.

Supposing this to be applicable as an explanation to the general philosophy of volcanism, it appears to mean that the accident of water explosion occasionally arriving in the conduit system when the lava goes low enough, is itself brought to a close by the effect on the lava column below of the reduced pressure which the explosion itself leaves in its wake. The explosion throws off a big weight of rocks. Its own pressure is spasmodic and the lava rises in spasms to seal off the water. Lessened water lessens the steam and the explosions come to an end. The lava gases are still potent enough to take advantage of such an extreme release of gravitative pressure as the enlarged pit and conduit occasion, so that the lava goes on rising until it effervesces in the open and exhausts itself in a short lived effort.

This checks very well with what happens in Vesuvian eruptions and in volcanoes of the Vesuvian class. A great explosion closes a long cycle of cumulative lava building, and is followed almost immediately by a very vigorous and destructive, but short lived lava flow. The interval between the explosion and the flow, and the volume of the flow are doubtless dependent on a balance of conditions such as saturation of the lava with gas, height of the orifice rent open and extent to which the lava gas and the extraneous steam are mingled in the great geyser-like discharge. In Kilauea in 1924 a lava flow was expectable to make the volcano comparable to Vesuvius. On July 19 the lava flow has come. That it was delayed a month and a half is due to the low saturation and high viscosity of the magma after years of voluminous flowing from levels lower than Halemaumau. Makaopuhi in 1922 showed outflow instantly when Halemaumau collapsed, but the saturation with gas was then higher. If in 1924 the Kapoho vents had opened there might well have been an explosive eruption of the Vesuvian type, followed instantly by a lava flow away down the mountain near the sea.

JOURNAL, JULY, 1924

July 2. In the afternoon some blowing noise was audible in Halemaumau and small avalanches fell from the northern wall. The weather was rainy and there was much steam on the bottom of the pit.

July 6. At 2:34 p. m. a roar was heard from the pit and a minute later steam and dust appeared, but were soon dissipated. Earthquake was registered at the same time.

At 3:43 p. m. there was a roar followed by a large volume of steam, but not much dust.

July 8. At 11 a. m. the main changes in the pit were found to be less steam and fewer avalanches. The steam jets rose from six or seven main locations of the lower talus and the bottom flat. This bottom flat was in no way horizontal, but merely a surface marked by mud and dust areas and overlapped by the bordering talus which rose at a higher angle. A northwest-southeast line of steam jets crossed this bottom area and at the east end of the line dense yellowish and bluish vapor rose from a patch of bowlders stained with sulphur. There were one or two other sulphurous places and a slight sulphur smell was perceptible at the rim. Distinct blowing noise was heard, even though the wind noises were obstructive to hearing.

Several old unconformities in the lava beds of the pit wall exhibited cross sections shaped like funnels. No ash was detectible in the wall section, nor was there any evidence of increased decomposition downward, such as was believed apparent in the wall of 1922. The lowest massive intrusive at the base of the northwest wall had been trenched by a gulch which exposed an intrusive vertical contact with lava layers on the northwest side. This is quite different from the long north intrusive lens of which the top and bottom

contacts are horizontal or approximately so. This body had now developed a horn standing out from the wall at its western prow. The cracks in the new ash at the road terminus appeared widening, the vapor from them was very hot and the ground all about was wet.

July 12. At 10 a. m. there were small avalanches at the northeast intrusive body and some blowing noise was heard.

July 15. At 3 p. m. the weather was rainy, there was much vapor in the pit and the blowing sound was louder.

An examination of the ground was made to determine thickness of ash layer of 1924 along a line south-southeast from Halemaumau toward the flow gap of 1921. Measurements were as follows:

1700 feet from center of pit.....	17	inches of ash.
2300 feet from center of pit.....	5	inches of ash.
2500 feet from center of pit.....	4	inches of ash.
3800 feet from center of pit.....	2	inches of ash.
4700 feet from center of pit.....	1.5	inches of ash.
6500 feet (S. tip 1921 flow).....	0.7	inches of ash.
7500 feet from center of pit.....	0.5	inches of ash.
9200 feet (the big wash in desert).....	0.4	inches of ash.

July 17. No change was detected in conditions at the pit. The interior was clear and plainly seen except for the small jets in the bottom in fair weather, and only in rainy weather or at night did a vapor column form above the rim as seen from a distance.

July 18. In the afternoon the bottom of the pit exhibited less steam than before. Yellow salts were observed on the rock at the base of the east wall. Blowing noise was perceptible and on one occasion a deep booming noise was heard. Blue fume rose from cracks in the upper part of the northwest wall.

An examination of the surface immediately northeast of Halemaumau was made, using a pickaxe to test the actual depth of the 1924 sand and gravel under the boulder field close to the edge of the pit. It was surprising to find the beds uniformly only five to ten inches thick. The rolling surface of the ground gave the appearance of heaps of gravel, but this was really the uneven contours of the older lava beneath. In places the width of the boulder and sand zone at the northeast is only a little over 100 feet from the rim of the pit. It should be noted that during the eruption in May two or three feet of sand were measured on this edge, but thereafter the edge caved in repeatedly and carried the thickest deposits in with it. Now steaming holes in the lava under the gravel showed in many places with blue-green algae in the apertures.

July 19. The pit was visited between 10 and 11 a. m. The bottom area was brilliantly clear, a few slides fell from the north intrusive, blowing noise was distinctly heard, and dense steam rose in spots especially toward the south and in the center. The sulphur patch was plainly exposed amid steam in the southeastern part of the bottom area, and the sulphates or acid coating at the base of the southeast wall were greenish as well as yellow.

At noon from the Observatory an unusual amount of blue fume was seen to stand over the pit, and an observer reaching the pit at 1:45 p. m. discovered a jet of blue gas almost free from lava at first spraying up through a vent in the southwest talus and almost atomizing the liquid lava which it carried with it. It made only a small trickle of lava and undoubtedly was flaming. The stream collected in a puddle at the bottom of the pit without fountains.

At 2:30 p. m. and thereafter the jet from the talus had developed into a frothy continuous fountain of the Mauna Loa type with a trajectory like a jet from a hose toward the northeast and about 30° from the vertical. It started from the basal region of the southwest talus on a line crossing the mid-

dle of the pit in an east-northeast direction, and west of the line of the Kau Desert rift tunnel of 1920. The fountain busily built up a cone and sent snake-like streams down the slope finding a lowest place of accumulation in the bottom of the pit about where the sulphur patch had been at the southeastern end of the line of steaming cracks across the center of the bottom. Three small bubbling fountains were active in the puddle. The puddle was surfaced at first with festooned lava flows of pahoehoe showing black edges of aa lava and in places the crusts broke and pulled apart revealing aa beneath. Long flows trickled down the slope eastward and northward from the main source fountain.

As the main fountain built up its cone the wind piled pumice of mossy appearance to the west of it, and some of this was borne up above the western margin of the pit on tangles of Pele's hair. The droplets of pumice were light brown in color and finely vesicular recalling the frothy pahoehoe of the Alika source cones on Mauna Loa in 1919. The gas odor was of sulphur dioxide and not oppressive.

The source fountain started at a place 125 feet above the bottom of the pit and threw its spray about 150 feet vertically. The bottom lava area appeared about 1000 feet long in a northwest-southeast direction, by 300 feet wide.

In the evening the pit was so bright that the glow of the northern intrusive body in the wall could no longer be detected owing to the light of the new fountains. Steam rose from the talus and blue fume from the new lava, especially at the fountains. In the lava streams big boulders toppled and rolled down, which were apparently disturbed blocks of talus, but they carried with them pasty lava which shredded and crumbled like aa. Fresh tongues of lava flow were pouring on the bottom area off to the northwest from the source cone.

July 20. At 9:30 a. m. it was evident that the source fountain had become less vigorous and the growth of the tract of bottom lava had not been great. In the afternoon there was an earthquake and avalanches fell in the pit. The hot fume cloud rising above the new lava caused brownish fringe to hang down from the usual white vapor cumulus at the condensation level. In sunshine the pit itself remained very clear.

The lava fountain had now developed a well formed cup around it inside its cone. The two lower fountains amid the flows lay in a pool and they built up grotto half-domes beside them. The main body of flows was festooned after the fashion of pahoehoe but the eastern edge of the lava area was clearly aa. After 11:30 a. m. the source fountain notably dwindled.

July 21. At 5 p. m. it was evident that a clean-cut cinder cone of the type common at sources of flows on Mauna Loa was being built around the source fountain. This has horseshoe shape open to the northeast and steep outer slopes with an arete that was circular in plan bounding the inner cup. This edge was made of spatter and was sharp. The activity continued and a steady cascade of lava poured out of the opening of the horseshoe.

Steam was issuing in puffs from a small flat area at the west side of the bottom, at intervals varying from 20 to 50 seconds. At 4 p. m. an avalanche from near the west end of the north intrusive body sent up cauliflower clouds which preserved moderately hard outlines a short distance above the rim of the pit.

July 22. At 11 a. m. the activity of the source fountain continued without apparent diminution. The surface of the lava field was much extended and it had become a mixture of aa and pahoehoe. The source cone had built itself up.

July 23. At 5 p. m. the source fountain was found much broader than on the previous day and at times it formed a dome-shaped artesian fountain without spattering. The lava stream followed the southwest side of the new fill.

The two fountaining cones in the fill, for such the grottoes had become, occasionally hissed loudly.

July 24. At 4 p. m. conditions were found to be much the same and the streaming was now along the north side of the bottom fill. The source vent in the cone had become wider than on the 22nd, and some vertical cracks had appeared in the cone.

July 25. At 4 p. m. a small pool had appeared which occupied a slight depression in the central region of the new lava field. The opening in the source cone was smaller. Light rain was falling and much steam rose from the floor of the pit. The source fountain and lava stream remained as before.

July 26. At 4 p. m. the lava area on the bottom of the pit was fully twice as big as it had been July 20. It had now spread over the western part of the bottom area except for one island of reddish gravel which was steaming. The source cone on the southwest talus slope had now become large and glowing lava streams progressed eastward in leaf shapes, while small trickles of lava lay along the north edge of the bottom field. No bottom fountains were seen.

In the evening the source cone made snorting noises that echoed from the northern wall of the pit. The spray shot up about fifty feet and the cone appeared 100 feet high above the lowest part of its base. The material inside its crater had a curious consistency in its surging suggesting pith.

July 27. At 10:45 a. m. an avalanche cloud rose above the northeast edge of the pit. At 11 a. m. the pit was visited and it was found that the opening of the source cone had slumped down changing the flow pattern of the live lava streams so that they now went forking out downward to the west side of the bottom fill. On the previous day their activity was on the east side.

The total volume of cascading lava appeared as great as a week before but it was less frothy and the cone gas made less noise. Three or four yellow sulphur patches had appeared in the talus bounding the eastern edge of the lava field. The eastern part of the field had cracked so that craggy lumps stood in relief with aa in the hollows. There was a suggestion of swelling in places.

July 28. At 5 p. m. the lava from the source cone was found flowing in a tube made by its own crust and where it emerged it divided into several small streams that were crusted over along the lower portions of their courses. Only occasionally did small lumps of spatter emerge from the top of the cone. The small island of old bottom west of the center was still uncovered.

July 29. At 11 a. m. the lava was seen surging in the pool inside the source crater and at times it was flung out but the violence had decreased. On the lava field streams were flowing sluggishly under crusts and only a few bright toes were visible. For three days the area of the lava field had not noticeably increased. At night the glow was duller than it had been.

July 30. From 10 to 12 in the forenoon a circuit of the pit was made and the cone was found to be making much blue smoke, but no visible fountaining. There were patches of glowing lava in the cone and on the floor. Some slight glow on the fume cloud over the pit was visible in the evening.

July 31. In the afternoon even the blue fume had ceased rising from the cone. No glow was visible anywhere in daylight, and over the pit as seen at a distance no glow was detected at night, though the cracks of the lava field were still glowing as seen from the rim. A few avalanches occurred mostly on the north side of the pit. A little steam rose here and there in the talus. The patch of bottom flat left as an island in the lava was now nearly covered.



Fig. 23. June 12, 1924, north end of Kilauea crater with the May dust blown by strong trade wind. Mauna Loa in the background. Photo Emerson.

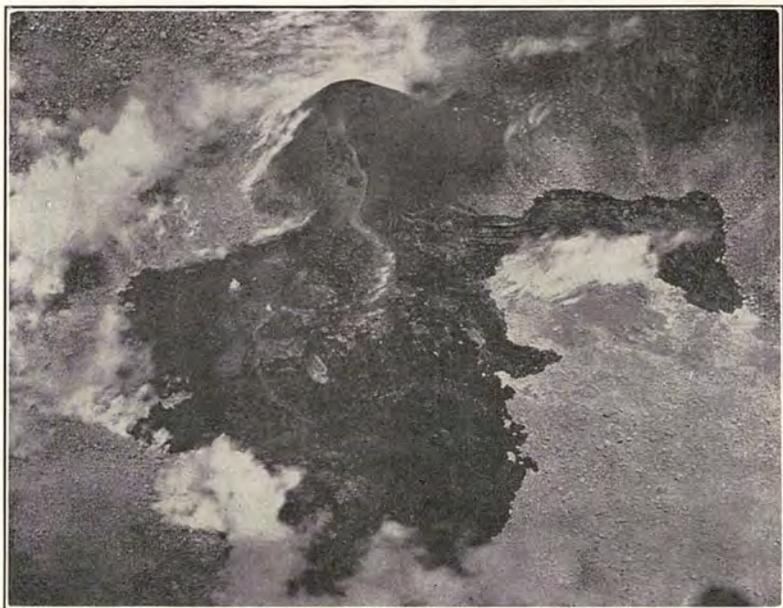


Fig. 24. Bottom of Halemaumau July 22, 1924, looking west. New punice cone in action, lava flow spreading on bottom of pit. Photo Emerson.



Fig. 25. July 19, 1924, new spraying cone and lava stream at night, bottom of Halemaumau from the southeast rim. Shows centers of fountaining in the lava puddle. Photo Emerson.



Fig. 26. New ash mud with impact pit made by stone that buried itself in May eruption, 2100 feet SE of Halemaumau. Shows also desiccation cracking and dog's footprints, surface now hard. Photo Emerson.

SEISMOMETRIC RECORD

During the month ended midnight July 31, 1924, 110 local earthquakes and two teleseisms were registered at the Observatory. These and other earth movements are exhibited below. Time is Hawaiian Standard, 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

Abbreviations have meaning as follows: Vf=very feeble; f=feeble; s=slight; fl=felt locally, and Δ =indicated distance to origin in miles.

July	July	July
1— 1:45 a. m. vf.	8—12:38 p. m. vf.	20— 1:25 p. m. s., fl., Δ 27.
3:30 a. m. vf.	12:46 p. m. vf.	21— 3:48 p. m. vf.
8:25 a. m. s.	12:48 p. m. vf.	22—12:20 a. m. vf.
10:15 p. m. vf.	12:52 p. m. vf.	11:58 a. m. vf.
2—11:43 p. m. vf.	12:59 p. m. vf.	4:42 p. m. vf.
3— 6:25 a. m. vf.	2:55 p. m. vf.	4:56 p. m. vf.
9:49 a. m. vf.	10— 8:18 p. m. f., Δ 3.	7:15 p. m. vf.
11:16 a. m. vf.	9:32 p. m. s., Δ 11.	23—11:08 a. m. vf.
5:08 p. m. vf.	11— 2:14 a. m. f., Δ 2.	12:42 p. m. vf.
8:00 p. m. vf.	3:36 a. m. vf.	10:53 p. m. vf.
9:07 p. m. vf.	8:10 a. m. vf.	24— 2:22 a. m. vf.
4— 2:55 a. m. vf.	10:41 a. m. vf.	3:01 a. m. vf.
11:45 a. m. vf.	12—11:34 a. m. vf.	1:10 p. m. f.
7:16 p. m. vf.	4:23 p. m. vf.	2:25 p. m. vf.
7:33 p. m. vf.	4:25 p. m. vf.	25— 9:43 a. m. vf.
11:05 p. m. vf.	6:28 p. m. vf.	26—10:13 a. m. s., Δ 6.
11:06 p. m. vf.	9:34 p. m. f.	4:08 p. m. s., Δ 2.
5— 3:04 a. m. s., fl.	13— 1:36 a. m. vf.	6:51 p. m. s.
5:35 a. m. vf.	2:08 a. m. vf.	27— 1:05 a. m. vf.
6:31 a. m. f., fl.	4:05 a. m. vf.	10:43 a. m. vf.
12:00 m. vf.	5:09 a. m. vf.	4:49 p. m. vf.
12:14 p. m. vf.	8:13 p. m. vf.	5:49 p. m. vf.
9:31 p. m. vf.	14— 3:55 p. m. vf.	7:15 p. m. vf.
9:32 p. m. vf.	15— 1:07 a. m. vf.	10:01 p. m. vf.
6— 2:58 a. m. vf.	6:20 a. m. vf.	10:34 p. m. vf.
5:43 a. m. vf.	4:06 p. m. vf.	1:02 a. m. vf.
9:23 a. m. vf.	16— 1:10 a. m. vf.	2:01 a. m. tremors for 4 mins.
2:30 p. m. vf.	1:37 a. m. vf.	8:06 p. m. vf.
2:31 p. m. vf.	11:04 a. m. f., Δ 4.	29— 1:35 a. m. vf.
2:33 p. m. vf.	9:17 p. m. vf.	11:34 a. m. vf.
3:25 p. m. vf.	17— 2:52 a. m. vf.	7:20 p. m. vf.
11:16 p. m. vf.	18— 6:59 a. m. vf.	31— 2:31 a. m. vf.
11:17 p. m. vf.	19—12:16 a. m. vf.	3:39 a. m. vf.
11:38 p. m. vf.	6:30 a. m. vf.	6:29 a. m. vf.
7— 5:28 p. m. vf.	12:08 p. m. vf.	6:30 a. m. vf.
6:11 p. m. vf.	3:38 p. m. vf.	
8— 8:10 a. m. vf.	20— 1:13 a. m. vf.	

Teleseisms

July 6.....4:24 p. m., Slight.
23.....7:00 p. m., Slight.

Spasmodic Microtremor

This type of tremor was slight throughout the month.

Harmonic Microtremor

This type of tremor was slight from July 20 to July 29 inclusive and absent on other days.

Microseismic Motion

The amplitude of microseisms was slight in July.

Tilting of the Ground

By weeks, this movement was as follows, expressed as angular change and direction of motion of the plumb line:

June 29-July 5.....	1.5 seconds	SSW.
July 6-12.....	2.3 seconds	NNE.
13-19.....	1.1 seconds	SE.
20-26.....	0.7 second	SW.
July 27-Aug. 2.....	1.8 seconds	NE.

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VOLCANIC CONDITIONS IN AUGUST

Activity of Halemaumau

The lava had come back to Halemaumau pit in July and had left a new bottom flat. This area was 1100 feet long and 800 feet wide, and the big source cone beside it on the southwest was over 100 feet high. The lava surface was 1305 feet below the rim, and its edges 1330 feet below the rim. Thus the new fill was about 25 feet thick. Active flowing had ceased July 31st, but the mass, part aa and part pahoehoe, was still glowing in cracks on August 1.

The pit was the enormous cauldron left by the May explosion and subsidence, 3400 by 3000 feet, in horizontal dimensions at the top. The most distinctive feature of the walls was large intrusive bodies still showing glow.

During the first week in August blue fume no longer rose from the lava conelet. There was a small patch of reddish debris left as an island of the

former pit bottom surrounded by the new lava field. Hydrogen sulphide rose from the pit. Some blue gas rose from the western wall and there were yellow-stained bottom slopes in three places. The new lava was red with iron oxide, much of it avalanche dust. There were avalanches mostly from the large north intrusive sill, and bowlders had rolled out from the talus on the new lava. In good weather, only slight vapor rose above the rim, though there were steam jets on the bottom, and slight gas blowing was audible.

By the middle of the month the new cone had eaved in somewhat so as to enlarge its craterlet. At night 12 or 15 glowing cracks showed in the lava floor. Avalanches and blowing were increasing.

