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WEATHER BUREAU
CHARLES F. MARVIN, CHIEF

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OF THE
Hawaiian Volcano Observatory

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HONOLULU, HAWAII, JANUARY, 1922

No. 1

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VOLCANIC CONDITIONS IN JANUARY.

Activity of Halemaumau.

The new year found the lava in Halemaumau pit essentially stationary, with a pattern of crags and lakes much like the illustrations in Bulletin of August, 1921. The lava column then rose slowly. The liquid pools were covered with crust and preserved their outlines with very little change. There was some hissing and snapping when gas accumulated under crust. About January 2 there was a spell of increased fountaining when fifteen open splashing blow-holes were counted, and some of the lava fountains were building small grottoes with sputtering and puffing. Fine views were had from the southeast side, the fume was thin, and occasionally the crust broke up and made a brilliant display. At the end of the first week in January the number of fountains diminished, and the glow became dull over the frozen pools, these events being signs of rising lava. A newly uplifted peninsula changed the form of the western arm of the lake.

The two southwest rift wells were sending up hot transparent gas and lining their walls with red dust brought up from below; sometimes the rush of gas was strong enough to blow out small pebbles.

By the middle of January the liquid lava in the fire-pit stood 335 feet below the rim, with daily fluctuations. The fume was thin and the floor and vari-colored walls of the great cauldron could be seen plainly. The bottom area was picturesque with mountainous crags reaching heights of 125 feet above the pools in the valleys. From five to ten fiery fountains were always in evidence, two or three of them in the east pond where the crust often cracked up and revealed an expanse of liquid melt. Occasionally the liquid overflowed the banks of the west and southwest pools, and encroached on the marginal talus slopes.

The southwest oven cone contained visible liquid lava far down its well, and the rift tunnel leading to the wells was sometimes brilliantly lighted at night when the crust broke up on the lava pool at its entrance.

By the third week in the month the rate of rising had increased from one foot per day to two feet per day, and the lakes were 315 feet down, maintaining a sluggish activity. There were some brilliant displays at night, when the pools broke up their crusted surfaces and a flood of seething molten matter illumined the fume cloud above. This was followed by consolidation of the surface, and sometimes the pit became dark, with only four or five blow-holes where lava fountains were spitting. There were recurrent spells of increased gas pressure, with formation of blowing and flaming cones on the banks of the lakes. The highest crag rose bodily 25 feet in twenty-one days, and on January 23 this peak stood 193 feet below the rim. The rising had as yet made little show, as it affected chiefly the hard lava benches and crags, and relative to these the lakes appeared lower. The interior landscape of isolated pools and crooked lakes amid rocky debris slopes and precipitous red crags was now in plain view day and night. The southwest rift wells were now blowing less and glowing more.

The upward pressure of the lava, wedged within the rift crack or fault that crosses the pit from southwest to northeast, had disturbed the rim, so that about January 6 the northeast surveying station had fallen in, and much of the edge of Halemaumau on that side had caved away. Other changes in the upper margin had taken place on the west side.

At the end of the month the lakes were stationary 312 feet below the rim. Crags were rising very slowly. The liquid lava spurted slightly and overflowed the floors January 24, but most of the time the pools were covered with crust, and sometimes only three or four fountaining pots in cone-shaped cups were all that could be seen of the glowing melt.

The fume frequently became thin. Movement of the crags among the pools produced from their flanks noisy avalanches. Some of the reddish slopes encircling the floor area were being buried under extending coves and flows from the lava lakes, as though a new ring-pool might soon surround the great cluster of crag masses. A small central island was rising bodily 40 feet high above the principal lake. The noises were hissings, plashings and the occasional crash of falling stones. The platforms constituting the lake margins were rising most in the center of the pit, so that the radial arms of the lake showed shorelines lower towards the outer circumference.

The rising movement made the cavern at the southwest margin of the floor area appear lower, for the liquid pool inside it was coming up. Over the interior of this cavern lay the open rift wells sending up very hot gas; these might be approached to within a few feet, and the well nearer to Halemaumau was surmounted by an oven half-dome lined with lava stalactites.