The north sill was always the most restless part of the pit wall. Slices of the southwest rim also fell in. Numerous and large rocks had rolled down the taluses and out on the lava floor. Fuming places increased in the vigor, hotness and density of their yellowish steam jets. Sometimes very sudden and noisy rock falls would break from the north sill and crash down on the talus below.

In the early morning of August 20 an earthquake was generally felt over the island of Hawaii. It appears to have been least noticed in Puna (where there was so much seismic excitement in April last), and both the reports and the distance evidence from the seismograms located the center near Kapapala and Pahala where the shock was somewhat severe. This would imply movement on the line of ruptures along the southeast flank of Mauna Loa. There were other such earthquakes on the 23rd and the 24th.

Halemaumau was now an enormous pit like an immense open mining cut. The lava field on its bottom was of diamond shape with black or reddish broken pahoehoe and dull patches of an especially in cracks. Toward the end of the month only four glowing cracks in this field were to be seen at night. There were debris slopes at the base of the walls around the lava bottom. In the debris at the eastern margin of the lava there were sulphur stain and hot fume, and there was other such solfataric action out in the middle. Faint blowing noise waxed and waned, heard in calm weather only. Rocks were falling from the walls most of the time. On August 26th there were several avalanches that sent up red dust clouds. These left patches of pink dust on the bottom lava, and also some big bowlders, that had left dark trails in the dust where they rolled across the floor.

In the evening, August 27th, a glowing crack became visible in the eastern end of the long white intrusive sill of platy fine-grained rock that extends across the middle of the northern wall. This place was glowing abundantly in June, but had cooled off on the surface. Probably the revival was due to revelation of interior rock by avalanching.

The avalanches were of considerable size at the end of the month, and made a fresh stripping of the walls especially at the west, enlarging the big talus cone below, and making it overlap the lava floor. There were small earthquakes nearly every day and northerly tilting of the ground. A new line of steam fumaroles developed at the base of the western slope.

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August 1. During a visit to Mauna Iki in the Kau Desert on this day, it was found that the ancient footprints of 1790 were being restored by the wind, after their partial obliteration by a thin film of ash of the May eruption. The wind is now removing that ash, which fortunately did not cement itself in place in the manner of the 1790 ash at this distance from the volcanic center. A strong and disagreeable odor of volcanic gas from Halemaumau was perceived at Mauna Iki.

August 2. At noon Halemaumau was found quiet. There was little steam in the bottom. A vent gave off dense steam at the base of the lower north intrusive body between the northern and northwestern talus cones. Blue gas emerged from the wall low at the west and high northwest. Smooth slopes of

what appears to be rock are stained yellow and lie between the taluses at their base on the northeast, south and east sides of the bottom. These places are above the new lava. In the talus itself sulphur patches are steaming in four places on the east. The new lava was reddish with iron oxide and wholly quiet.

August 3. At 3 p. m. the weather was bright and dry and the steam jets small. Blowing noise was heard, waxing and waning as before the lava outbreak. There were small slides mostly at the north. A round patch of reddish rock surrounded by the northeast intrusive body appears as though it might be the extension across the pit of the west red boss.

August 5. At 10 a. m. there was fresh heavy avalanche debris on the northeast talus. Recent rain had made the vapor denser on the bottom. Some talus boulders had rolled on to the new lava, numerous and large east and southeast, and a very few at the west.

August 6. At 3:30 p. m. no positive blowing noise was detected. One avalanche fell at the southwest and rocks fell elsewhere. The new lava area was in general of diamond shape and occupied the same area as the bottom "flat" of June. The lava cone appeared completely stagnant. The steam on the long southwest talus occupied the middle and lower part in an inverted V.

August 10. In the forenoon the pit was quiet with a little steam rising above the rim and a few small slides. The source-cone on the southwest side of the lava field of July appeared a little more broken in at its craterlet.

August 11. At 8 p. m. by moonlight twelve or fifteen glowing cracks could be traced in the lava field, notably near the cone and at the east and west sides. There was some glow also near the smoking spot where an island of the former bottom shows through the new lava. No glow was detected in the intrusive bodies.

August 13. At 11 a. m. avalanches were found more numerous and some blowing was heard. Twice the scaly or columnar portion of the eastern part of the north intrusive body, where was the red heat in June, made sudden avalanches. One of these was heavy and made a loud noise as the rocks struck the talus. The fummy island or sulphurous flat west of the center of the lava floor appeared to be increasing its solfataric activity as though it were the source of the blowing noise, for no fume was visible at the cone vent.

August 15. At 11 a. m. it was found that rock falls had deposited new boulders at the base of the conelet on its west side. The northern hot body was restless in its avalanching and seemed clearly to be in some sense mobile. The yellow stain was increasing at the west central fume patch. A circuit of the pit was made and new avalanche scars were seen on the walls. At the west-southwest corner, over the big talus, the rim had caved away back to the survey flag. At the north corner the prow of the hot intrusive had become blunter by caving away.

August 17. During the forenoon there were avalanches from the north corner.

August 18. The general condition of Halemaumau now was that of a quiet pit, with fume and greenish yellow stain in a few places on the bottom, with vapor jets variable according to atmospheric humidity, dry patches in places indicating heat, a lava conelet and flat left from July about 1300 feet below rim, and conspicuous blue smoke emerging from the wall of the pit 100 feet below the rim north.

On this day after rain there was increase of dense steam from the talus northwest and northeast and of hot blue gas condensing into steam at the east base of the lava cone, along the east edge of the lava field and at a

yellow-green area west of the center. Distinct blowing noise was heard in sudden spells. A few slides occurred at the north.

August 19. About 10 a. m. there were several avalanches from the NW. and NE. walls. Fume at one place outside of the east edge of the lava field was hot, voluminous and rapid-rising. Occasional blowing was heard.

August 20. At 11 a. m. there were trickling slides, faint blowings, and not much blue fume. The yellow-stained cracks west of the center of the lava floor, made visible fume or steam at intervals, and then cleared off. At night the cracks in lava floor were reported still visibly incandescent.

About 6:20 a. m. an earthquake centering near Kapapala was felt here, at Hilo, Pahala and Kona, but not at Kapoho.

August 21. At 3 p. m. the weather was very clear and dry, steam jets were small, blowing was faint, and rocks fell singly here and there from the walls. In such bright weather the pit is perfectly clear as seen from a distance, except for vapor at rim cracks northwest and southeast.

August 22. At 7 p. m. by evening light four small glow holes, all nearly alike, appeared in the southeast lobe of the bottom lava field. No glow was seen elsewhere. The spots glowing were not visibly fuming by daylight, but were merely cracks, possibly maintained hot by gas through a tunnel, or by oxidation by hot air.

August 23. Two sharply felt earthquakes were registered at 12:10 and 12:13 a. m. and a Geological Survey party at east rim of the summit crater of Mauna Loa felt these as very severe. They were alarmed to the point of leaving the cavern where they were camping, and reported that the ground cracked open and some stone monuments were shaken down.

At 3 p. m. everything was quiet in Halemaumau. The weather was windy and dusty. Dust had been seen over the pit several times during the day. Now there were slight rock slips. There was a dust patch from some recent slide on the west side of the floor.

August 24. There were dust whirls in the desert. At 11 a. m. the densest steam was in the north and south corners and the yellow-stained patch in the center lay between these jets. There was slight blowing noise.

August 25. At 9:30 a. m. the hot band of fuming at the east edge of the lava floor appeared to be increasing. A visit to the floor of Keanakakoi crater discovered about one inch of grit and dust on the smooth lava there from the May explosions of Halemaumau, and the stones scattered about varied from 4 to 2 inches diameter, decreasing in number from west to east. There were very few at the east.

August 26. At 10:25 a. m. there was a strong avalanche from the WSW. corner, at noon another, and at 4 p. m. a third. When the pit was visited at 11 a. m. a new notch appeared in the rock at the southwest corner of the pit, and another above the west end of the north intrusive sill. Stones were falling from the walls, and fresh avalanche dust lay on the northwest point of the lava floor.

August 27. At noon the effect of the avalanching was seen in a trail of pink dust across the east side of the bottom lava. At the south corner it was especially thick and seven or eight big boulders had there rolled out on to the lava. Two of them showed trails in the dust from the south talus to their present position. This talus overlapped the lava floor. The slides were working as usual. The slope at the base of the southeast wall was wet, steaming, greenish and acid-looking with its sulphurous stain.

During a calm spell when the bottom steam jets were rising idly, blowing noise was heard. The noise appeared to come from a straight crack extending

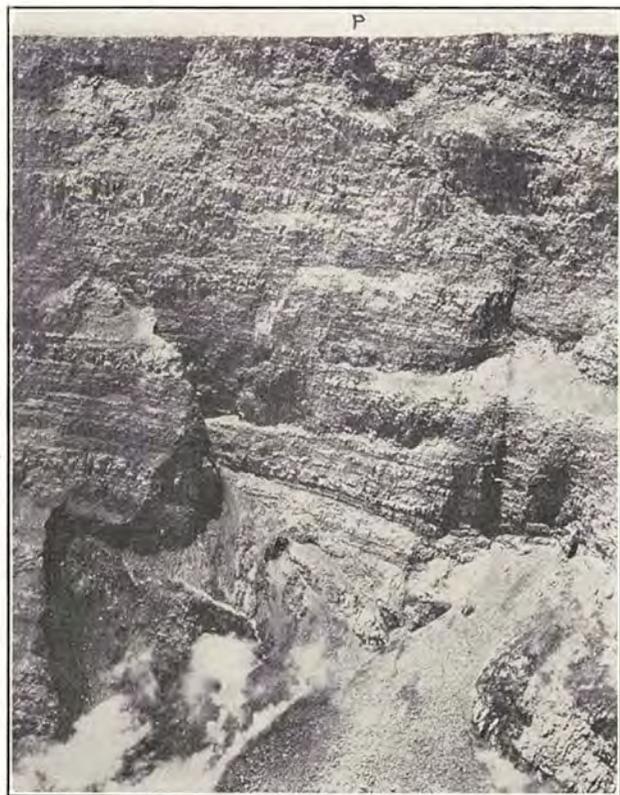


Fig. 27. South corner of Halemaumau, showing south pinnacle at the top and typical outcrop of tangential cracking below it. Such cracks have developed two gulches at the bottom. Shows also south talus and some white intrusives lower right corner. Photo Emerson.



Fig. 28. Northeast corner of Halemaumau and north talus. Shows dykes below and east prow of the hot north sill overlying indurated basalt layers. The top contact of the sill has irregularities and reddish bodies. The dyke on left is the 1920 rift and cuts the sill. Photo Emerson.



Fig. 29. Kau desert with distant Puu Koa and simoon of May dust blowing. Foreground covered with May dust. Photographed May 22, by Emerson.



Fig. 30. New fallen rock debris on north rim of Halemaumau, looking NE June 1, 1924. Photo Emerson.

eastward from the horse-shoe opening of the craterlet. Along this line was white stain. There was recurrent gaping along this line as though the lava were swollen up on each side. Along this line was the night glow.

At 11:30 p. m. on this night there were four main glow holes in the southeast lobe of the lava floor, two of them being cracks incandescent inside. There was also discernible a glowing upright crack near the east end of the northern big sill in the wall, as in June, but with visible incandescence greatly decreased. Blowing noise waxed and waned, seemingly direct from the conelet, and some rock slides were heard.

August 29. At 10 a. m. the steam in bottom of pit had increased after rain. Sulphur gases made blue edges to the steam jets east of the bottom flat. Blowing noise was distinct. Two avalanches fell from the north intrusive body. An avalanche cloud had been seen **August 28** at noon, and also this morning at 8, the latter from the west corner.

SEISMOMETRIC RECORD

During the month ended midnight, August 31, 1924, 90 local earthquakes and four teleseisms were registered at the Observatory. These and other earth movements are exhibited below. Time is Hawaiian Standard, 10 h. 30 m. slower than Greenwich.

Local Earthquakes

Abbreviations have meanings as follows: Vf=very feeble; f=feeble; s=slight; m=moderate; fl=felt locally; d=instruments dismantled, and Δ =indicated distance to origin in miles.

August	August	August
1— 1:16 p. m. vf.	15— 2:10 p. m. vf.	25—10:15 a. m. vf.
2—12:54 a. m. vf.	17—11:47 a. m. f.	26— 5:01 a. m. vf.
4:40 a. m. vf.	11:51 p. m. vf.	27— 2:23 p. m. vf.
1:07 p. m. vf.	18— 5:30 p. m. vf.	10:38 p. m. vf.
3—12:24 a. m. vf.	19— 1:00 a. m. s.	11:25 p. m. vf.
4—12:26 a. m. vf.	20— 6:20 a. m. m., Δ 16.	28— 5:10 a. m. vf.
2:49 p. m. vf.	Felt all over Hawaii.	5:34 p. m. vf.
4:55 p. m. vf.	10:44 p. m. vf.	6:44 p. m. s., Δ 11.
5— 2:39 a. m. vf.	10:48 p. m. s.	9:50 p. m. vf.
10:04 a. m. vf., Δ 10.	21— 3:30 a. m. vf.	10:00 p. m. vf.
12:02 p. m. vf.	11:57 p. m. vf.	29— 4:28 p. m. vf.
12:24 p. m. vf.	22— 7:14 a. m. vf.	7:18 p. m. vf.
12:42 p. m. vf.	7:21 a. m. vf.	7:19 p. m. vf.
4:11 p. m. vf.	7:51 a. m. vf.	8:18 p. m. vf.
4:11 p. m. f.	7:58 a. m. vf.	8:26 p. m. vf.
6—12:11 a. m. vf.	8:11 a. m. vf.	8:27 p. m. vf.
12:12 a. m. vf.	8:16 a. m. vf.	8:28 p. m. vf.
2:51 a. m. vf.	9:33 a. m. vf.	10:52 p. m. vf.
7—12:10 a. m. vf.	9:38 a. m. vf.	11:47 p. m. vf.
8— 4:32 a. m. vf.	1:05 p. m. vf.	30—12:26 a. m. vf.
10:24 a. m. vf.	1:24 p. m. vf.	12:27 a. m. vf.
9— 3:15 a. m. vf.	1:29 p. m. vf.	5:07 a. m. s., fl.,
3:48 a. m. vf.	23—12:10 a. m. s., Δ 2.	Δ 6.
4:29 a. m. vf.	12:13 a. m. m., d., Δ 20.	5:40 a. m. vf.
10—12:35 a. m. vf.	9:28 p. m. vf.	5:44 a. m. vf.
5:45 p. m. vf.	9:30 p. m. vf.	5:05 p. m. vf.
11:25 p. m. vf.	9:40 p. m. vf.	11:05 p. m. vf.
11— 7:12 a. m. vf.	9:43 p. m. vf.	31— 3:17 a. m. vf.
11:26 a. m. vf.	24— 1:40 a. m. vf.	5:42 a. m. vf.
12— 9:59 a. m. f., Δ 2.	7:48 a. m. s., Δ 2.	10:28 a. m. vf.
3:51 p. m. vf.	3:58 p. m. vf.	

Teleseisms

August 7.....6:09 a. m. slight.
13.....2:28 p. m. slight.
14.....7:37 p. m. slight, distance 3750 miles.
29.....4:40 p. m. slight.

Spasmodic Microtremor

This type of tremor was slight during August.

Harmonic Microtremor

This type of tremor was absent throughout the month.

Microseismic Motion

The amplitude of microseisms was slight during August.

Tilting of the Ground

By weeks, this type of movement was as follows, expressed an angular change and direction of motion of the plumb line:

August 3- 9..... 0.4 second W.
10-16..... 0.1 second S.
17-23..... 1.3 seconds NW.
24-30..... 1.7 seconds ESE.

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Volcanologist.

MONTHLY BULLETIN
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VOL. XII

HONOLULU, HAWAII, SEPTEMBER, 1924

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VOLCANIC CONDITIONS IN SEPTEMBER

Activity of Halemaumau

Halemaumau pit remained ostensibly quiet so far as volcanic activity was concerned at the beginning of September. It was an immense open quarry steaming at the bottom, with numerous rock slides, some blowing of gas, a little glow in the remnant lava sheet on the bottom from July activity, and a little glow in a north wall intrusive sill remnant from the May collapse. There were avalanches of some size the mornings of September 2 and 3. Hydrogen sulphide produced a disagreeable odor all the way to Kapapala when the ordinary northeast wind was blowing. Indeed, Mr. Finch, while on an airplane trip around the island July 10, permitted through the courtesy of the U. S. Army, encountered both gas and dust from Kilauea 45 miles southwest of the volcano at an elevation of 4000 feet.

The falling away of the cliffs increased during the early part of the month, some of the avalanches sending up clouds of pink dust three to four thousand feet. This increased tumbling appeared to be connected with marked increase of numbers of local earthquakes as equinox approached. Perhaps the land-

slides made some of the tremblings, or the fault movements that caused the earthquakes also moved the pit walls, or the earthquakes as extraneous motions loosened the debris. Doubtless in different cases all three of these causations are operative.

There were 3961 local earthquakes at the time of the May eruption for the month, 779 in June, 110 in July, and 89 in August. But at the end of August the numbers began to increase, mostly small shocks, but some of them felt. There were 8 the week ending August 20, the next week 33, the next 54, and during the week ending September 10 there were 46 shocks in six days. A number of the seismograms indicated distances of origin 11, 14, 16 and 36 miles. These coupled with reports from the western stations suggested that lava was in motion under Mauna Loa.

About September 5 and 6 a big niche broke away from the north rim of Halemaumau showing a new cavern and a large surface of fresh rock. Some blowing or hissing noise was heard about the 16th. Faint glow was still visible in the north intrusive and in the lava floor. Fume was plainly visible over Mauna Loa in the middle of the month. An earthquake on September 10 was felt over most of Hawaii, and was especially strong over the northeast part of the island. On the southwest rift of Mauna Loa earthquakes were felt on the 8th and 9th by a Geological Survey party. An earthquake on September 20 appeared to originate in the Kau desert and was strongly felt at Pahala.

Avalanches continued, some of them big the third week of the month, and strong northeast winds swept up great clouds of dust from the crater floor of Kilauea and from the desert. The volcano appeared to be in eruption as seen from Pahala, and that district received another deposit of dust. Possibly some such happening accounts for the dust on southern Mauna Loa encountered by Menzies in 1794, and attributed to active eruption.

The last week of the month produced only five earthquakes, the smallest number recorded in such a period since February, when the liquid lava was present.

Some avalanches continued to make the pit dusty, with maximum peeling from the northern and western walls. A small quantity of blue smoke was issuing from a place far up on the northwestern wall. This place had been smoking more or less ever since the May explosions, and is near the former "Pele's Kitchen," now destroyed, and known for thirty years past as a place of very hot fume.

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September 2. The west half of the lava floor of Halemaumau was covered with new red avalanche dust. A protuberance of the north intrusive sill in the wall was seen to be caving away. Several avalanche clouds were seen during the forenoon from the Observatory. From all sides fresh talus material had overlapped the floor. There was much bottom steam when the pit was visited at 9 a. m. and some blowing noise was heard.

September 3. Three earthquakes were registered during the preceding night and heavy avalanches occurred at Halemaumau about 7 a. m. Also about midnight a loud roar from avalanching had been heard.

At noon the entire lava floor of the pit was found coated with pink dust. The northwest side of the lava was overridden widely with new massive talus. The WNW wall had been stripped and along the base of the talus at the new overlap a hundred crowded steam tails rose side by side, and farther north in the talus was another very active solfatara. The suggestion was that the weight of rocks on the lava sheet had broken it and opened wider the marginal wall crack.

Slides were falling from the west and northwest walls. There was fresh encroachment of the south talus on the lava floor. The July pumice conelet was covered with red dust. The new overlaps of debris had truncated the floor

outline and the point of aa lava which had made a lobe northwest was all buried. Some portions of the pit wall were coated with dust like old statuary, and others were freshly stripped.

At the base of the east wall sulphur patches in the talus and sulphate stains on the rock were green and wet. Blowing noise in distinct puffs was heard.

September 4. There were occasional avalanches. One in the afternoon was heard two miles away.

September 5. At 10 a. m. increased dust was found on the lava floor. Avalanches were evidently abundant. Slides were seen falling from the northern sill. Steam was less dense, smell of hydrogen sulphide was strong, and the sulphurous patches of the bottom were masked with dust.

September 6. At 10 a. m. it was evident there had been a big avalanching newly stripping the north wall above the west end of the north sill all the way to the top rim. The blue fume and a gully in the rim were near the top. A depression in the rim here represented an old valley with aa lava and pahoehoe cascades, back of the former "Pele's Kitchen," where there had been down-faulting of the surface of an old slag heap, probably in the early nineties.

There was a new talus below the break and several big falls of rock debris were seen tumbling. The oxidized lavas of the old wall made red cauliflowers, those from the white sill made gray dust. The cliff above the new break was cracked, overhanging and dangerous. It was vertical below for hundreds of feet and rocks detached above would fall clear for a great distance. The continuity of the avalanches was impressive. A big block would dislodge from the high wall. It would break up and the bounding fragments started a train of slide cascades. Individual slides on slopes, and the rock shower pounding on the talus slope below developed a waterfall effect, without any water. Both the slope cascade and the bottom bombardment made cauliflowers boiling up with hard outlines. The heat of the north sill made its sand and dust tend to convectional uprush.

It is easy to understand what colossal cauliflower cloud vortices would be produced where a whole crater pit were collapsing as at the beginning of May last.

September 7. Several small earthquakes occurred during the preceding night and several avalanche clouds were seen over the pit during the day. At noon the north corner was found to be working with rock slides, there was fresh dust chiefly on the west side of the bottom, and the north wall was freshly peeled. Portions of the eastern part of the north sill had fallen. The broken section of the wall in contact with the top of the sill towards the west appeared to be bedded at about 30 degrees with eastward dip, with horizontal lavas unconformable above it. The material slid away easily and appeared to be fragmental. It is probably an old talus enclosed in the wall.

September 8. At 5 p. m. there were avalanches falling from the north corner of the pit and fresh debris from the northeast wall lay on the talus. The north sill appeared to be undermining all that lay above it. More steam was visible in the evening, at the conelet, all around the edges of the lava floor, from a patch in the center, and from the taluses. Two earthquakes were felt about 10 p. m.

September 9. At 10 a. m. there were small slides. An avalanche at 11:30 a. m. sent up a dust cloud 3000 feet high.

September 10. At noon the only dense steam jets in the pit were at the north and south corners of the bottom. Avalanching continued increasing the depth of the gully above the west horn of the north sill. No blowing noise had been noticed for several days. Every night, however, the seismographs

showed one or two earthquakes. The development of the bulk of the hot north sill towards its east side, as it caved back, indicated that it was thicker inward. Below this the talus was white and fresh, whereas it was rusty red at the north.

September 14. At 5 p. m. no avalanching was observed and no noise from the pit floor. The spicy odor of free sulphur was noticed.

September 15. Small slides occurred, at the north corner, when the pit was visited at 3 p. m.

September 16. At 9 a. m. hissing from the bottom of the pit was plainly heard. Small slides occurred.

September 17. The hissing was less distinct, but it could be detected occasionally. A large avalanche had fallen from the north wall, the intrusive sill there showed yellow stains, and slides at the north were seen.

September 18. At 9 a. m. no hissing was detected. Numerous small slides fell from the north wall.

September 19. At 2 p. m. hydrogen sulphide odor at the pit's edge was strong. Small avalanches at the north were frequent.

September 20. High wind produced very heavy dust clouds from the crater floor of Kilauea and from the Kau desert.

September 23. At 10 a. m. some avalanches of moderate size were observed.

September 26. At 10 a. m. small slides were frequent.

September 28. The pit at 10 a. m. was quiet and avalanches were less frequent. The atmospheric humidity was high and the bottom of the pit was steamy.

SEISMOMETRIC RECORD

During the month ended midnight, September 30, 1924, 116 local earthquakes were registered at the Observatory. These and other earth movements are exhibited below. Time is Hawaiian Standard, 10 h. 30 m. slower than Greenwich.

Local Earthquakes

Abbreviations have meaning as follows: Vf = very feeble; f = feeble; s = slight; fl = felt locally, and Δ = indicated distance to origin in miles.

September	September	September
1— 4:55 a. m. vf.	3— 2:54 a. m. vf.	5— 2:19 p. m. vf.
8:30 a. m. vf.	2:56 a. m. vf.	5:16 p. m. vf.
2:44 p. m. vf.	2:59 a. m. s.	8:00 p. m. vf.
2:47 p. m. vf.	3:03 a. m. s.	10:55 p. m. vf.
3:40 p. m. vf.	3:13 a. m. vf.	2:24 p. m. vf.
6:47 p. m. vf.	3:25 a. m. vf.	6:20 p. m. vf.
6:48 p. m. vf.	8:23 a. m. vf.	8:47 p. m. vf.
7:25 p. m. vf.	4— 3:15 a. m. vf.	8:54 p. m. vf.
7:26 p. m. vf.	3:16 a. m. vf.	9:23 p. m. vf.
8:59 p. m. vf.	7:17 a. m. vf.	9:25 p. m. vf.
2— 4:07 a. m. vf.	1:44 p. m. vf.	9:36 p. m. vf.
5:31 a. m. vf.	1:50 p. m. vf.	9:38 p. m. vf.
6:45 a. m. vf.	1:51 p. m. vf.	9:41 p. m. vf.
11:48 a. m. vf.	2:08 p. m. vf.	9:48 p. m. vf.
6:34 p. m. vf.	2:09 p. m. vf.	



Fig. 31. Halemaumau from Observatory June 7, 1924, showing thin vapor cloud over pit. Photo Finch.



Fig. 32. Halemaumau direction from Waldron's ledge June 12, 1924, showing Kilauea floor obscured by a simoon of ash dust, windy day. Photo Emerson.

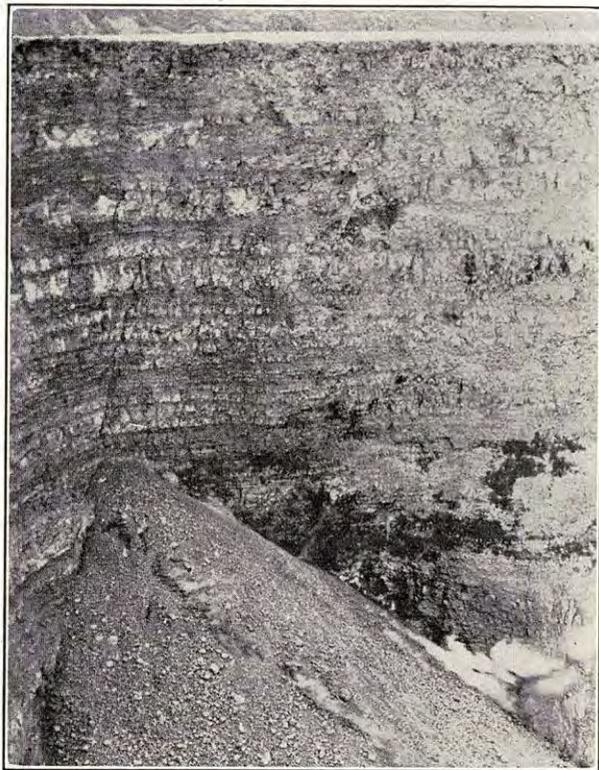


Fig. 33. Southwest talus and west wall in Halemaumau pit, showing new ash above rim and transition from thinner bedded flows below to thicker above. Photo made July 1, 1924, by Emerson.

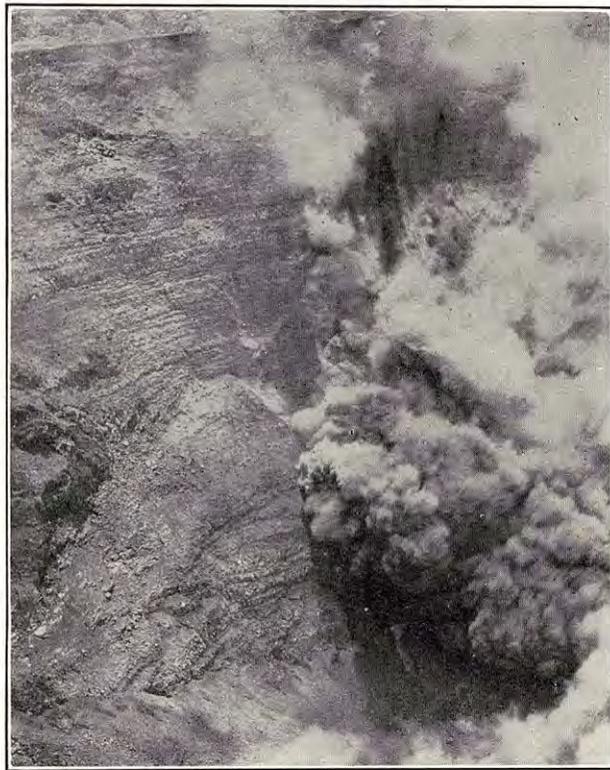


Fig. 34. July 1, 1924, avalanche falling from upper part of west wall Halemaumau, making cascades of dirt and cauliflower clouds. Photo Emerson.

September	September	September
6— 5:36 a. m. vf.	4:56 p. m. vf.	17— 3:24 a. m. vf.
5:39 a. m. f., Δ 14.	5:03 p. m. s.; felt in	6:44 a. m. vf.
7:50 p. m. vf.	Hilo and Honokaa	6:30 p. m. vf.
8:14 p. m. vf.	11—10:05 a. m. vf.	8:23 p. m. vf.
7— 1:39 a. m. vf., Δ 5.	1:26 p. m. vf.	9:15 p. m. vf.
4:57 a. m. vf.	3:52 p. m. f., Δ 13.	18— 4:29 a. m. vf.
5:40 a. m. f.	11:01 p. m. vf.	5:16 p. m. vf.
6:03 a. m. vf.	12— 2:41 a. m. vf.	20— 9:54 a. m. vf.
1:42 p. m. vf.	6:20 a. m. vf.	11:48 a. m. vf.
6:37 p. m. f.	7:23 a. m. vf.	7:36 p. m. s., Δ 11, fl.
10:47 p. m. vf.	2:33 p. m. vf.	21—10:36 a. m. vf.
8— 2:46 a. m. vf.	9:30 p. m. vf.	10:46 a. m. vf.
11:48 a. m. vf.	13— 5:47 a. m. vf.	10:08 p. m. vf.
11:54 a. m. vf.	14— 3:58 a. m. vf.	10:48 p. m. vf.
5:46 p. m. vf.	4:03 a. m. vf.	10:50 p. m. vf.
9:59 p. m. s., Δ 2.	5:05 p. m. vf.	22—12:51 a. m. vf.
10:07 p. m. s., Δ 36;	10:23 p. m. vf.	23—11:04 a. m. vf.
felt in Kona.	15— 2:34 p. m. vf.	7:35 p. m. vf.
9— 4:02 a. m. vf.	4:04 p. m. vf.	10:41 p. m. vf.
9:11 a. m. vf.	4:06 p. m. vf.	25— 9:23 p. m. vf.
3:39 p. m. vf.	16— 6:29 a. m. f., Δ 8.	27—10:07 a. m. vf.
7:34 p. m. s., fl., Δ 2.	8:03 p. m. f.	10:40 p. m. f.
9:48 p. m. s., fl., Δ 2.	8:17 a. m. vf.	30— 7:12 p. m. vf., Δ 1.
10—12:30 a. m. vf.	10:57 a. m. vf.	9:45 p. m. vf.
8:10 a. m. vf.	11:58 p. m. vf.	

Spasmodic Microtremor

This type of tremor was slight during September.

Harmonic Microtremor

This type of tremor was absent throughout the month.

Microseismic Motion

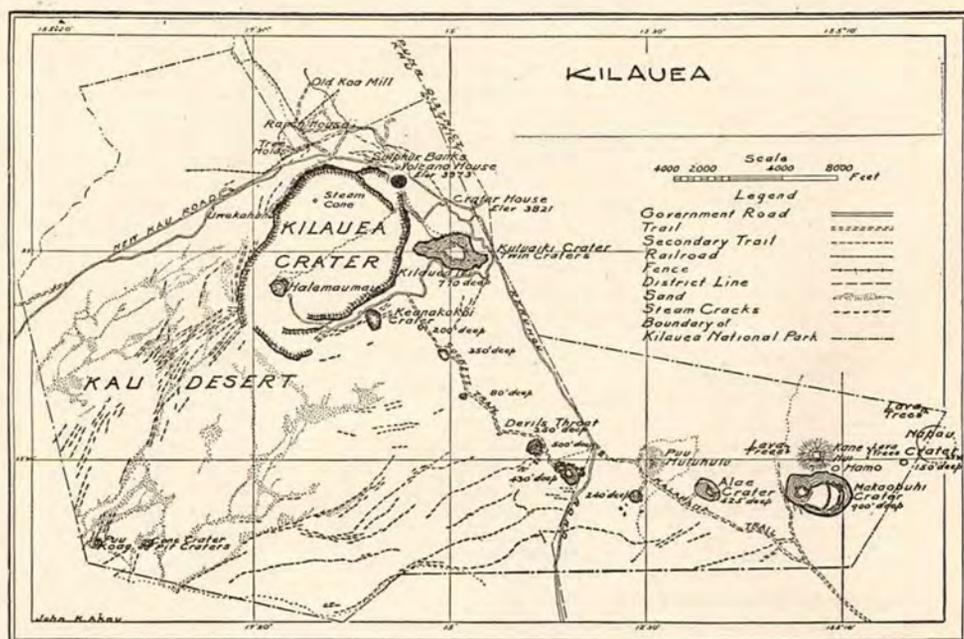
The amplitude of microseisms was slight in September.

Tilting of the Ground

By weeks, this type of movement was as follows, expressed as angular change and direction of motion of the plumb line:

August 31—September 6.....	2.8 seconds NNE.
September 7—13.....	1.5 seconds NNW.
14—20.....	1.4 seconds E.
21—27.....	2.3 seconds SE.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges, gifts to library, news notes about Pacific volcanic and seismic events, and correspondence should be addressed HAWAIIAN VOLCANO OBSERVATORY, Volcano House, Hawaii.

The Observatory is operated by the U. S. Geological Survey, and its work is supplemented by the Hawaiian Volcano Research Association. The main station is on the northeast rim of Kilauea Crater. Subordinate seismograph stations are operated by the Research Association under the direction of the volcanologist in Kona, Hilo and Hilea.

The Kilauea station operates horizontal pendulums of the Bosch-Omori type and receives time by wireless from the Honolulu Naval Station. Observatory Lat. $19^{\circ} 25' 54.2''$ N.; Long. $155^{\circ} 15' 39.2''$ W.; Elevation cellar 1214.6 meters (3985 feet). The Hilo and Hilea stations operate normal pendulums and the Kona station a horizontal pendulum. Their seismograms are sent to the Observatory.

The Hawaiian Volcano Research Association founded the Observatory in 1911, transferring the plant to the Government in 1919, but continuing cooperation in experimental work by furnishing funds and apparatus and workers as needed by the Government Volcanologist. It is a corporation under the laws of Hawaii, governed by a board of directors, and financed by the subscriptions of its members and patrons. Its aims are identical with those of the Observatory, namely, (1) To keep record of Hawaiian volcanism, (2) To attract volcanologic specialists to Hawaii, and (3) To promote worldwide knowledge of volcanoes and earthquakes and the foundation of more volcano observatories.

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VOLCANIC CONDITIONS IN OCTOBER

Activity of Halemaumau

At the beginning of the month Halemaumau was dormant so far as visible molten lava is concerned and the spell of seismic activity with avalanching which had culminated with the September equinox had now died away so that the week prior to October 1 registered only five earthquakes at the Observatory, the smallest number in such a period since February, before the liquid lava disappeared. A small quantity of blue smoke from a place far up on the northwestern wall of the pit has been issuing ever since the May explosions.

Avalanches continued during the first week of the month and twenty-one earthquakes were recorded. The second week, however, they were not so numerous, and avalanches decreased in number.

After heavy rain the interior of the vast cauldron was wet, dark rusty red in color, and white vapor rose in dense jets at many places around the edges of the flat lava floor. Blue fume was mixed with the steam. The lava cone left from the July activity on the southwest side of the floor was covered with hot jets of vapor and heavy masses of steam rose from the crater cup on its summit. Blowing noise was distinctly heard. In certain places dry hot streaks make exceptions to the prevailing steaminess and wetness of the talus, and this is true also of the eastern half of the lava floor which has recently been seen glowing at night.

The most interesting wall of the crater is at the north, where there is a great whitish mass of intrusive rock shaped like a hammock clear across the lower part of the steepest precipice that borders the pit. The vertical columns or joints of this body have recently been seen to be red hot in the cracks and to show a red hot wall when the surface flakes off in an avalanche. The jointing is platy or laminated and fragments of similar rock that were ejected in the May eruption are found to be a fine grained olivine gabbro. Evidently this hot body exerts an undermining effect on the whole wall above which works uneasily and makes more avalanches than any other part of the pit. On wet days this wall remained nearly dry. The sulphur stain on the bottom of the pit had nearly disappeared, but the smell of sulphuretted hydrogen and of spicy sulphur are both noticeable and there is plenty of heat above the pit as shown by the rapid boiling up of vapor which condenses night and morning, even when the pit is perfectly clear in the daytime.

Slides increased after the middle of the month, and earthquakes increased from thirteen shocks in the second week to twenty-six in the third. At least one of these was felt at the Observatory. The sliding became almost steady at times and the avalanching alternated between the northeast and southwest walls, but was always heavier at the northeast. The lava on the bottom of the pit became covered with red dust. After heavy rains the vapor jets in the bottom region increased and in calm weather a purring noise was heard waxing and waning over some volcanic pressure accumulated below. The pit walls are astonishingly red when wet, showing how intensely the rock was oxidized. Much vapor rises from cracks in the Kilauea floor back of the Halemaumau rim.

Toward the end of the month there was increase in avalanches and earthquakes and forty-six shocks were recorded. One of these, on October 28, was the strongest shock felt here for many years. It knocked over vases, pictures, bottles, boards leaning against a house, and threw down books from shelves. It appears not to have been felt in Puna, Hilo or lower Kau. Small cracks appeared in the earth an eighth of an inch across, breaking the soil above the hot cracks in front of the National Park office and parallel with the cliff near the Observatory, and others opened back of the Volcano House. The motion came as three or four quick jerks not prolonged, and on that account did not start avalanches from the precipices. This earthquake recalled the one on October 25, 1913, a time that was like this in being the middle of a quiet year at Kilauea.

At the end of the month the avalanching increased, frequently sending up dust cauliflowers visible from the Observatory. Sometimes the red dust billowed up over the whole cauldron. The walls on some days were grinding or tilting continuously, for the avalanches were incessant. The northeast wall would start dropping blocks with a crash from some upper portion and this would start the hot intrusive ledge sliding below. Then the southwest wall across the pit would make a little slide in sympathy. There are hot intrusive bodies in both of these opposite walls. With all of this peeling big notchings back of the walls became apparent. Yellow green salts probably ferric sulphate again appeared at the bottom of the pit. New cracks opened back from the rim of Halemaumau and two of the flag stations for surveying were carried away respectively northeast and southwest of the pit.

DISCUSSION OF SPECIAL FEATURES

October was much like September at Kilauea volcano in producing a minor spell of earthquakes and avalanches at Halemaumau. An outstanding event of the month was the strong earthquake of October 28, which recalled the similar event of October 25, 1913.

This earthquake was especially interesting, because it was expected, and on October 25, the Observatory staff had discussed the possibility. This discussion was based on the parallelism of 1924 and 1913, supposing both these years to represent repose periods between two cycles. In both years the lava had disappeared and the pit collapsed in May and the lava had slightly returned in July. The year 1913 was different from 1924 in that the lava column at all times was higher, about 600 feet down, and the pit was very smoky. In 1924 the lava is over 1300 feet down and the pit is perfectly clear with only a little fume and rain water vapor in the bottom.

It seemed possible in 1913 that the October earthquake represented a turning point in the lava under Mauna Loa or something of the sort, because in 1914 the lava in Halemaumau returned to view in May, making October the middle of the repose year. It was remarkable that the lava remained mostly out of sight for just a solar year, and that the biggest earthquake of that year happened half way between its disappearance and its return. After that return it rose steadily and Mauna Loa broke out in the summit crater the following autumn.