JOURNAL.

December 31, 1921. At 2 p. m. the fume within Halemaumau pit was moderately thin and the entire floor was visible. The central pool was heavily crusted. Seven fountaining areas were in action. Near southwest pool a gas-vent hissed loudly, but elsewhere there was little noise. The lakes were surrounded by platform banks about ten feet high.

January 2, 1922. The lakes were now 335 feet below the datum station on rim of pit and the south crag peak stood 117 feet above lake level. At 4 p. m. fume was thin, there was some hissing, and fifteen fountains were in action. There was splashing and puffing at small border grottoes. From the southwest side a fine view of the whole pit was obtained. Cracking and foundering of crusts was observed.

January 4. At 3:30 p. m. the lakes were crusted, only eight fountains were seen, and hissing occurred where gas accumulated under crusts. The crusts were snapping.

January 6. The glow at night was dull, but a brilliant breaking up occurred at 1 a. m. At 11 a. m. activity was as before. The southwest bay of main lake had joined the west cove in a hook along base of west wall of pit; the west island had risen and tipped north, joining across the channel which formerly led radially from central lake to west cove. There were numerous reports of avalanches from the northeast wall, and the northeast surveying station, on ground remnant from the 1919 activity, was found to have fallen in, leaving the rim of pit on that side farther back by about ten feet of width for perhaps 100 feet of length.

January 10. At 10 a. m. fume was thin and five fountaining patches were in action. Three of these were in east pond, there was one in central lake and a spatter grotto was being built up at the end of southeast arm. Several times the crust was seen to break up on the west pond. There was one hissing gas vent at west pond, and several near east pond. The lake level appeared about one foot lower than the overflow level of the last stream that had invaded the base of the talus.

January 11. At 11 a. m. gas hissing was louder. The east pond showed more activity of fountaining and breaking up of crust than the other pools. There was one fountain at end of southeast arm and one in west pond, while four were usually playing in east pond. The pool at southwest rift tunnel opening in the pit wall showed molten lava, and red hot lava could be seen down the well of rift oven.

January 12. At 9 a. m. gas hissing had decreased. All the lakes showed crusts occasionally cracking and foundering. Six fountains were counted, two of them in east pond, where cracking and foundering was most persistent. A small pond remained in the midst of the north crag jumble. Out of southwest rift cavern a recent lava flow had poured into the southwest arm of the lake.

January 13. At 11 a. m. the east lake was 340 feet below rim and the central lake 331 feet. The northwest crag stood 110 and the south crag 129 feet above central lake. Fume was thicker and the liquid lava appeared to be a foot or two lower. On the previous afternoon there had been some lava flooding along the base of southwest talus slopes. Small avalanches were seen to fall from northwest wall of pit and from east crag mass. There were six fountains in the pit, three of them in the east pond, where break-ups were frequent.

January 15. At 3 p. m. the liquid lava appeared two or three feet lower than on the 13th. Seven fountaining patches were counted, the east pond was the most active, and the general situation was unchanged.

January 17. At 11 a. m. the liquid lava appeared higher and gas hissing was noticeable. Four fountains were seen. A general breakup was seen to spread rapidly over the main lake region, beginning in southeast arm pool and spreading to central, southwest and west cove pools. East pond remained open and active as before. A spatter rampart of March, 1921, which had been a conspicuous hump in rim of pit at the old west niche locality, was observed to have fallen in.

January 21. At 4 p. m. there were seven puffing pots in the crusted lakes. The west cove was now a separate pool. The ridge of debris which had lain across mouth of southwest rift cavern inside Halemaumau was now not more than 50 feet above the fill below. The east pond showed high walls around its cup. A bright fountain was in action in the extreme northern cove, north of the north tower crag. Cracking and foundering of crust were observed in the southwest bay. Central island was now a large mass standing high. There were flaming cones on the platform bordering southeast arm. At the bottom of rift oven-well, about 150 feet down, a glowing crack in hot lava could be seen. The lower rift well was blowing less noisily than before and emitting stronger gas.