1924 has now rehearsed the happenings of 1913 very successfully in the three events of recession in May, temporary return in July, and earthquake in October.

So far as the meaning of the several earthquake spells and avalanching spells is concerned, it is clear that under Kilauea the ground is still going down, whatever the lava may be doing under Mauna Loa. The lava pit Halemaumau is still enlarging and is elongating slowly in the direction of the center of the big crater. Investigation of the results of the October earthquake showed that blocks of the northeast rim of Kilauea crater had been settling and these blocks have tended from time immemorial to slip inward and downward, just as the blocks inside of Halemaumau, constituting its rim, slip inward and downward at a more rapid rate now while the underpinning is subsiding. This subsidence is reflected in an effect on the older and bigger outside blocks. The effect may be a very small slip, with very small opening of cracks, but as it involves a big piece of the mountain moving suddenly, it makes an earthquake.

We must file a caveat to restrain the reader from concluding that we have any certainty that this is a repose period. As previously pointed out in earlier discussions, the year 1924 so far is more like 1922 than like 1913, and recent years have produced enough temporary repose periods to make one cautious about defining the close of a cycle. This caution is especially needed now that we know from the May explosions that we are dealing with an exceptional cycle at the crisis of a long-term period. Until a full year has elapsed with no repetition of exceptional phenomena at the end of it or within it, and until the lava comes back to stay, in either Mauna Loa or Kilauea or both, we have no assurance that the cycle usually nine years long may not lengthen itself out in such an exceptional time to twelve, fourteen or twenty years. And we have no assurance from the vague accounts of the natives who conversed with Ellis after the eruption of 1790, that major or minor explosions, with or without lava flows, did not continue for several years at the time of that crisis.

JOURNAL, OCTOBER, 1924

October 9. During visit to Halemaumau after 3 p. m. occasional avalanches occurred. During the previous week they had been less numerous than before.

October 11. Inspection of the pit at 4 p. m. revealed little change in its general aspect from what it had been in September. At the moment rain had left the walls wet and dark red. Hot dry streaks extended along the west side of the high southwestern talus cone, also at the base of the western talus and along the eastern edge of the lava floor that had been left in July as a filling of the bottom of the talus funnel. Most of the north wall was dry, especially the large intrusive body known to be red hot inside.

This north wall was working uneasily, scaling off in small slides mostly at northeast corner of pit. The talus areas must have increased during the month, but their appearance had changed very little. In the wall section of lava flows west and north there were signs of old talus sections. The large north intrusive body appeared bigger as result of increased revelation by avalanching.

Blue fume was mixed with steam in many places and distinct blowing noise was audible, as there was no wind. Steam jets were numerous over the bottom region, especially so on the July lava cone, but they were notably absent on the eastern surface of the lava floor; they appeared, however, in the talus along its edge.

October 13. At 11 a. m. the pit was drier and in sunlight its interior was wholly clear from all sides. Blue fume arose from cracks in the wall below the northern edge as before. Seen from the Observatory the vapor condensed over the pit evening and morning above the western edge, exhibiting a rapid boiling up of cumulus as though the gas were quite hot, often producing an umbrella shape above. On this day there was little sliding of rocks. Sulphur stain was seen to be no longer conspicuous on the north, east and south flats adjacent to the lava floor.

Seismometrically at this time the ground was quiet at the Observatory, though on the 9th a sharp shock at Hilea in Kau had dismantled the instrument there.

October 15. At 2:15 p. m. the pit, after rain, showed dense white vapor jets at the foot of the north wall, in the west central part of the lava floor, from the cup crater of the lava cone, and from between the southern taluses. A spicy sulphur smell was perceptible at southeast rim of pit.

Small avalanches were working along the northeast wall. There were now six principal talus slopes at the base of the walls respectively west, north, northeast, east, south and southwest. Distinct notches or gullies had been eaten out by avalanching above the eastern and western horns of the north intrusive body. They follow vertical zones of contact characterized by solfataric decomposition completing the U shape of an old pit section, of which the intrusive body marks the bottom.

At the top of the northwestern talus a cavernous place has been etched out in the wall by slides, which appears to be old fragmental material of looser texture than the hard beds on either side.

The pinnacle rock that stands out from the edge of the pit near the south trig station was found to be still in place, though precariously overhanging the precipice below. It contains a massive layer of basalt nine feet thick near the top, which is also seen exposed under the southern rim of the pit where it is underlaid by thin beds of lava. There are three or four such layers above it and then about eighteen inches of 1924 explosive gravel.

October 16. During the previous day 2.16 inches of rain had fallen, continuous thunder storms were in progress, pools of water occupied the depressions in the May ash and the impact pits, made by both 1790 and 1924 boulders near Keanakakoi. There was snow on both Mauna Loa and Mauna Kea.

The pit appeared dark red and wet with much steam in the bottom and blue vapor mixed with it on the east slope of the lava cone, along the east margin of floor and at the foot of the west talus. Little feathery tufts of steam occurred on the east surface of the lava flat, which is usually without

vapor. The eastern and hottest part of the northern intrusive was partially dry. With strong northeasterly wind the rising vapor clung to the western wall. What appeared to be an unconformity in the lava beds was made conspicuous by the wetness on the east side of the southwest tunnel and inclined down to the east therefrom at 45 degrees.

October 17. A circuit of the pit was made in the afternoon, going first north and then west. A changeable blowing noise was audible in the bottom. Numerous slides occurred from the north wall and some southwest and south. From the northwest rim the columnar joints of the north intrusive appeared bowed outward as though oppressed by the weight of the beds above. From the southwest rim the west wall, which forms a buttress or promontory was seen to show vertical breaking all through its mass as though crumbling under pressure.

The whole west half of the lava floor was steaming, there were dry hot zones as described before and another extended up the east talus. A little sulphur stain was detected at the east edge of the lava floor. The north wall appeared to be kept steep by the undermining effect of the ever avalanching intrusive body below and the north talus under this was a wide belt extending from side to side along the whole bottom of this precipice.

Wide reddish comparatively smooth surfaces, free from steam and covered with compact red sand or mud, lay northeast and south of the lava floor. On these surfaces occasional boulders had bounded out to isolated positions from the adjacent debris slopes. These flat floors sloped gently toward the center, at flatter angles than the talus.

Small caverns were seen in the wall of the pit near the top at the southeast and at the north.

October 18. With much rain accompanied by thunder cascades were produced over Uwekahuna cliff at 1 p. m. and over the cliff south of Byron's Ledge at 2:45 p. m.

October 18. With much rain accompanied by thunder, cascades were present rain so that even the cliff walls were steaming east, west and south, but not the north intrusive, which remained dry. Under it there was fresh dry avalanche material and two slides fell from it in the course of ten minutes. The behavior of the lava floor, which remained free from steam on its eastern half suggested that that half remains hot where the deeper lava pools accumulated in July. Vapor arose from upper cracks in the Kilauea floor back of the Halemaumau rim west, south and east, but not at the north. Here again there may be some effect of the hot intrusive body below.

October 21. Inspection of the pit after dark at 7:30 p. m., with a blustery northeast wind blowing, did not discover any visible glow in the walls either at the north and west intrusive, nor elsewhere. Avalanche dust had been seen rising from the pit in the early morning and two avalanches from the north wall occurred in a few minutes during the evening visit.

October 22. At 9:30 a. m. and for a half hour thereafter there was practically steady sliding in progress at the north intrusive. The floor of the pit was dusty from the slides. An avalanche occurred at the southwest. The many avalanches since July have caused overlap of the talus on the lava floor at the west, northwest and north, but hardly at all east and south. Much fresh gray avalanche debris lay on top of the northeast talus. After one dry day the steam on the bottom was much less and the interior walls were dry. The large western boss of red rock partly surrounded by massive platy intrusive rock below and at the sides appears to have its counterpart in the northeast wall within the big intrusive body where a circular red mass occurs one-third as big as the western boss. This is entirely surrounded by the gray intrusive. There is much reason for thinking that the large intrusive masses extend clear across the bottom of the pit.

On this day the odor of hydrogen sulphide was perceived. From the Observatory at 10:30 a. m. much dust was seen hanging over the pit due to avalanches.

October 24. At this time avalanching was increasing. About 3 p. m. a dust cloud was seen rising and at 3:15 a big avalanche fell from the north corner making cauliflowerers of red dust. This carried away fragments of the upper lava flows of the wall above the west horn of the north intrusive. This place continued to slide. A big new red talus cone had formed below, different from the gray talus under the intrusive at its east end. There was fresh gray talus at the top of the big southwest slope, from new slides at the wall above. A slide was seen from the east end of the north intrusive.

The whole north wall had now receded by avalanching, retaining its essentially vertical character, but leaving the long lenticular hot body 600 feet down standing out as a slight bench with vertical columnar face below. At the eastern end of this north wall of the pit there is a broad vertical belt of rocks with solfataric stain extending up to the rim from the east end of the hot body.

Rocks were heard falling at the west side of the pit. The force stimulating this fresh spell of avalanching appears to be a slight lowering of the bottom of the pit, coupled perhaps with earthquaking from settlement around the greater crater. Steam rose from the usual places. In the outlying country the recent rain had washed off much of the new ash from the lava floors of Kilauea, revealing gray rock surfaces and causing the new ash to puddle deeply in many places and to furnish grinding material for new trenches in the old ash cliffs.

October 25. At 2:15 p. m. there was an avalanche southwest, followed by other small slides in the northeast corner of Halemaumau. The fresh dust on lava bottom had been washed off by rain. Yellowish green salts had again appeared on the rock slope at base of southeast wall.

October 26. At 3 p. m. the pit was quiet with only slight slides trickling occasionally from north corner over west horn of the big intrusive.

October 27. At 11 a. m. big red cauliflower clouds rose from an avalanche at the northeast corner of the pit and the air over Halemaumau continued dusty for hours. The northeast wall of the pit was actively avalanching all day. With this the southwest wall above the big talus cone appeared to be working in sympathy and slides fell also from the western boss. The similar red body at the east end of north intrusive was the principal locus of slides and a set of upright dark cracks below it were conspicuous as the line along which the avalanches fell. There would be sudden spallings off from the upper part of the northeast wall and big masses would crash down on the intrusive ledge below. Then the ledge avalanches would start making red dust at the round body and salmon colored at the adjacent platy rock. Some slides occurred at the north corner.

The west station flag had stood about over the southwest talus cone and it was found to have fallen in, while new cracks in the dirt there gave indication of motion within the many fissures that lie parallel with rim of pit. Back from the west-northwest edge of Halemaumau a cavern opening in the Kilauea floor was found, farther south than the Postal Rift cavern. Much vapor was welling out of the cracks southwest and west of Halemaumau.

The lava cone of July lies in the line connecting the red bosses northeast and west-southwest where the avalanching this day was going on. This line projected would head towards Kilauea Iki.

October 28. At 2:20 p. m. a strong earthquake occurred at the Observatory, making three or four sharp and alarming jolts, which dismantled and broke the seismographs, upset the oil damper tank and threw down various objects.

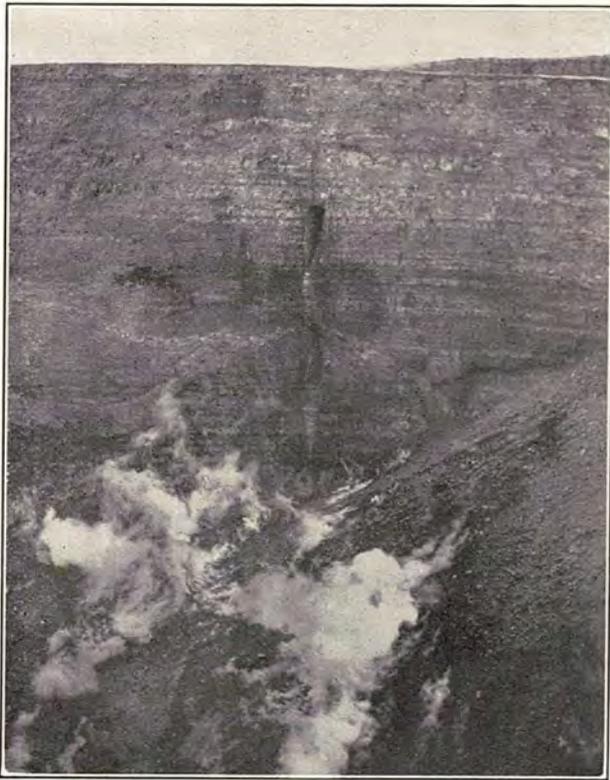


Fig. 35. Southwest rift outerop in wall of Halemaumau showing two tunnels and dyke. June 5. Photo Emerson.



Fig. 36. Lava flow of August, 1923, in Puna forest near Makaopuhi. The flow has moulded tree stumps as shown. On account of fumes this was inaccessible at time of its eruption. Photo Emerson.



Figure 37. Typical fissure eruption, source of 1923 Puna flow, showing hot fissure, its spatter and sulphur stain. Photo Emerson.



Fig. 38. Trees spattered with lava along zone of fissure eruption of August, 1923, in Puna. Photographed June 21, 1924, by Emerson.

The direction of first displacement was south-southeast, the preliminary was very short, the shock was not noticed in Hilo, Kapoho or Waiohinu, but was recorded on the seismograph at Hilea. Local effects appeared in the form of cracks in the earth over the rock fissures about the Observatory and Volcano House grounds.

The earthquake was followed by aftershocks recorded seismographically. No volcanic concomitants or effects were noticed. At the pit no new cracks were discovered, nor were any noticed near Keanakakoi. The shock produced no marked avalanches around Kilauea crater and in this it was unlike the earthquake of October 25, 1913. That shock had been more prolonged and of slower period. There were some avalanches in Halemaumau at the time of the present earthquake and during the inspection of the pit at 4 p. m. small slides occurred at the north corner. The south pinnacle remained intact.

October 29. At 11 a. m. the wind was such that the odor of hydrogen sulphide from the pit was strong on its southeast edge. Rocks were sliding at the north and west walls. A big piece of the wall surface had fallen away above the western part of the north intrusive body. There was here revealed what looked like an old talus section above the intrusive. The greenish yellow ferric sulphate, if such it is, again showed on the smooth flat south of the lava floor. Steam jets on the bottom showed very little sign of the blue fume. Some of the slides at the west made such continuous trickling streams of gravel that they sounded like running water. These were breaking down the promontory of crushed rock above the western boss. In the intrusive rock under this boss vertical lamination shows, like that of the northern intrusive.

At the Observatory a sharp earthquake was felt at 10:56 a. m., not noticed by the observer at the crater.

October 31. At 4 p. m. the crater was visited, forty minutes after a great cloud of avalanche dust had been seen to rise from the northeast corner followed by a second cloud from the southwest. Between 4 and 5 p. m. the northeast wall was making slides continuously. These became bigger until at 4:50 p. m. a long segment of the northeast rim was carried away. The whole surface of the cliff below this point down to the round red area in the intrusive body showed the scar of fresh falls. Occasional small slides fell from the west wall above the red boss and a very little sliding occurred at the north corner. An occasional low pitched sound was heard from the bottom of the pit, possibly a blowing noise, but not identified.

SEISMOMETRIC RECORD

During the month ended midnight, October 31, 1924, 106 local earthquakes were registered at the Observatory. These and other earth movements are exhibited below. Time is Hawaiian Standard, 10 h. 30 m. slower than Greenwich.

Local Earthquakes

Abbreviations have meanings as follows: Vf=very feeble; f=feeble; s=slight; m=moderate; fl=felt locally, and Δ =indicated distance to origin in miles.

October

- 1—12:28 a. m. vf.
- 3:25 p. m. f., fl.
- 2— 5:33 a. m. vf.
- 7:11 a. m. vf.
- 8:05 p. m. vf.
- 10:16 p. m. vf.
- * 3—10:25 p. m. vf.
- 4— 3:10 a. m. vf.
- 5:22 a. m. vf.
- 3:59 p. m. vf.
- 6:39 p. m. vf.
- 11:03 p. m. vf., $\Delta 2$.
- 5—10:44 a. m. vf.
- 1:32 p. m. vf.
- 10:56 p. m. vf.
- 6— 6:45 a. m. vf.
- 12:43 p. m. vf.
- 4:27 p. m. vf.
- 11:34 p. m. vf.
- 7— 7:15 a. m. vf.
- 6:50 p. m. vf.
- 8:44 p. m. vf.
- 8:49 p. m. vf.
- 9— 8:14 p. m. vf.
- 10—12:21 a. m. s., $\Delta 32$;
felt in Hilea.
- 5:17 p. m. vf.
- 10:32 p. m. vf.
- 11— 5:51 a. m., tremors
continue 8 mins.
- 12—10:00 a. m. vf.
- 4:57 p. m. vf.
- 13— 4:47 a. m. vf.
- 7:26 a. m. vf.
- 14—12:24 a. m. vf.

October

- 15— 1:06 a. m. vf.
- 1:07 a. m. vf.
- 16— 3:59 p. m. s., fl., $\Delta 2$.
- 18—12:25 a. m. vf.
- 2:10 p. m. fl., m.,
 $\Delta 25$.
- 19— 2:52 a. m. vf.
- 2:54 a. m. vf.
- 2:57 a. m. vf.
- 12:22 p. m. vf.
- 5:14 p. m. vf.
- 9:39 p. m. vf.
- 20—12:31 p. m. vf.
- 3:53 p. m. vf.
- 21— 1:09 a. m. vf.
- 3:08 a. m. vf.
- 5:58 a. m. vf.
- 8:42 a. m. vf.
- 8:44 a. m. vf.
- 1:44 p. m. vf., $\Delta 1+$.
- 4:28 p. m. f., $\Delta 1+$.
- 7:35 p. m. vf.
- 22—12:03 a. m. vf.
- 3:19 a. m. vf.
- 3:24 a. m. vf.
- 4:36 a. m. vf.
- 4:37 a. m. vf.
- 4:38 a. m. f., $\Delta 10$.
- 1:32 p. m. s., $\Delta 9$.
- 2:23 p. m. vf.
- 3:35 p. m. vf.
- 23—12:14 a. m. vf., $\Delta 2$.
- 12:16 a. m. vf., $\Delta 2$.
- 10:50 a. m. vf.

October

- 23— 1:28 p. m. vf.
- 2:44 p. m. vf.
- 9:55 p. m. vf., $\Delta 2$.
- 24— 3:10 p. m. vf.
- 25— 1:38 a. m. vf.
- 2:26 a. m. f., $\Delta 9$.
- 4:32 p. m. vf.
- 5:54 p. m. vf.
- 7:06 p. m. vf.
- 7:16 p. m. f.
- 7:18 p. m. vf.
- 26—12:46 a. m. vf.; felt
in Pahala.
- 27— 7:07 a. m. vf.
- 7:37 a. m. vf.
- 8:57 a. m. vf.
- 10:58 a. m. f., $\Delta 18$.
- 11:07 a. m. vf.
- 6:19 p. m. vf.
- 28— 1:04 a. m. vf.
- 5:33 a. m. vf.
- 12:15 p. m. vf.
- 2:15 p. m. strong $\Delta 2\pm$.
Then follows in one
hour 4 vf., 1 f., and
4 s. shakes.
- 29—11:00 a. m. m., $\Delta 5$.
- 11:00 a. m. s.
- 1:01 p. m. vf.
- 31— 4:17 a. m. vf.
- 1:42 p. m. vf.
- 3:03 p. m. vf.
- 5:33 p. m. vf.
- 9:50 p. m. vf.

Spasmodic Microtremor

This type of tremor was slight during October.

Harmonic Microtremor

This type of tremor was absent in October.

Microseismic Motion

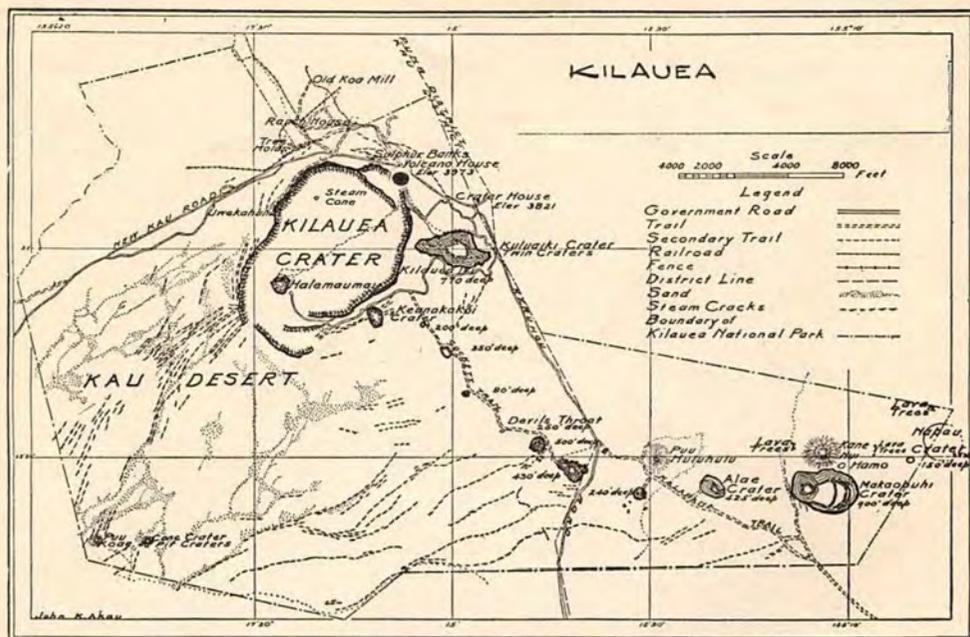
The amplitude of microseisms was moderate on the 16th and slight on other days.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

September 28—October 4.....	2.0 seconds NW.
October 5—11.....	1.7 seconds ESE.
12—18.....	1.1 seconds ESE.
19—25.....	2.5 seconds NNE.
26—November 1.....	2.0 seconds WSW.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges, gifts to library, news notes about Pacific volcanic and seismic events, and correspondence should be addressed HAWAIIAN VOLCANO OBSERVATORY, Volcano House, Hawaii.

The Observatory is operated by the U. S. Geological Survey, and its work is supplemented by the Hawaiian Volcano Research Association. The main station is on the northeast rim of Kilauea Crater. Subordinate seismograph stations are operated by the Research Association under the direction of the volcanologist in Kona, Hilo and Hilea.

The Kilauea station operates horizontal pendulums of the Bosch-Omori type and receives time by wireless from the Honolulu Naval Station. Observatory Lat. $19^{\circ} 25' 54.2''$ N.; Long. $155^{\circ} 15' 39.2''$ W.; Elevation cellar 1214.6 meters (3985 feet). The Hilo and Hilea stations operate normal pendulums and the Kona station a horizontal pendulum. Their seismograms are sent to the Observatory.

The Hawaiian Volcano Research Association founded the Observatory in 1911, transferring the plant to the Government in 1919, but continuing cooperation in experimental work by furnishing funds and apparatus and workers as needed by the Government Volcanologist. It is a corporation under the laws of Hawaii, governed by a board of directors, and financed by the subscriptions of its members and patrons. Its aims are identical with those of the Observatory, namely, (1) To keep record of Hawaiian volcanism, (2) To attract volcanologic specialists to Hawaii, and (3) To promote worldwide knowledge of volcanoes and earthquakes and the foundation of more volcano observatories.

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VOLCANIC CONDITIONS IN NOVEMBER

Activity of Halemaumau

During the month of November the number of registered earthquakes each week became fewer and for a time the pit Halemaumau was very quiet. At the end of the month there was renewal of strong avalanching from the western wall, while the north wall that had been so active in October became quiet.

For the week ending November 5, twenty-four earthquakes were registered, about half as many as in the preceding week, and on November 1 the seismographs were registering a southerly tilt. Investigation of the ground after the big shock of October 28 indicated that there had been movement between blocks of the rim of Kilauea crater on its northeast side near Volcano House. These cracks outside of the big sink bound portions of the ancient rim, which have tended from time immemorial to slip inward and downward, just as the blocks inside Halemaumau at a more rapid rate slip inward and downward now. With the underpinning subsiding, the inbreak at the pit is reflected in an effect on the older and bigger outside blocks.

The northeast rim of Halemaumau, after the big avalanches of the end of October, showed new cracks concentric with the pit for forty feet back of

the edge. The whole wall below was fresh broken. The surveying station was gone. The pit was elongating towards the center of the big crater.

Sulphur stain again appeared at the southern edge of the lava floor. Most of the lowest layers in the walls of the pit show upright lamination like the large platy intrusives as though the lava beds had been penetrated and heated.

The next week only eight shocks were registered, one of them, at 9:59 a. m. of the 10th, making a concussion and detonation like a single thunder-clap. At this time weak blowing noise was audible in Halemaumau, seemingly from the inner lava cone. The odor of hydrogen sulphide is always noticeable now about the pit in marked contrast to previous years, and it comes up from the solfataras on the bottom. The avalanching was becoming less, and the solfataric staining of the bottom consequently became more conspicuous as the dusting of the surface decreased. A low-lying body of massive rock had become tarnished and stained.

During the third week only five earthquakes were registered and the ground-tilting was now tending northeast in accordance with its normal autumn habit, which should be evidence that the lava in underground passages has resumed upward pressure. This checks with the quietness of the pit, for earthquakes and avalanches are most numerous when the crater ground is sinking. The pit is quite fireless and looks like the abandoned open cut of a mine. A few rocks fall singly here and there. The blowing noise ceased. Steam jets were very abundant over the western half of the bottom. The high walls were streaked with white salts and were green in some places, and greenish yellow deposits of sulphur and sulphates were growing more conspicuous all over the bottom.

During the last ten days of the month avalanching was renewed along with the peculiar waxing and waning seismic movements which we have come to associate with avalanches. The slipping of the wall-blocks adjacent to the pit may indeed generate these tremblings. The north corner of Halemaumau developed large slides on November 20 and thereafter, and by dint of breaking away, a new notch was made in the rim fully 500 feet across and throwing the rim back ten or twenty feet. Here the upper wall exhaled blue smoke, representing probably a rotten zone eaten by sulphurous fumes. This place lies above the western horn of that remarkable intrusive lens of platy rock which was visibly red hot until August.

The slides would begin by rocks falling from the upper part of the wall. This started a deluge of debris below. Across the intrusive sill this material would pour like a waterfall. By fall after fall at the same place the cascades of gravel ground a vertical niche or groove in the ledge.

On the 25th a second spell of avalanching began, this time taking off the face of a huge promontory of split and crushed-looking rock on the west side of Halemaumau. These slides also worked their way all the way up to the top, and carried away a pinnacle in the edge rock. Two and three days later bigger avalanches occurred here and the one on the 28th started a landslide in the large southwestern talus heap. The whole face of the heap slid off to the bottom of the pit, obliterating the lava cone completely and burying the western half of the lava floor. There was left a terrace of boulders and sand, through which the steam percolated, until the whole front of the lobate delta-like mass was steaming. Not the slightest trace of the lava source-cone of July was left. At the end of the month the avalanches dwindled.

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November 1. In early afternoon avalanche dust rose mostly at northeast wall of Halemaumau. The steam rising there had some blue fume mixed with it.

At 3 p. m. avalanches were found tumbling at the northeast wall, and occasionally rocks would fall elsewhere. A visit to the ground above this wall showed that fresh cracks had opened parallel to the rim of pit, as far back

as forty feet, and the northeast survey station had fallen in. The pit from this viewpoint appeared bigger and deeper than ever.

From here looking down a clear view was obtained of the north intrusive ledge. The light-colored rock and its platy jointing are believed to be identical with a granular light gabbro with ployhedral cleavage abundantly found in the May debris, and especially conspicuous on this side in the stone-fields.

Over the west middle region of this long ledge a notch in the wall had enlarged itself by caving, the talus below was higher, and some of the beds in the notch were brick red.

November 2. At 3 p. m. yellow stain of sulphurous aspect amid small steam jets was observed on the south lobe of the bottom lava. Other sulphur patches have again appeared in the steam at two places near the lava edge east, but among the talus fragments. A dense jet of steam arose at the eastern lip of the lava cone craterlet. There was little rock-sliding.

November 3. After 5:30 p. m. noisy avalanches were seen occasionally at Halemaumau to the NE., N. and SW. A prolonged hissing noise after an avalanche at the southwest appeared to be not a gas hiss at all, but was occasioned by the sliding of long ribbons from above downward in the big southwestern talus heap. It was really rock debris in motion, but it sounded like steam. Several avalanches occurred between 6 and 6:30 p. m. There were dust whirls in the desert on this day.

November 4. Owing to southwest wind several avalanches at Halemaumau were heard distinctly at the Observatory, though little dust rose. Dust was seen at the southwest rim at 5:30 p. m.

November 5. The weather was calm with light airs from the southwest. Steam was sweeping southward in the bottom of the pit at 9:30 a. m. when pit was visited. The induration and vertical lamination of the lower stratified beds in the pit wall were conspicuous, where the north and west intrusive bodies lay above, as though lavas were soaked with the intrusives and partly replaced. No blowing was heard. A small slide occurred at the NE.

November 7. About 4 a. m. a watchman reported lightning flashes from the direction of the pit while a large dust cloud was drifting northward. Roaring of avalanches was heard in the afternight, and two loud roars at 5:45 a. m.

At 9 a. m. the sulphuretted hydrogen odor from the pit was strong north of Keanakakoi. After rain the pit walls were wet and there were only slight rock falls. SW. and NE. new talus debris was visible. Steam was dense from the cup of the lava cone, the western floor and the north talus. Yellow salts were conspicuous on a sloping bank at the base of the east wall.

November 8. At 11:30 a. m. in bright sunlight the pit was very dry, with the sulphate stains conspicuous at five places. The stain appeared to be increasing, but the salts are partly soluble and washed away by rains, or they are masked by avalanche dust, so that appearance and disappearance of the sulphates are variable. All the May ash develops white coatings on drying after rain.

The low massive rock body presumably intrusive at the base of the north-west wall, which at first was pinkish white fresh rock, had become a tarnished gray, possibly the effect of fume in the dense steam just below. The middle region of the northeast wall now exhibited a large area dark yellowish green in color. The wall over the southwest tunnels had developed its crack more than at first, in the zone of the Kau desert rift. White sublimates occur in streaks on the wall of the pit in many places.

The pit on this day was still, with only one or two rocks falling occasionally. At 11:15 a. m. some dust arose. No blowing noise was audible.

November 9. At 5 p. m. some small avalanches were seen to slide from the southwest wall. There was much steam on the floor and slight hissing was audible.

November 10. The vapor tails in pit were drifting eastward. At 2 p. m. odor of hydrogen sulphide was rising at east rim. An avalanche across the red boss on the west wall made dark lines up and down the cliff occasioned by steady cascades of earthy debris, the finer material of the slide. A fresh broken notch in the wall northeast had formed. The falling away of the west rim of pit had left a pinnae or pulpit rock where blocks of rim rock had caved in on both sides of the remnant.

Green, gray and yellow stains in the northeast wall suggest that the revelation by stripping, of solfataric decomposition buried in the wall, may induce spells of avalanching by the undermining effect of exposure of such rotten rock. The whole northeast corner above the intrusive mass is stained as though much decomposed. There were numerous freshly broken cavernous niches in the northwest wall.

Faint blowing was audible. Steam was not abundant. Blue fume was conspicuous oozing through the rock near the top of the north cliff.

November 12. At 10 a. m. unusual quantities of vapor drifted up the northeast and south walls. There was strong smell of hydrogen sulphide and an occasional distinct blowing sound seemed to come from the lava cone. In the craterlet of the lava cone lay large rusty red blocks. Steam hugged the outer wall of the cone.

Halemaumau was so full of steam that only occasionally could the bottom be seen. Some slides fell at the north and northeast. Over the west boss the wet wall was intensely red with oxidation products. The edge of the lava field on the bottom east and south was all stained with whitish yellow sulphates, and this edge appeared to be a hot and active solfatara. The weather being rainy and misty, there were vapor jets up and down all the talus slopes. The north and northwest taluses had increased in width and height during the last two months. There were many small whirlwinds about hot cracks on the southeast rim of the pit.

November 13. At 11 a. m. small avalanches were falling from the north wall. Steam was dense at the cone and in the south talus corner.

November 14. At 3:30 p. m. the pit was rainy and vaporous. Vapor rose even from the tops of the taluses. A few falls of rock occurred SW. North of Halemaumau a line of vapor jets on the Kilauea floor outside of Halemaumau was made visible by the nucleating effect of the blue fume from the north Halemaumau wall, blown by light wind drift from the south. The fume was entirely invisible where this nucleation took place, but the vapor jets along this zone were clearly developed to view in a band, whereas the moisture from the cracks on each side of this band was taken up by the atmosphere without condensation.

November 15. At 7:15 a. m. and 1:15 p. m. the roar of avalanches at the pit was heard at the Observatory, though little dust could be seen.

At 2:30 p. m. the pit was visited, but the changes were slight. The falls had been from the usual places north and southwest. Sulphate stains on the bottom appeared to be increasing. Greenish stains were observed high on the north as well on the northeast walls. There was much steam from the west part of the lava floor.

An interesting find made on this day was two boards about five feet below the rim of Halemaumau southeast, protruding from under the lava rim, with nails in them, and evidently part of an ancient construction buried under lava and revealed by the caving away of the present rim. The boards could only be seen by looking over the edge at the inner layers inside the pit, below the

debris stratum of 1924 and the basalt flow next below it. One of the boards had a charred edge. As this place was some 700 feet back of the southeast rim of the pit of 1917, it would correspond to the hut at the old road terminus before the overflow of 1918.

November 18. At 12:15 p. m. the sky was bright and the pit remarkably still. A few rocks fell singly from the north and west walls. Vapor rose from the taluses, from the west part of the lava bottom and from the lava cone. Sulphate stain was marked at the west central part of the floor and outside of the floor south and east. Though the air was calm no blowing noise was heard. Somewhat vertical streaks of white stain, probably magnesium sulphate, showed above the north intrusive and along much of the south wall. The wetness of the walls, abundance of vapor, and conspicuousness of this white salt were all greater in the southern shadow than in the northern sunlight. At the south station odor of hydrogen sulphide rose with the pit vapor. The northwest talus was brown, as also the southern heap; northeast and southwest the talus was gray, and the fine material under the west boss was red. The bigger boulders at the bottom, on the north and south sides, were estimated to be from 15 to 20 feet long.

November 19. At 8:50 a. m. there were small slides from the west boss and the north wall. After a cool, misty night the steam had increased over the west floor and up the north talus. All night there had been a vapor cumulus over the west end of the pit, now there was none. Dust from small slides arose over the pit at 10:45 a. m. and at 1 p. m.

November 20. At 8:45 a. m. dust clouds rose from the north and southwest corners of the pit uniting in one considerable cauliflower, and avalanches continued all day mostly from the north wall.

When the pit was visited at 10 a. m. several fairly large slides were seen. Chocolate dust rose at the north and red at the west boss. The floor was powdered with new dust, most thickly northwest and north, least in the center, and the sulphur and sulphate patches were all masked with red dust.

The north wall had developed a new scar of peeled rock above the western horn of the north intrusive, a V-shaped niche 400 feet wide at the top, and a new notch appeared also above the WSW long talus heap. The wind whirled the dust along the face of the north wall, and the strong wind of this day may have started the avalanches. Dust appeared even at the edges of the floor east and south, where avalanches are unusual, although the center was free from dust.

A noteworthy feature of the western Halemaumau wall above the intrusives is that there is a lower series of thin-bedded lavas and an upper series of thick massive layers. The dividing line is about a third the way down the wall where at the west there is sudden transition.

November 22. At 9:15 a. m. after a day of very heavy rain the floor of the pit was found all covered with steam tails, thickest at the edges of the floor, at the north and south taluses, and across the west half of the floor: this, of course, means a major belt of steam from north to south.

The avalanching of November 20 carried off the wall all the way up to the rim, notching it 10 or 20 feet back for a segment 500 feet long, including the upper wall north that has been continuously emitting blue smoke. The gulch above the west horn of the north intrusive was left bigger with an upper talus on the intrusive ledge. The whole area of wall caved away appeared decomposed by solfataric action.

As the torrents of big rocks and gravel had fallen across the intrusive sill below again and again at the same place they had produced "avalanche erosion" in the sill. The falling stream finds a groove and enlarges it by attrition, and this becomes a vertical striated scour-way, a half-circle in plan open in

front, extending up and down for the whole thickness of the columnar ledge. The width of the vertical niche was ten or fifteen feet.

November 23. At 5 p. m. the steamy bottom revealed bluish fume mixed with the vapor at the east edge of the floor, the east flank of the cone and at the base of the northwest talus. The east half of the center of the floor was notably free from steam jets. There was some steam up to the top of the east and west walls, but not at the NNE wall over the hot intrusive body. Some purring sounds were heard, possibly volcanic, possibly wind. Following very heavy rains, the steam tails were boiling up by hundreds.

November 24. Avalanche noises were heard during the night preceding. The weather was calm with light drift from the southwest and the odor of hydrogen sulphide was perceptible at the Observatory. At 2:30 p. m. the bottom vapors in Halemaumau were found moving southward with the eddy and the volume of vapor jets at NNW was notably small. From the lava cone the steam rose rapidly at the NW inner lip, and the SE outer lip. A big red rock could be seen in the interior of the cone cup, which was free from steam. A blowing sound was audible. Fresh dry debris had fallen from the northeast corner and some falls were seen at the north wall. Salts were beginning to appear again at the bottom as the rain washed off the dust.

November 25. After 9 a. m. the west wall above the red boss was working and making avalanches. At 9:30 a. m. the top of the pinnacle standing out from the west wall fell. At 9:50 two-thirds of the remainder of the pinnacle fell. This last made the bigger avalanche of the two, but its cauliflower cloud was the smaller of the two. The first sent up a moderate sized red cloud, which boiled up from the hot intrusive body at the bottom of the red boss. The second sent its dust out over the floor of the pit, and a thin diffuse cloud resulted. Another avalanche fell from the west wall at 10:20 a. m. There appeared to be some blowing at the cone and sulphurous stains were again abundant.

A phenomenon observed frequently at this time was change in density of the steam jets at the same place, for instance the lava cone, in the course of a few minutes. It looked as though with slight change of wind the ventilation of the cracks changed, and with it the condensation of the inner moisture.

November 26. A large portion of the much fractured buttress of rock forming the west wall of Halemaumau had scaled off during the last week leaving a scar wider below and narrower at the top. On the other hand the channel that had caved away at the north was wider above and narrower at the bottom. The west pinnacle had been removed through trenching at the sides by slides until it leaned out and toppled.

At 9:45 a. m. the west wall was still working and a piece of rim fell at 10 a. m. The rocks bounded down the protruding buttress below in a noisy shower breaking smaller as they fell. They loosened everything in their track. The streams of finer matter developed brown cascades of the moister dirt. The shower bounded out on to the surface of the big talus cone.

This started the talus. The big boulders rolling down the surface developed a stream of matter flowing in a belt 20 feet wide within the big talus cone, the motion being propagated from above downward. This was finally flowing all the way to the bottom burying large boulders that it found at rest there. This torrent of rocks made an increasing noise which lasted about two minutes after the avalanche sound had ceased. The noise of the stream was almost exactly like the roar of a steam jet, and in darkness would have been so described. As the big roar died away lighter slides made noises like hissing. The stream moving was brown owing to the disturbance of wet dirt, whereas the talus in general was gray. The sun in a half-hour dried these places to lighter colors.



Fig. 39. Flow of 1823 east of Pahala. A hill plastered with the lava high above the general level of the flow, which forked about the hill and rode up on its flank. Photographed July 28, 1924, by Emerson.



Fig. 40. Explosive fissure of the 1823 eruption, (see May Bulletin, Discussion) east of Pahala, 700 feet above sea-level. Angular rocks strewn about by a steam explosion from the crack. Photo Emerson.



Fig. 41. Lower explosive vent of 1823 eruption, 280 feet above sea-level, showing gradation of gravel and sand away from the vent. Photo Emerson.