January 23. At 11 a. m. measurements made west pond 306 feet, southeast arm 313 feet, and east pond 319 feet below rim of pit (northeast datum level), showing as usual that the source well of highest upbuilding was at the west and the sinkhole of lowest drainage at the east.

Lakes were quiet and crusted, with four fountaining areas. The liquid lava had been overflowing the banks of lakes, invading the talus north and south of the southwest bay and of the east pond respectively, and pushing all along the wall opposite west pond. A new puddle had formed in southeast wall-crack. A little puffing was heard and some heavy snapping. Cracking and foundering took place in east and west ponds. A crack had developed athwart the middle of central island, and sulphur stain appeared at numerous blowing cones. An elongate peninsula of floor uptilted to the northwest now separated the central lake from the west cove pond. The fill of the rift cavern was apparently a cove of the southwest bay.

There was a shore bench on the wall side of the east pond, immediately under the place where the rim had fallen in near northeast station. The old cone in the central valley was smoking. Dribble overflows had piled into the talus at southeast end of southeast arm, and there was dribble lava heaped all around southwest side of south peak. There was still much of the October veneer and shelf left clinging on the walls of Halemaumau. Hot transparent gas was rising noiselessly from the two southwest rift wells.

January 24. At noon the fume was very thin, there were hissing noises, and the lakes appeared to be rising. A puddle of live lava at the southwest bay was sending out flows over the crusted area on all sides. The crusts of north cove and east pond were cracking and foundering. Spatter cones were active about southwest bay. Five fountains were counted, three of them in the east pond. The western and northwestern overflows were trickling over the foot of the talus.

January 26. At 4 p. m. the cups around the lakes were four feet deep. Six open puddles were seen, only two of which were fountaining. The west cove pond was again a hooked cove attached to southwest bay.

January 28. At 10 a. m. measurements showed that the lava column was rising but slowly, there were only four fountains, and the noises were of hissing and plashing. The central island was 40 feet high and motion was indicated by a fall of rock from the south end of the east central crag mass. There were two cone pots at the edge of west cove pond, and one each at southeast arm and at west pond. The bank on east side of southeast arm showed progressive uplift increasing from south to north as though the southeast crag were being uplifted and sliding on the fault-plane of the east central valley. Further evidence of this was a crack in new lava across the wall valley southward, in line with the upraised bank. Similar movement with maximum uplift toward center of pit, was shown by the west side of the south crag sector, where the bank was three feet high at central lake and only one foot high at southwest bay. Other such movements had been pronounced at northwest peninsula as part of the block north of southwest arm, where the whole sector was tilted northwest.

A ledge of the west crag had been rising and fresh tumble lay at its base; there was new fallen rock also on northwest slopes of the southern crags. A fountain broke out in a small spatter grotto at southwest bay. The roof of rift tunnel was low and fresh debris lay on the floor beneath it. There was a freshly-broken face on the north side of the central island. Fresh driblet and festoon flows covered floor areas at the west. The northeast region was a tumbled mass of crags, floors and debris. The crag bluff east of central lake showed large broken faces of red rock.

January 30. At 9:30 a. m. there was fresh flow lava submerging the debris of the southeast wall crack. Four fountains were counted. The pool of the southwest bay was flush with its edge and the east pond one foot below its edge. Steady hissing was heard. It was evident that liquid lava was engulfing wall-crack debris.

January 31. At 2:30 p. m. signs of rising were evident. There was strong overflowing of banks of lakes everywhere into talus and along the wall-crack. With southwest wind after rain, blue fume was coming up both rift wells. Fume from pit was thin and the whole bottom area was visible, only two or three fountains being in action. Glowing floods poured from southeast arm to the wall-crack; northward and southward from the east pond; from the west pools to the talus, the west cove and west pond being connected, and the southwest bay flooding level with the pool in rift cavern and showing no outline. There was overflow from the north cove across the northwest peninsula. The bases of all the crags were slightly submerged. Gas was hissing through cracks.

LAVA MEASUREMENTS.