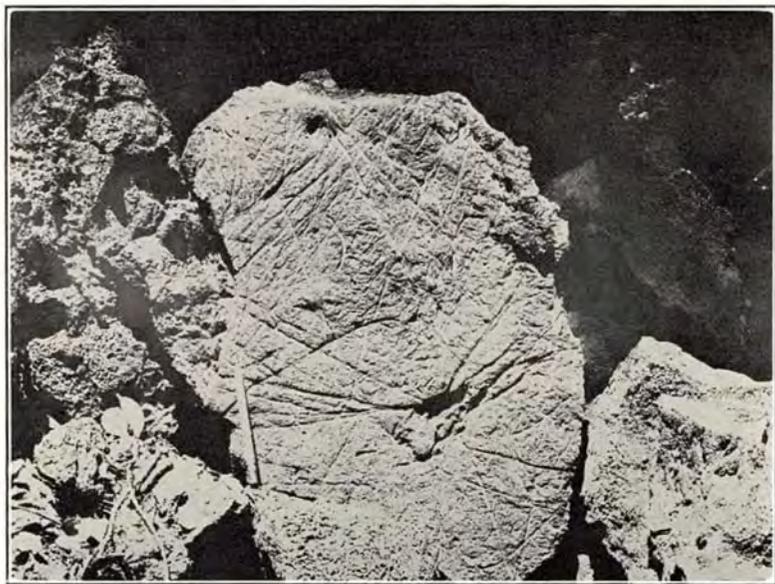


Fig. 42. Fragment of bottom surface of 1823 lava, where the liquid lava in freezing moulded grass stems and sticks. Photo Emerson.

Trickling slides of small stones were heard both north and west, a western one being noted at 10:40 a. m. At 9:45 the lava cone had been giving dense steam and a purring noise like boiling water was audible; the steam totally changed in half an hour so that it was only a thin jet and the craterlet was clear. Could the dense vapor have been due to nucleation by fume that was now withdrawn?

After rain lately it had been repeatedly demonstrated that white salts (magnesium sulphate?) flower out on the sand and ash near Halemaumau when the sun dries the ground, but not where the steam cracks keep the soil wet.

November 27. Between 10 and 10:35 a. m. avalanching at the west wall worked up to a climax.

The sunshine was on the wall. Two cracks parallel to the wall sliced the western buttress. One made an open fissure back of the rim. The other, new since the previous day, appeared on the wall surface as the scene of incessant slides. The avalanches worked back and forth on opposite sides of the loosened slice, and then would fall straight down across its middle, those that struck the red boss below making salmon colored cauliflowers that boiled up from the hot rock. The whole southwest wall was working, even on the east side of the big talus, but the north wall now remained very quiet. Sometimes three avalanches would be falling at once, and the talus was streaming ceaselessly.

At 10:35 the rim began to yield in big masses, and at the same time the seismograph at the Observatory two miles away developed a prolonged trembling earthquake reaching its maximum gradually. The outer slice on the wall fell, and then the inner slab back to the gaping fissure. A large avalanche ensued with a wonderful color scheme of chocolate colored breaks behind the upper rim rock; the boulders leapt downward until the shower was an inverted V; this became a thousand brown gravel cascades over the buttress; the slide grated over the red boss of intrusive rock in the wall which mixed its red cauliflower clouds with the brown ones that boiled out into the center of the pit. Then the clouds softened and rocks rolled down the talus slope and a steady roar ensued as the slope slid in streams. An immense scar was left in the high wall.

November 28. At about 12:50 p. m. after a forenoon of many small avalanches just as on the preceding day, and from the same west wall, a big red dust cauliflower was seen to rise spreading from west to north, boiling up in especially hard volutes at the north. At the beginning there was roar from the west. This slide obliterated the lava cone of July in the bottom. The fall had carried away another slice of the western wall back to a fissure behind the rim, and the dust cloud that shot across the bottom of the pit had rushed up the northern wall, leaving it powdered red from bottom to top.

There was added to the avalanche a landslide taking down the western half of the long talus heap. This had streamed forward over the bottom lava field. No trace of the cone was left. There was left a delta-like lobate bank or terrace, with a long lobe covering the whole west floor and directed north, and a shorter lobe overlapping the floor south. Coarse blocks followed the frontal slopes and the top was finer-grained, and relatively flat or undulating. The product of the landslide resembled a glacial moraine. The east half of the lava floor remained, overridden by the boulder bank. The vacated part of the big talus conoid was a slope of fine-grained material with rock jutting through and all of the graduation destroyed, from gravel above to boulders below, which had existed before, and which still showed on the eastern half. Some steam came irregularly through the new debris in the afternoon.

A circuit of the pit was made and six of the nine survey flags of July were found still in place. There were many fresh breaks in the soil back of the new western avalanche notch, showing movement on the cracks parallel to rim. On all sides of Halemaumau the ground is cracked some distance back, but

farthest back on the west. The western wall still appeared precarious, with outward swelling columns and crushed appearance. Rocks were falling there. The odor of the blue fume at the north wall was found to be slight, and a rather indefinite foundry smell.

During this landslide as on the previous day there was a prolonged tremulous seismographic earthquake, without preliminary vibration or sharp phases. It was not noticed at Volcano House, but a dog was observed to leave his food, run forward and look towards Halemaumau, give a short bark and run away, all a half-minute before the roar that preceded the dust-cloud. There were several of the tremulous earthquakes during the day, corresponding to the several slides. These prolonged earthquakes were of the type so common during the May eruptions.

November 29. At 2 p. m. the big avalanches and seismic movements had ceased. Small falls of rock were observed on north and west walls. At the landslide terrace the vapor of the pit bottom had now adjusted itself to emerge along the frontal slope of the new bank, coming through the boulders.

SEISMOMETRIC RECORD

During the month ended midnight, November 30, 1924, 51 local earthquakes were registered at the Observatory. These and other earth movements are exhibited below. Time is Hawaiian Standard, 10 h. 30 m. slower than Greenwich. The majority of the earthquakes were imperceptible and accompanied avalanches at the pit.

Local Earthquakes

November

- 1— 1:21 a. m. Very feeble.
- 8:16 a. m. Very feeble.
- 1:17 p. m. Very feeble.
- 2:03 p. m. Very feeble.
- 2:04 p. m. Very feeble.
- 5:07 p. m. Very feeble.
- 5:08 p. m. Very feeble.
- 9:57 p. m. Very feeble.
- 2— 2:08 a. m. Slight.
- 10:54 a. m. Very feeble.
- 11:01 a. m. Very feeble.
- 2:04 p. m. Very feeble.
- 8:35 p. m. Very feeble.
- 3— 5:27 a. m. Very feeble.
- 3:44 p. m. Very feeble.
- 4— 6:31 a. m. Very feeble.
- 10:04 a. m. Very feeble.
- 10:28 a. m. Very feeble.
- 2:35 p. m. Very feeble.
- 5— 10:50 a. m. Very feeble; tremor
for 4 minutes.
- 2:25 p. m. Very feeble.
- 6— 12:22 a. m. Very feeble.
- 8— 4:56 p. m. Very feeble.
- 8:16 p. m. Feeble.
- 9— 12:58 a. m. Very feeble.
- 10— 9:59 a. m. Slight, accompanied
by deep rumble.
- 16— 7:46 p. m. Very feeble; tremor
for 6 minutes.

November

- 16— 8:02 p. m. Very feeble.
- 9:08 p. m. Very feeble.
- 17— 12:41 a. m. Feeble, distance 4
miles.
- 8:24 a. m. Very feeble; tremor
continues for 4 minutes.
- 20— 9:11 p. m. Very feeble.
- 9:13 p. m. Very feeble.
- 9:14 p. m. Feeble.
- 9:26 p. m. Very feeble.
- 24— 1:52 a. m. Very feeble.
- 5:11 a. m. Very feeble.
- 25— 9:44 a. m. Very feeble.
- 27— 10:32 a. m. Very feeble.
- 10:33 a. m. Very feeble.
- 10:34 a. m. Feeble.
- 28— 10:30 a. m. Very feeble.
- 11:55 a. m. Very feeble.
- 12:35 p. m. Very feeble.
- 12:45 p. m. Very feeble.
- 12:47 p. m. Feeble. Continuous
for 3 minutes, large aval-
anche at pit.
- 6:25 p. m. Very feeble.
- 8:03 p. m. Very feeble.
- 30— 7:41 a. m. Very feeble.
- 10:53 p. m. Very feeble.
- 10:57 p. m. Very feeble.

Spasmodic Microtremor

This type of tremor was slight in November.

Harmonic Microtremor

This type of tremor was absent throughout the month.

Microseismic Motion

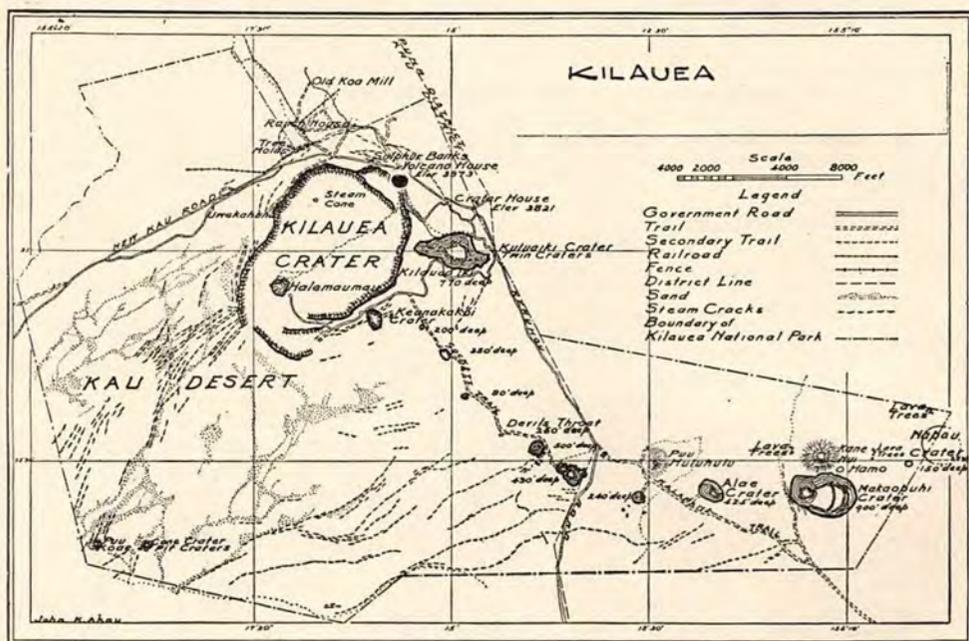
The amplitude of microseisms was moderate on November 16, 20, and 29, and slight on other days.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

November 2- 8.....	1.2 seconds SSE.
9-15.....	2.3 seconds SE.
16-22.....	3.3 seconds NE.
23-29.....	0.5 second SE.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges, gifts to library, news notes about Pacific volcanic and seismic events, and correspondence should be addressed HAWAIIAN VOLCANO OBSERVATORY, Volcano House, Hawaii.

The Observatory is operated by the U. S. Geological Survey, and its work is supplemented by the Hawaiian Volcano Research Association. The main station is on the northeast rim of Kilauea Crater. Subordinate seismograph stations are operated by the Research Association under the direction of the volcanologist in Kona, Hilo and Hilea.

The Kilauea station operates horizontal pendulums of the Bosch-Omori type and receives time by wireless from the Honolulu Naval Station. Observatory Lat. $19^{\circ} 25' 54.2''$ N.; Long. $155^{\circ} 15' 39.2''$ W.; Elevation cellar 1214.6 meters (3985 feet). The Hilo and Hilea stations operate normal pendulums and the Kona station a horizontal pendulum. Their seismograms are sent to the Observatory.

The Hawaiian Volcano Research Association founded the Observatory in 1911, transferring the plant to the Government in 1919, but continuing cooperation in experimental work by furnishing funds and apparatus and workers as needed by the Government Volcanologist. It is a corporation under the laws of Hawaii, governed by a board of directors, and financed by the subscriptions of its members and patrons. Its aims are identical with those of the Observatory, namely, (1) To keep record of Hawaiian volcanism, (2) To attract volcanologic specialists to Hawaii, and (3) To promote worldwide knowledge of volcanoes and earthquakes and the foundation of more volcano observatories.

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VOLCANIC CONDITIONS IN DECEMBER

Activity of Halemaumau

The week ending December 3 at the inner pit of Kilauea had exhibited the revival of avalanching reported in the November Bulletin, and along with this the seismographs of the Observatory showed increase in numbers of earth-

quakes registered. There were nineteen local seismic movements for the week, and seven of these occurred November 28, the day of the big inner landslide. Simultaneous with the slide there was a shock registering as prolonged spasmodic trembling.

Probably a variety of causes unite to start an avalanching spell. The tilt at this time had been southerly, possibly meaning a lowering of the deep lava under the pit, and consequent withdrawal of support to the structure. Other stimuli of breakdown are alternations of sunshine and nightly cold, high winds and rains, extraneous earthquakes, and the slow readjustment of the whole volcano after the May disturbance.

The first third of December was characterized by extreme quiet after the noisy avalanching spell. Nevertheless, 41 small earthquakes were registered during the week ending December 10. Many of these were simultaneous with small slides in Halemaumau pit, but at 8:49 a. m. December 5 a true local earthquake occurred, felt at Kilauea and more strongly felt at Mountain View. The seismogram indicated origin distance of 11 miles and the place mentioned is about that distance to the northeast. The tilting of the ground for the week was slightly southerly or toward the volcanic center.

From December 4 to 8 there were small slides in the pit occasionally making dust that rose above the rim, and these checked with observed seismograph movements not having the sudden beginnings of local earthquakes. The yellow stains of the pit floor began to reappear after their obliteration by avalanche dust, and the frontal slope of the terrace debris left by the landslide of November 28 developed wetness and steam jets. The north wall showed fresh broken places and dustiness.

The pit at times on December 9 was completely still, without even the tinkle of a sliding pebble, a very unusual condition. By the 10th there were quiet spells lasting more than a half-hour each. Hot sulphurous steam rose from a pocket in the debris on the west side of the bottom and there were numerous fuming and solfataric cracks, notably dry, stained with sulphur and sulphates, about the bottom area. Some of them appeared very hot.

The next week there were 50 seismic movements, earthquakes and avalanche tremors, and among these occurred a notable earthquake at 10:11 p. m. December 14. This was a quick twisting shock rather prolonged and generally felt near the volcano, limited to the Kilauea district. Many of the instrumental records were prolonged jarrings simultaneous with avalanches at Halemaumau, the noise of which was frequently heard at the Observatory, especially at night.

A big avalanche at 12:30 p. m. December 12 in the midst of a southwesterly storm sent up such a cloud of dust as to cause a muddy rain at the north side of Kilauea crater. The country was coated with red mud on the steaming flat near the Sulphur Bank.

This avalanche stripped the north wall of the pit, carried away the surveying station and completely destroyed the solfataric spot in the upper wall that had been giving off blue fume for several months. Blue fume was not seen here thereafter.

About the middle of the month avalanches were common, making numerous rumblings, sending up dust clouds, carrying away a promontory at the west end of the north sill, and changing the shape of the north corner of the pit including parts of the upper rim. There were also changes in the northeast wall. All of this avalanching culminated about the time of the winter solstice. The greater number of seismic disturbances were of the avalanche type, the tilting of the ground was to the south-southwest, and it seems probable that there was magmatic subsidence. The week ending December 24 produced 33 local seismic movements of which 26 were of the avalanche type.

As usual at the solstice large distinct earthquakes were registered on the seismographs both at Kilauea and elsewhere, a damaging shock was reported from Japan and the press gave notice of volcanic outbreaks in Nicaragua and at Lassen Peak in California.

The last week of December produced 30 local shocks, two of them felt and about half of them of the prolonged type characteristic of Halemaumau avalanches. Tilting changed to the northeast. The avalanches of the end of the month produced greatest effect in the strait and steep strip of wall on the northeast side of Halemaumau lying above the big intrusive sill. Here cracks back of the rim showed fresh movement outlining freshly broken segments scores of feet back from the edge of the pit. The earth was broken along new steaming cracks parallel to the rim. At one of these a big chasm had caved in revealing a cavern plunging downward at an angle of 30 degrees, its aperture 10 to 15 feet across. A slope of debris led into it. Its roof and sides were of broken material and it was so close to the pit, where avalanching was in progress, that the whole mass of ground appeared to be settling. A faint sulphur odor was detected at some of the cracks back of the north-northwest rim.

DISCUSSION OF SPECIAL FEATURES

Volume Relations of the Explosive Eruption 1924

By T. A. Jaggard

Lava Sinkings

It has been shown in earlier Bulletins that the explosive eruption of May, 1924, at Kilauea came near the end of a cycle that began in 1913. The cycle rose to its culmination with lava outpouring on both Mauna Loa and Kilauea, and declined after 1919 with a succession of sudden lava sinkings and enlargements of Halemaumau. Sinkings were restored by intervening risings. Even the final explosive crash, itself a sinking, was followed in two months by inflow of lava at the pit. Now prolonged quiet has ensued. The cycle had revealed successive flow vents on both Mauna Loa and Kilauea progressively lower. When the lava dropped below water-level inside the mountains, explosions were superadded to avalanches at Halemaumau, and the pit was again enormously enlarged by engulfment.

Volume Removed by Explosion

The volume of rock removed from the pit by explosion is easily computed from the area and thickness of the deposits, and the condensation of the loose ash needed to restore it to the density of basalt. Without such condensation, taking the known thickness of ash in four directions and the probable areas covered at distances 200 feet to 20 miles from the pit, Mr. Finch arrived at a maximum of 58,300,000 cubic feet. Calling the specific gravity of the ash 1.4 and of the rock 2.8, the rock would occupy half the volume of the loose matter, or 29,150,000 cubic feet. By two other assumptions in computation we independently figured the total boulders, gravel and ash at 26 million and 28 million cubic feet of rock. The mean of the three estimates would be 27,710,000, or in round numbers 28 million cubic feet (793,000 cubic meters) removed explosively in May, 1924.

Volume Removed by Engulfment

The total volume of rock removed from Halemaumau, measured as a funnel-shaped cavity before and after the May eruptions, was approximately 7,120 million cubic feet (202,000,000 cubic meters). This was computed as follows:

Elliptical area pit aperture May 1.....2000x1500x 500 feet
Elliptical area pit aperture May 30.....3400x3000x1300 feet

Area pit May 1.....2,200,000 square feet
 Area pit May 30.....8,000,000 square feet

Taking depth of pit 20% less than actually observed to allow for funnel taper:

Depth pit May 1.....400 feet
 Depth pit May 30.....1000 feet
 Volume pit of May 1.....880 million cubic feet
 Volume pit of May 30.....8000 million cubic feet

The rock lost between the two dates was the difference between these two figures, or 7,120 million cubic feet. This was lost partly by explosion upward and partly by engulfment downward.

But we have computed the explosion matter as 28 million cubic feet, or **four-tenths of one per cent** of the rock lost.

In other words, engulfment removed from Halemaumau 253 times as much rock as explosion did. We might quadruple the estimate of ejection products, and still have engulfment of over seven billion cubic feet. The crater pit was enlarged fourfold in 1924, not by the attrition and ejection due to gas rushes, but by collapse of the walls into a void below, just as it was enlarged by collapse repeatedly before in 1913, 1918, 1919, 1920, 1921, greatly in 1922 and again in 1923, all without explosions. The explosive eruption was merely an incident in a mechanism of engulfment.

Similar subsidence is shown in the past history, 1790, 1823, 1868, 1886, and April, 1924, affecting both the Kilauea sink and the Puna shoreline. And the sink country itself is geologically a subsided area for several square miles outside of Kilauea crater.

Depth of Engulfment

For calling my attention to the difference in volumes between ejection and engulfment I am indebted to Mr. R. H. Finch, meteorologist at the Observatory. Mr. Finch further pointed out that if the volume engulfed were computed as filling an upright shaft of diameter equal to the bottom of the pit of May 30, this shaft would reach down over 3000 feet. Calling the average bottom of the present pit 2700 feet above sea-level, this would require the lava column to withdraw at least 300 feet below sea-level, if the shaft is conceived as a cylinder packed solid with the engulfed material above the retreating lava. As it could not be packed solid, and also as it probably narrows, the depth of engulfment was still greater. The only alternative is for the lava chamber to widen out downward, and for the broken matter to founder in a sea of melt. This alternative is not likely at these shallow depths.

Rate of Return of the Lava

That the shaft was not packed solid was shown by the return of the lava up the "wall crack" in July. That is, the slag appeared spurting through lateral talus. Rising as a glassy froth impelled by expanding sulphurous gases, it percolated through crevices of the engulfed breccia. This fluid especially followed the boundary wall, where a slight lift of the fill opens a circular chasm between the fill and the wall, if the wall tapers as a funnel. And the lava pushing upward cakes the fill and lifts it.

If the lava about May 18 began rising from a depression 300 feet below sea-level, the explosions would dwindle as the rising lava filled and sealed the water-boiler. From May 18 on the explosions dwindled. The lava appeared in the pit at elevation 2400 feet above sea-level on July 19. These dates give us a rate of rising of 44 feet per day. At this rate the top of the lava column passed sea-level in its upward progress May 25, when the heavier ex-

plussions stopped. On June 8, when the last traces of explosion ceased, the lava would have been over 600 feet above sea-level, an elevation probably far above the ground-water table for this porous mountain.

Forty-four feet per day is a reasonable rate for recovery of lava in confined ducts. Rapid recovery at 30 feet per day for three weeks in the open pit happened after sudden collapse of November 28, 1919. And this 1919 instance showed that such immediate recovery by effervescence is habitual with lava that has been relieved of pressure. The relief of pressure on that occasion was proved by the yielding of the mountain and the opening of the Kau Desert rift. The relief of pressure in 1924 was proved by the yielding of the mountain and the opening of the Kapoho rift. Hence the subsidence block of Puna shoreline, the earthquakes and the gaping chasms of April.

Mechanism of Engulfment

Engulfment appears to be a vital process in Hawaiian volcanism. It requires (1) a mechanism for breaking open subterranean voids, (2) a succession of collapses whereby billions of cubic feet of crater rock fall thousands of feet into voids, (3) a relation of these mechanisms to underground lava that appears to be always ready with its gas tension, but seeking a path of least resistance.

Relation of Engulfment to Overflow

A rough estimate of volume for all the lava outpourings of both Kilauea and Mauna Loa during the last decade, by the method of approximate area and thickness, gives the following results:

Kilauea floor 1918-21.....	800 million cu. ft.	(22,700,000 cu. meters)
Kilauea, Kau Desert 1919-20.....	500 million cu. ft.	(14,200,000 cu. meters)
Mauna Loa, Alika flow 1919.....	1500 million cu. ft.	(42,500,000 cu. meters)
Mauna Loa, Kahuku flow 1916.....	1000 million cu. ft.	(28,300,000 cu. meters)
Mauna Loa, Mokuaweoweo 1914...	500 million cu. ft.	(14,200,000 cu. meters)
Total.....	4 billion, 300 million cu. ft.	(121,800,000 cu. meters)

The total outpouring, then, of both volcanoes for the decade was much less than the seven billion cubic feet of engulfment at Halemaumau in May 1924. But this was only one engulfment of several. There were successive collapses with enlargement of Halemaumau in 1919, 1920, 1921, 1922 and 1923, not to mention the subsidence of ground at Kapoho in April, 1924, of perhaps 600 million cubic feet. We have no measured record of what engulfments took place on Mauna Loa, nor of what changes of level in the summit of Kilauea in the last three years prove down-sinking of fault blocks. The tilt measurements at the Observatory indicate such subsidence. All of these collapsings account for many billion cubic feet more of matter engulfed and of voids to be accounted for.

Parenthetically, it is worthy of note that the trivial explosion output of 28 million cubic feet is negligible in comparison with any one of the above lava effusions.

All of this leads to the surprising conclusion that the explosive eruption of Kilauea in 1924 was primarily a collapse that left a void in the crater 250 times greater than the bulk thrown out explosively, and nearly twice as great as all the lava emitted from both Mauna Loa and Kilauea in the last decade.

Volume of Kilauea Crater Fill

The surprises contained in the foregoing led to an estimate of what volume of lava had poured into the greater crater of Kilauea. Taking only the century 1823 to 1921, and disregarding the collapses (such as 1868 and 1886, which were large), what is the difference of bulk between the big crater of 1823, the bottom of which was 1700 feet below Uwekahuna bluff, and

the crater of 1921 filled to overflowing, when Halemaumau was only 300 feet below Uwekahuna?

Treating the fill as a cylinder 8000 feet in diameter and 1200 feet high, which is conservative when one considers that the black ledge of 1823 was buried by an elliptical fill nearly three miles long, with a dome-shaped summit 1400 feet above the bottom of 1823—the bulk is 60 billion, 319 million cubic feet (1,708,000,000 cubic meters).

This is the inflow of a century into Kilauea crater, filling it with a wedge of heavy rock. In volume it is equal to twelve Mauna Loa flows each 20 miles long, 1 mile wide and 10 feet deep. In other words the fill of Kilauea in a century has about equalled the flow output of Mauna Loa in a century. This also is a surprise, for Kilauea has been supposed to be relatively unproductive as compared with Mauna Loa. And this takes no account of the several collapses that dumped the fill into the interior of the mountain and required extra flowing to heal the wound. Moreover it takes no account of the Kilauea outflows of 1823, 1840, 1868 and 1920. Counting all of these, the lava output of Kilauea may have equalled that of Mauna Loa. Mauna Loa also has increased the fill of its summit crater. To such extent as it has paralleled Kilauea in crater filling, it has maintained its supremacy.

Weight of Kilauea Crater Fill

What is the weight of sixty and a third billion cubic feet of basalt? At 12.8 cubic feet to the ton, the weight is 4 billion 712 million tons (4 billion 275 million metric tonnes or milliers). This is the weight of a century's filling in Kilauea crater. Of this one and a third per cent (1.3%) of the total was piled on top of the heap between 1918 and 1921, the great overflows of 1919 and 1921 aggregating about 63 million tons.

Advisedly I have spoken of this fill as a wedge. It is the wedge-shaped occupant of the angle in plan of a system of upright fissures, with the thin edge of the wedge pointed downward. The Kilauea, Mauna Loa, and Haleakala craters are each at the apex of meeting fissures. The wedge bears downward at the bend in a crack that has yielded to movement from time immemorial. In Kilauea it bears down with a pressure growth of nearly five billion tons to the century, five hundred million to the decade. And by projection downward of the funnel-shaped walls this pressure-growth takes effect on inclined planes from 10 to 25 degrees from the vertical, and on a bottom area that must narrow down to a very small unit. The actual wedge is vastly heavier than the century's accumulation, for the crater bottom after the drainage of 1823 had a circumference of six miles, and was itself the top of the wedge, remnant from 1790 and 1823 collapses. In Kilauea the cracks that meet at the crater are the Kau Desert rift and the Puna rift. In Mauna Loa they are the Kahuku rift and the Hilo rift.

Suggested Mechanism of the Crater Fills

These rifts are the sources of outflows. The usual sequence is activity of flowing and filling at the crater, then a breaking open of the rift and a flow from the flank of the mountain, with cessation or lowering of crater activity.

When the writer first studied Vesuvius and Mauna Loa, he was baffled to account for the opening of the flank rift. Hydrostatic pressure of lava never seemed a satisfactory cause, for there are many events wherein it appears that the mountain yields independently, and the lava follows. In Halemaumau sinkings are very sudden and from all sorts of levels, and flank outflow, represented on one occasion by a hydrostatic level in the pit, does not consistently accompany a second or third rise to the same level. After lava has flowed and congealed at a flank vent, that orifice does not usually flow again; another crack opens, the next time that rift belt enters into activity.

This yielding of the mountain along definite rifts converging at the crater implies growth of tension. Pressure-growth of fault-block wedges in the rift belts would help create tension. The volcanic rifts of Hawaii are places of "graben" faulting, or block subsidence.

Levels run from the sea to Kilauea in 1912 and 1922 show change, whereby the Kilauea crater floor went down two feet, and the marginal country up two feet, in the ten years. The lift was three feet at Cone Peak, southwest of Kilauea, adjacent to the maximum gaping of cracks of 1920, when Halemau-mau lowered and the flank opened at the Kau Desert. (Kilauea sheet, U. S. Geological Survey, editions of 1912 and 1924.) The lowering of the crater floor was greater at a bench mark near Halemau-mau than at one farther away.

This appears to show that at the time of high lava pressure 1919-20 the carapace or shell of the mountain was swollen upward; and the wedge of the crater fill, the Kilauea floor, was weighted down with the overflows of Halemau-mau in 1918-19. These flows had poured over the floor for an aggregate of nine months.

Illustration of the Mechanism

The most dramatic collapse of the lava in the fire-pit, November 28, 1919, occurred just after the Mauna Loa flow ceased, and while a voluminous flow was pouring up border cracks of Halemau-mau pit. The pit was full to the brim and its lava fill was partly lakes and partly domed floors and crags. The flow swept through tunnels to a great field of new lava on the border of Kilauea floor which it had been feeding for seven months.

The subsidence came without warning at 2 a. m. with swarms of earthquakes, and the whole lava column in the pit sank 400 feet in an hour and a quarter, like a piston into a cylinder. Instantly the outflow ceased. Crags, floors and lakes went down en masse amid glowing avalanches from the walls. The lava puddle left at the bottom began to rise immediately 30 feet per day for three weeks. There was noticed at once in the wall of the pit on the southwest side a long upright crack, with gape widening downward. The outcrop of this crack on the lava field above, 200 yards outside of the pit, immediately developed a sulphurous, smoking solfatara.

The subsidence seemed to imply that the Mauna Loa lava had withdrawn to a depth that caused sympathetic withdrawal tendency at Halemau-mau. The sudden drop seemed to imply that the withdrawal of lava support in the pit had acted as trigger for releasing the downward pressure of the Kilauea wedge. The alignment of the crack seemed to imply that the rift zone of the Kau Desert had yielded to the wedge, opened subterraneously, and suddenly drained Halemau-mau. The gaping downward of the crack seemed to imply that the Kilauea fault block had broken and settled crookedly.

Then in three weeks the lava rose nearly to the brim, burst out through the solfatara on the Kilauea floor, then broke through the newly opened rift in the desert, the added weight of the flood pushed the wedge deeper, and there was another earthquake swarm with avalanches from the Uwekahuna fault cliff that bounds the wedge on the west. Then the desert rift yawned open day by day near Cone Peak five, ten and fifteen feet, **gaping upward**. Finally came the desert flows on the same fissure four, six and nine miles down the mountain flank.

A subsidence in Halemau-mau resembling 1924 was presented by the crisis of May 13 to 30, 1922. From a level 50 feet below rim, the lava lakes, floors and crags, which had been rising a foot per day, lowered 900 feet with an acceleration from 11 feet to 100 feet per day. The topography of the floor maintained its integrity as it sank until the top of the piston was smothered under avalanches. The rim fell in, the pit enlarged, and the edge was left cracked and overhanging. Immediately lava appeared in Puna pit craters eight miles away and then became quiet, leaving the mountain in tension. This was proved by return of lava to Halemau-mau soon thereafter.

The tilt at this time was interesting. When upward pressure under Kilauea ceases, the ground tilt at the Observatory on the north side is sudden and prolonged to the south. In 1922 the lava started lowering May 13, but the tilt was strongly northward until the 20th, when it changed sharply to the south and the tilt accumulated so until June 6. Earthquake swarms began May 17.

Thus the lava lowered 250 feet before the tension of the mountain ceased. Does not this mean that the Kilauea wedge sank and held the tension for a week, even after the Puna rift had started to open underground?

Apparently both the sector of mountain crust and the wedge are always mobile in the conflict between tumescence and gravitation. When tumescence is overbalanced by pressure growth of the wedge, gravitation moves the wedge. When tumescence is withdrawn, gravitation moves the sector, resisted by the wedge, in whatever new direction is determined by the horizontal component of slope and the vertical component of gravity. An equation between growing weight of wedge and decay of tumescence thus determines a rift crisis.

It should be noted that the lava withdrew to depths of the order of magnitude of 1000 feet under Halemaumau in 1919, 2000 feet in 1922 and 3000 feet in 1924. These figures are based on observed subsidence plus engulfment volume of wall material.

There was another subsidence in 1923. The crises of engulfment of 1922, 1923 and 1924 were nearly a year apart. Therefore no one can yet say what will be the nature of the crisis of 1925.

Summary

In the foregoing discussion it appears that

- (1) The lava cycle of a decade was marked by upward pressure first, followed by a succession of crateral engulfments.
- (2) In the explosive engulfment of 1924 the volume of ejected matter was only 28 mcf. (million cubic feet).
- (3) There was engulfed, on the other hand, 7092 mcf. of crater wall matter.
- (4) Accordingly the exploded matter was only 0.4% of the bulk of crater enlargement, and 253 times more rock was engulfed than was ejected.
- (5) This collapse was only one of several, and volumetrically the explosions were mere incidents in a mechanism of engulfment, which is of age-long standing.
- (6) The engulfed matter would fill a vertical shaft the size of the pit down to 300 feet below sea-level. Presumably the lava column retreated that far.
- (7) If so, the rate of return of the lava up the crevices of the fill was 44 feet per day until it flowed into the pit in July. Such a rate accounts for the dates at which the explosions ceased.
- (8) The bulk of all the lava flows of both Mauna Loa and Kilauea for the decade is only 60% of the engulfment void of 1924, not to mention five preceding yearly crises of engulfment.
- (9) In the last century 60,319 mcf. of lava filled Kilauea Crater, disregarding several collapses and taking only the net fill. This, taking no account of Kilauea outflows, equals the Mauna Loa flow output of a century.
- (10) This Kilauea fill weighs 4712 million tons of which 1.3% was added between 1918 and 1921. This means a pressure growth of 471 million tons per decade, acting as a wedge on the rift faults that meet at the crater, and these are alive with lava, or weak with openings by retreat of lava.
- (11) Comparative elevations determined by leveling after the 1919 crisis showed that the Kilauea rim had risen and the floor had sunk.



Figure 43. Halemaumau, first stage avalanche November 27, west wall. Shows the large talus and the steaming cone below, destroyed the next day by a landslip in the talus. Trickle slides in this talus made a roar like steam. Photo Boles.



Figure 44. Second stage avalanche November 27, a few seconds after the first. Slides on both sides of buttress, and block of rim yielding. Photo Boles.

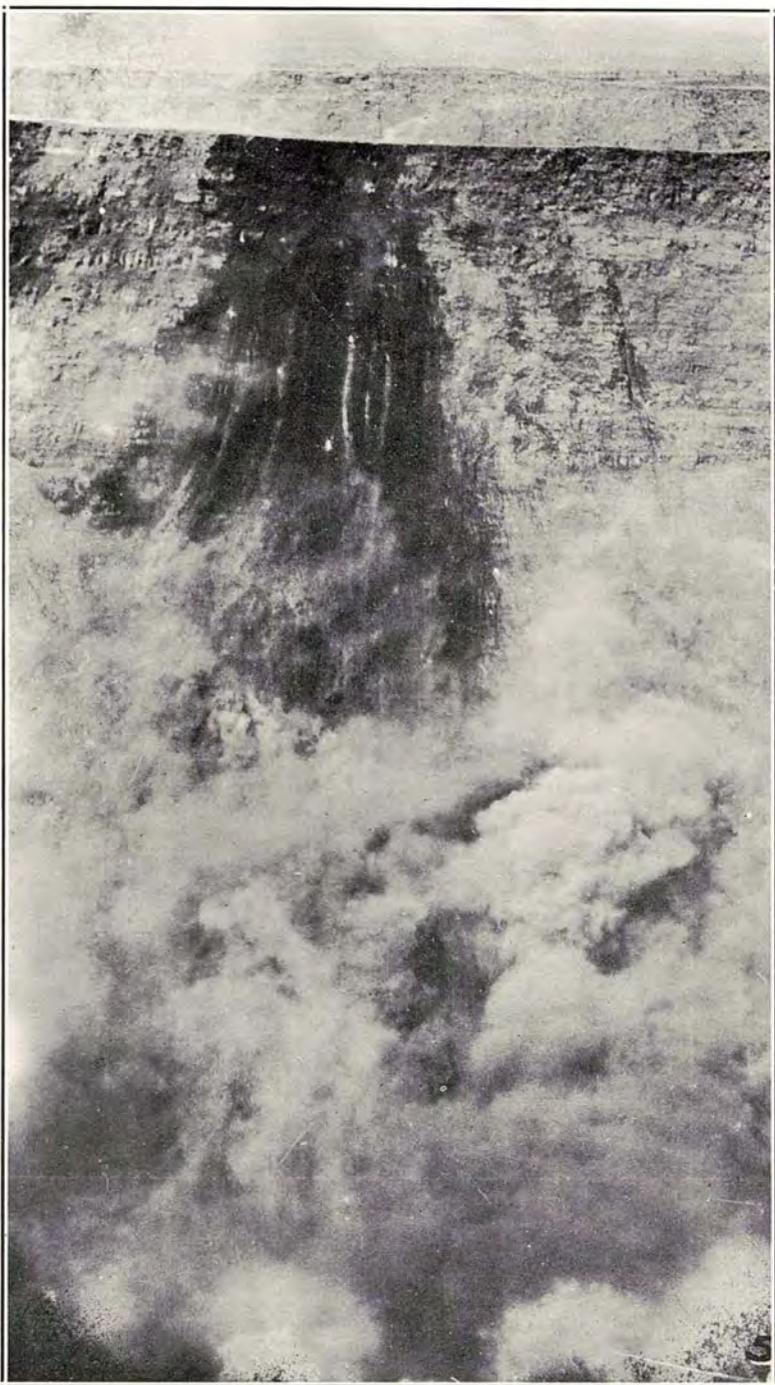


Figure 45. Climax of the avalanche November 27 showing brown gravel cascades and cauliflower clouds.—Photo by Boles.

Conclusion

The mechanism appears to show an age-long tensional lava pressure that keeps the volcanic edifice alive with its fissures underground charged with lava containing dissolved gas.

The lava is forced into short-term rhythms by gravity adjustments. The lava-gas pressure is resisted by sector-shaped lids. The sector lifts and releases lava at the central crater. This accumulates by crater filling as a heavy wedge. With excessive accumulation the wedge slips by its own weight, the lid cannot close, and the lava subsides suddenly and escapes at the radial fissures of the sectors. Wedge and sector slip are the basis of volcanic seismology.

With two or more lava domes in connection, the one may drop its depleted lava and make trigger release to the other, according to adjustments which set a term to a given spell of flowing. Hydrostatics plays only a subordinate role of affecting slags that move mostly by foaming. Within the small scale of lava and mountain, gas appears to be always ready to vesiculate lava if the mountain will release pressure.

In the mountain mechanism illustrated by Mauna Loa and Kilauea, the short term cycle begins by overweighting the highest crater fill, the wedge drops and opens the flank, and the lava lowers and flows from the flank. Meantime the lower crater has been flooding in sympathy. When the high flank eruption ends and the lava subsides, the lower crater fill loses support, its wedge drops and opens the lower flank; its lava sinks in turn and flows from the flank. This sinks away and the flank vents seal.

The lava now enters on pulsations of alternate rising and sudden sinking at the lower crater. Each sinking may be occasioned by the wedge dropping under the tensional stress of the preceding rise. The crater pit enlarges at each collapse with profound engulfment of its avalanching walls.

Finally the lava sinks below the ground-water level at a time when the collapsing pit above is choked with debris. Steam explosions ensue, opening vents through the pit, and lubricating the engulfment. The engulfed material is in enormously greater volume than that ejected. The void wedged open receives a subterranean landslide.

The collapse has released pressure once more on the lava in the depths, gas expands within it and it rises and shuts off the water. It flows sufficiently to reassert pressure by its own congelation, and the mountain again enters into tension.

This is a theoretical statement of what has happened in Hawaii between 1914 and 1924. The lower crater is Kilauea, the upper one Mokuaweoweo. It may be objected that the weights of the wedges are trivial in comparison to the enormous mountain sectors. This is true, but it is not claimed that the wedges **move** the sectors, but that when the sectors heave and pressure is withdrawn the wedges slip and block them. It is the gravitative adjustment of the sector, prevented from closing, that opens the rift. The heaving of the sectoral blocks is due to the secular magmatic expansions that affect the whole volcanic system. Tilt measurement proves that they heave.

It will be readily seen that the volumetric relations here adduced are applicable to most of the volcanoes of the world, and discrepancies between crater losses and ejected matter have appeared in controversies about all the Plinian eruptions. The discussion of this will be left for a later communication.

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December 2. At 9:30 a. m. the long southwest talus in Halemaumau was seen to be resuming its normal appearance after the landslide of November 28. Fresh rocks were becoming distributed over its surface. Recent rain had made the bottom of the pit wet but the terrace of landslide debris along the foot of the big talus remained dry in the region where the lava cone had been.

Dense steam puffing rapidly arose from the base of the northwest wall between the northwest and southwest taluses at a depression or pocket on the west side of the new landslide lobe. This place will be called the west pocket.

The wind was light from the southeast and in calm spells no blowing was audible from the bottom of the pit. Trickle slides of rock from the walls north and west fell occasionally. The bank at base of southeast wall was again bright yellow with salts. At 9:35 a. m. a small avalanche fell from the middle of the west buttress above the red boss.

December 3. At 9:15 a. m. steam jets were aligned from south to north across the bottom of the pit, and very dense in the west pocket. One slide fell from the south wall and a few rock falls occurred elsewhere.

December 4. At 2:30 p. m. there was some sliding from the wall at the top of the northwest debris cone where an ancient talus section is exhibited in the wall. There were also light falls of rock and dust slides on what was left of the west buttress above the north end of the red boss.

December 5. At 10:30 a. m. steam was fummy and dense at the south talus and at the west pocket. The northeast wall had been working above the middle part of the big sill as shown by wall scars and fresh talus. This may have been started by an earthquake recorded 8:30 a. m. Some rock falls occurred at the west and north. A bank stained with sulphur was noticed at the base of the south wall on the east side of the south talus.

The dyke crack above the southwest tunnel in the Halemaumau wall could now be seen abruptly ending upward under a ten-foot sheet of heavy lava at the top. In 1920-21 this place was where the red solfatara lay some 600 or 700 feet southwest of the Halemaumau rim. The upper sheet is the lava of March 1921.

December 6. At 4 p. m. conditions were quiet, there was some dustiness on the pit walls and a small slide was heard toward the northwest.

At this time spasms of tremor on the seismograms, apparently coincident with slides at the pit, occurred occasionally and also rarely dust was seen over the pit.

December 8. The weather was calm and some rain had fallen in the night. At 9:20 a. m. it was noticed that the north talus corner was no longer making dense steam jets. That activity had been transferred to the west pocket. Stain was reappearing at the east edge of the floor and in one place in the middle at the edge of the landslide debris. The wall of the pit was stained on both sides of the south talus. Steam jets were rather dense at the top of the northeast talus as well as at the usual vents south and west. Steam followed along the front of the terrace of landslide debris on the bottom and made the ground wet in contrast to the dry top of the terrace.

Notches where the wall had fallen away had extended themselves over the western half of the north sill as far east as the big dyke, and there was another freshly broken patch on the northeast wall east of the big dyke. The odor of hydrogen sulphide was perceived. There was dust on the north-northeast wall and slides fell west and north.

The walls of the pit showed the following geological details: West of the south station there were three marked unconformities; on top lay the massive 1921 flows, overlying thin-bedded flows; the latter had a thickness of about 100 feet and rested on a wavy surface rising toward the west. Next below were about 300 feet of rather massive flows thinner below, ending at a protruding ledge about the lower cavern level of the 1920 rift. This ledge appeared to be the veneer lining of an old pit extension. Below this was a thinner bedded series with some massive intrusion toward the base and yellow

stains at the bottom. The veneer ledge sloped down passing under the big southwest talus at about the level of the intrusive bodies of the west boss on the other side of the talus.

At the northwest again the upper 1921 flow was identifiable, and the 100-foot section below with wavy lower surface, there showing a veneer ledge. Below that again was the massive series, then the thin-bedded series above the west boss; then an unconformity and a flatter slope making a buttress at the level of the top of the west boss. This sloped down to the northwest talus and again appeared as a buttress north of that talus as far as the north corner of the pit. Beyond that the north-northeast wall contains the great U-section of the big sill overlain by old talus and lavas.

Intrusive bodies at the bottom of the wall northwest are in doubtful relation to the beds next them.

December 9. At 4 p. m. and thereafter the pit at times was completely still with no noise of slides. About noon the north corner had made some dust. Now occasional slides fell from the north, northwest and west walls. The north corner showed fresh scars above and below the west horn of the big sill revealing inclining dykes under the horn extending upward to the west at 45 degrees. Blue fume arose from near the top of the wall west of the gulch above the horn.

December 10. From 9 to 11 a. m. the pit was extraordinarily quiet, sometimes for a half hour or more at a time. Rocks fell at the north once or twice and a little slide occurred at the west side of the Kau rift southwest.

At the west pocket in the bottom the steam appeared hot, dense and bluish. The talus there was hot and whitened, and other very hot fissures in talus banks were seen at the east and southeast edges of the lava field. There may have been a little blowing noise.

December 11. During the preceding night there were numerous tremors of the avalanche type on the seismogram and at 9 a. m. the north wall appeared to have fallen away somewhat but only a few slides were observed. The night had been rainy and the pit was steamy.

December 12. A southwesterly rain and wind storm was in progress. At 12:30 p. m. a large avalanche at the pit sent up dust that mixed with the rain so as to fall as red mud over the region north of Kilauea crater. From 2 to 3 p. m. great quantities of vapor were rising on the floor of Halemaumau and numerous small avalanches were falling from the north wall at the west end of the big sill.

December 13. Southwesterly wind with rain and thunder continued. From 10:30 to 11 a. m. the pit cleared only rarely. Avalanches at the north and west were heard three or four times in a half hour. The bottom was all covered with lines of steam tails mixed with blue fume in spots. The southeast sulphate bank appeared red and muddy. The avalanche of the preceding day appeared to have stripped the wall at about the blue fume locality west of the gulch above the west horn of the north intrusive. The columnar face of this north sill appeared wet with the beating of the southerly rain showing that it had cooled down since June. There was snow on the mountains below the 10,000-foot level.

At 10:05 p. m. there was an avalanche rumble followed by a dust cloud at Halemaumau and the same thing happened again six minutes later. About 11:21 p. m. there was another avalanche roar for more than ten seconds.

December 14. At 11 a. m. the weather was clearing after rain, slides occurred at the north corner of the pit and there was abundant steam. As the blue-edged steam jets rose from the bottom the steam dissipated, leaving

the blue fume rising visibly. The slides this day were from the east side of the north gulch. An earthquake was felt about 10:11 p. m.

December 15. At 2 p. m. there were small slides at the north and west. There was much less steam on the bottom. The clear view obtained this day of the north wall showed that a segment over 1000 feet long had fallen from the upper wall in the big avalanches of December 12 and thereafter. The north flag station had gone in. The protuberance that had created the north gulch on the west side of the west horn of the north sill had largely fallen away. The most remarkable happening was the entire disappearance of the blue fume oozing out of the upper part of the wall which had been conspicuous here ever since the May collapse. Not a trace of the fume was left even in the steam at the base of the wall. Where the fume had been the wall was stained yellow and green and appeared decomposed, but what had become of the smoke vent was a mystery. It appeared exactly as though the source of the smoke had been a chemical reaction in local material. The only other explanation was that some unseen vent extended from the hot north sill had furnished the smoke or that it rose from the foot of the cliff and the new talus had effectually blocked the orifice there. The avalanche in that case would have stripped off the entire vent mechanism and buried it.

December 16. At 11:15 a. m. it was evident that a big avalanche had fallen from the northeast corner of the pit, for the wall had peeled off in the neighborhood of the red body above the east end of the north sill and the talus below was fresh and brown. The dust clouds from the avalanche had powdered brown the east half of the bottom lava and the south talus. Slides were observed falling at the northeast, north and southwest corners and there was possibly some slight blowing noise. A stained patch vigorously steaming was observed in the wall on the south side of the western red boss.

At 10:20 p. m. a long avalanche roar was heard from the pit.

December 18. At 10 a. m. after a windy night with rain and southwest-erly gale the pit was full of steam. No slides were heard nor indicated on the seismogram.

December 19. At 10 a. m. there was partial clearing, much steam rose from the bottom of the pit and a few slides fell at the north corner.

December 20. From 10 to 12 a. m. steam was less obstructive to seeing and fresh talus debris was observed at the north corner. Slides occurred there and some falls of rock at the northwest. The walls of the pit were wet except at the west boss and at the north sill. The east side of the lava floor also was partially dry.

Visits were made to the 1920 chasm and Mauna Iki on this day. The trig station near the chasm had been marked with an iron pipe braced with wire, and the May ash falls, mud rains and accompanying phenomena had torn down and rusted the galvanized iron stake and supports. At the south end of Kilauea large shallow ponds of rain water stood in the depressions filled with the finer ash.

At Mauna Iki intense heat was found at orifices in one of the large rusty red areas on the west side of the top of the hill. There was no sulphur stain, no odor, and no visible steam or fume. A stick put in a two-inch crack was charred, and caught fire when so slightly withdrawn that the oxygen of the air and the draft of the wind passed the charred portion. Pieces that fell in the crack flamed inside showing that there was plenty of oxygen for combustion there. The place was a few paces west of the summit pit. The rock was burnt looking, brittle rusty lava of ochreous appearance and the hottest places were somewhat darker red than the rest. The oxidized area was about 50 feet across. There are several such areas on Mauna Iki where

the air above may be seen dancing with the heat. It is as though the hill were glowing inside, and a blast of air rose through it keeping certain orifices oxidizing, as though a catalytic action were maintained by the iron oxides in the presence of some unknown gas.

December 22. At 4 p. m. the pit was very still, the only motion of sliding rock occurring once at the north. There was dense steam with some sulphur fume at the south talus. Yellow sulphur was seen at a hot vent in the talus steaming at the east edge of the lava floor. The long talus southwest appeared to be growing in height. The pinnacle standing out from the south rim of the pit was still intact.

December 23. There was light snow on the mountains and southerly wind. At 10:13 a. m. a moderate avalanche was observed at the north niche, another at 10:15 at the northeast and a third at the north at 10:50. The north wall was evidently working. There was dense steam in the center and at the west and south. Yellow-green stain was observed along the line of steam vents around the frontal lobe of the landslide terrace on the bottom. The western wall was also working and a very slight pattering of falling rocks was heard almost all the time at the west side of the southwest talus. Up and down the middle of this talus there was a line of dense steam jets and thinner vapor arose along its edges. Comparing the figure of a man seen on the opposite side of the cliff with one of the largest boulders on the north side of the bottom of the pit, it was estimated that the boulder was from 18 to 20 feet long. The odor of hydrogen sulphide from Halemaumau was perceived at the Observatory.

December 24. At 11 a. m. there were small but continuous avalanches from the north wall. There was no trace of blue fume from that wall.

December 26. At 5 p. m. there was very little sliding. A considerable deposit of white sulphates stained all the wall around the spot where the blue fume had formerly been above the west end of the north sill.

December 27. There were several small avalanches and the larger ones were recorded by the seismograph.

December 28. At 10 a. m. small avalanches were nearly continuous from the north wall and a faint sulphur odor was detectable along cracks at the north-northwest rim of the pit.

December 29. At 2:30 p. m. it was evident that there had been more peeling away of the north wall of the pit so that fresh rock was exposed extending three-quarters of the way from the north corner of the pit to the east end of the north sill. The north talus had been built up in a wide band so that its top now rested against the lower part of the north sill. There was much sulfataric stain on the high north and northeast walls and the bank at the base of the southeast wall was conspicuously yellow.

December 30. During the forenoon after 9:30 a.m. there were occasional slides at the north, dense steam rose at the west pocket and always during this period there was abundant steam puffing up through wide cracks back from the rim at the west corner of the pit.

A circuit of the pit was made. A big freshly broken segment of the rim on the north side was cracked and had settled. In one of the cracks a cavern 15 feet in diameter and descending at an angle of 30 degrees was revealed by caving. The interior did not show glazed linings. A slope of tumbled debris formed its bottom, its roof and sides being greatly fractured. All of this breaking and caving was back of where the wall had recently peeled and over the north sill.

Along the northwest side of the pit there were chasms parallel to the edge 30 to 50 feet back, some of them steaming. No blue smoke could be detected in the north wall. The smoking place had been stripped off by avalanching and where the smoke formerly was white with sulphates.

At 8:50 p. m. an earthquake was felt with a swaying motion east and west, and at the same moment a pheasant was heard squawking, just as noted by Omori.

December 31. At 11:15 a. m. there was a noisy avalanche and others less strong thereafter. The day was dry with northeast wind and there was less steam on the bottom of the pit. Much dust was blowing on the Kilauea floor and in the Kau Desert.

The Kau Desert chasm of 1920 was visited and it was observed that the 1924 ash had greatly thinned in that vicinity owing to rain wash and wind, so that only a thickness of from 6 to 8 inches was found. The rain pools had dried up leaving ripple marks in the mud, and coarse rill markings appeared in the ash on the southern slope of Kilauea.

SEISMOMETRIC RECORD

During the month ended midnight December 31, 1924, 169 local earthquakes and two teleseisms were registered at the Observatory. These and other earth movements are exhibited below. Time is Hawaiian Standard, 10 h. 30 m. slower than Greenwich.

Abbreviations have meanings as follows: Vf=very feeble; f=feeble; s=slight; m=moderate; d=instrument dismantled; fl=felt locally; Δ=in-dicated distance to origin in miles; and a=peculiar type of tremor that builds up gradually without phases, continues longer and with lesser amplitude than ordinary local earthquakes of similar intensity. There is a close correlation between these tremors and the occurrence of avalanches at Halemauau.

Local Earthquakes

December	December	December
2—a 1:05 a. m. vf.	7—a 12:22 a. m. vf.	9—a 11:16 p. m. vf.
a 5:24 a. m. vf.	a 12:45 a. m. vf.	10—a 12:51 a. m. vf.
a 9:28 p. m. vf.	a 1:52 a. m. vf.	a 4:31 a. m. vf.
3—a 12:11 a. m. vf.	a 2:06 a. m. vf.	a 11:34 a. m. vf.
a 1:17 a. m. vf.	a 4:16 a. m. vf.	a 11:08 p. m. vf.
a 2:43 a. m. vf.	a 10:50 a. m. vf.	a 11:11 p. m. vf.
a 10:31 a. m. vf.	a 1:07 p. m. vf.	11—a 3:18 a. m. vf.
a 3:43 p. m. vf.	a 5:13 p. m. vf.	a 3:21 a. m. vf.
a 8:40 a. m. vf.	a 6:40 p. m. vf.	a 3:26 a. m. vf.
4— 7:57 a. m. vf.	a 9:03 p. m. vf.	a 3:30 a. m. vf.
a 6:22 p. m. vf.	9:38 p. m. vf.	a 3:35 a. m. vf.
6:25 p. m. vf.	8—a 7:09 a. m. vf.	a 4:20 a. m. vf.
5— 8:49 a. m. SΔ11	a 7:10 a. m. vf.	a 4:57 a. m. vf.
Felt at Mountain	a 7:11 a. m. vf.	a 5:12 a. m. vf.
View.	a 7:48 a. m. vf.	a 5:29 a. m. vf.
4:10 p. m. vf.	a 7:48 p. m. vf.	a 5:44 a. m. vf.
a 5:32 p. m. vf.	9:08 p. m. vf. Δ ²	a 6:06 a. m. vf.
a 5:33 p. m. vf.	9—a 2:11 a. m. vf.	a 6:09 a. m. vf.
a 11:36 p. m. vf.	a 4:32 a. m. vf.	a 6:42 a. m. vf.
6—a 4:54 a. m. vf.	a 8:09 a. m. vf.	a 9:32 a. m. vf.
a 5:47 p. m. vf.	a 12:32 p. m. vf.	a 11:44 a. m. vf.
7—a 12:06 a. m. vf.	a 12:33 p. m. vf.	a 3:42 p. m. vf.
a 12:07 a. m. vf.	6:09 p. m. vf.	a 8:01 p. m. vf.

December

- 12—a 12:17 a. m. vf.
- a 12:22 p. m. s.
- a 12:23 p. m. f.
- a 12:28 p. m. vf.
- a 12:57 p. m. f.
- a 3:38 p. m. vf.
- a 5:26 p. m. f.
- a 8:54 p. m. vf.
- a 10:09 p. m. vf.
- 13—a 12:16 a. m. vf.
- a 1:12 a. m. vf.
- a 2:28 a. m. vf.
- a 2:37 a. m. vf.
- a 3:32 a. m. vf.
- a 2:40 p. m. vf.
- a 10:29 p. m. vf.
- 14—a 10:27 a. m. vf.
- 10:11 p. m. m,fl,d.
- a 10:48 p. m. vf.
- 15—a 3:07 a. m. vf.
- a 4:03 a. m. vf.
- 9:10 a. m. vf.
- a 11:08 a. m. vf.
- a 9:54 p. m. vf.
- 16—a 5:13 a. m. vf.
- a 10:11 p. m. vf.
- a 10:13 p. m. vf.
- a 10:59 p. m. vf.
- a 11:14 p. m. vf.
- 17— 1:30 p. m. vf.
- 18— 6:07 a. m. vf.
- 9:43 a. m. vf.
- 19— 2:50 a. m. vf.
- a 6:34 a. m. vf.
- a 2:14 p. m. vf.

December

- 19—a 6:30 p. m. vf.
- a 7:11 p. m. vf.
- a 7:15 p. m. vf.
- 20—a 12:13 a. m. vf.
- a 12:15 p. m. vf.
- lasts 3 min.
- 20—a 2:51 a. m. vf.
- a 4:53 a. m. vf.
- a 5:55 a. m. vf.
- a 11:42 a. m. vf.
- 21—a 8:58 a. m. vf.
- a 3:17 p. m. vf.
- 4:02 p. m. vf.
- 22—a 10:54 a. m. vf.
- a 11:02 a. m. vf.
- a 11:55 a. m. vf.
- a 1:32 p. m. vf.
- a 7:35 p. m. vf.
- 11:52 p. m. vf.
- 23—a 6:01 a. m. vf.
- a 6:19 a. m. vf.
- a 2:34 p. m. vf.
- a 3:59 p. m. vf.
- a 5:38 p. m. vf.
- a 5:49 p. m. f.
- 5:54 p. m. vf.
- a 6:21 p. m. vf.
- a 8:44 p. m. vf.
- 24—a 12:01 a. m. vf.
- 4:11 a. m. vf.
- 9:21 a. m. vf.
- 9:46 a. m. vf.
- 11:04 a. m. vf.
- 1:46 p. m. vf.
- 11:30 p. m. vf.

December

- 25—a 1:29 a. m. vf.
- a 1:26 p. m. vf.
- 10:52 p. m. s,fl,Δ1
- 26—a 8:05 a. m. vf.
- a 10:02 a. m. vf.
- a 7:10 a. m. vf.
- 27—a 1:48 a. m. vf.
- a 1:17 p. m. vf.
- a 1:18 p. m. vf.
- 4:54 p. m. vf.
- a 4:56 p. m. vf.
- 4:59 p. m. vf.
- 7:29 p. m. vf.
- a 10:31 p. m. vf.
- 28—a 1:13 a. m. vf.
- 4:55 a. m. vf.
- a 9:45 a. m. vf.
- 1:37 p. m. vf.
- a 3:13 p. m. vf.
- a 5:37 p. m. vf.
- a 5:39 p. m. vf.
- 5:43 p. m. vf.
- a 8:30 p. m. vf.
- 9:28 p. m. vf.
- 29—a 11:04 a. m. vf.
- a 1:51 p. m. vf.
- 30— 1:04 a. m. vf.
- a 9:31 a. m. vf.
- a 9:44 a. m. vf.
- a 7:20 p. m. vf.
- 8:51 p. m. s,fl,Δ3
- 31—a 2:27 p. m. vf.
- 2:28 p. m. vf.

Teleseisms

- Dec. 27..... 1:01 a. m. slight.
- 28.....12:34 p. m. slight.

Harmonic Microtremor

This type of tremor was absent in December.

Microseismic Motion

The amplitude of microseisms was moderate from December 11 to 14th inclusive and slight on other days.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

- Nov. 30-Dec. 6.....0.9 second ENE
- 7-13.....3.5 seconds S
- 14-20.....0.7 second S
- 21-27.....1.3 seconds S
- Dec. 28-Jan. 3.....4.4 seconds NNE.

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