Measurements of depression of the mobile lava column, referred to north-east station on rim of Halemaumau pit (3727 feet above sea-level), for the month ending January 31, 1922, including crag peaks of bench magma and mean liquid level of lake magma, were as follows:

	Mean lake level	South crag	Northwest crag
Dec. 26, 4 p. m.....	344 feet	225 feet	...
Jan. 2, 4 p. m.....	335 "	218 "	...
" 13, 11 a. m.....	335 "	202 "	221 feet
" 23, 11 a. m.....	313 "	193 "	207 "
" 24, 12 noon.....	312 "	192 "	205 "
" 28, 10 a. m.....	310 "	189 "	202 "
" 30, 10 a. m.....	312 "	189 "	...

Progressive changes were as follows for the liquid lava:

Dec. 26—Jan. 2, 7 days, lake rose 9 feet, averaging per day.....	+1.3 ft.
Jan. 2-13, 11 days, lake stationary, averaging per day.....	0.0 "
Jan. 13-24, 11 days, lake rose 23 feet, averaging per day.....	+2.1 "
Jan. 24-30, 6 days, lake stationary, averaging per day.....	0.0 "

Progressive fluctuation in level of south crag summit was as follows:

Dec. 26—Jan. 2, 7 days, crag rose 7 feet, averaging per day.....	+1.0 ft.
Jan. 2-13 .....11 days, crag rose 16 feet, averaging per day.....	+1.5 "
Jan. 13-24.....11 days, crag rose 10 feet, averaging per day.....	+0.9 "
Jan. 24-30..... 6 days, crag rose 3 feet, averaging per day.....	+0.5 "

Northwest crag summit moved as follows:

Dec. 21—Jan. 13, 23 days, crag rose 20 feet, averaging per day....	+0.9 ft.
Jan. 13-24.....11 days, crag rose 16 feet averaging per day....	+1.5 "
Jan. 24-28 4 days, crag rose 3 feet, averaging per day....	+0.7 "

Relief of peaks above lake was as follows:

Dec. 21.....south crag	123 feet,	northwest crag	94 feet
Dec. 26	" "	119 "	" "
Jan. 2	" "	117 "	" "
Jan. 13	" "	133 "	" 114 feet
Jan. 24	" "	120 "	" 107 "
Jan. 30	" "	123 "	" 108 " (Jan. 28)

The following table shows comparative monthly changes of level for mean lake lava and mean crag lava beginning with July, 1921:

July	liquid lava	— 22 feet,	bench lava	— 14 feet
August	" "	+119 "	" "	+118 "
September	" "	+138 "	" "	+158 "
October	" "	—259 "	" "	—253 "
November	" "	— 18 "	" "	— 21 "
December	" "	+ 16 "	" "	+ 18 "
January	" "	+ 25 "	" "	+ 29 "

SEISMOMETRIC RECORD.

During the month ending midnight January 31, 1922, thirty-six local earthquakes and seven distant shocks were registered at the observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W, 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

January	1....	4:25 a. m.	Very feeble.
"	1....	1:14 p. m.	Feeble, distance 16 miles.
"	2....	6:22 a. m.	Feeble, azimuth SE-NW.
"	4....	8:21 a. m.	Very feeble, distance 9 miles.
"	5....	5:45 a. m.	Very feeble.
"	5....	6:45 a. m.	" "
"	5....	6:52 a. m.	" "
"	5....	7:11 a. m.	" "
"	5....	7:26 a. m.	Feeble.
"	5....	7:33 a. m.	Very feeble.
"	8....	12:31 a. m.	" "
"	8....	4:18 a. m.	" "
"	8....	8:06 a. m.	" "
"	11....	10:14 p. m.	Feeble.
"	11....	10:17 p. m.	Very feeble.
"	14....	10:14 p. m.	" "
"	16....	8:11 a. m.	" "

January	16....	7:49 p.m.	Feeble.
"	17....	2:32 a.m.	"
"	17....	5:57 a.m.	Very feeble.
"	17....	6:30 a.m.	" "
"	18....	5:17 a.m.	" "
"	19....	6:02 p.m.	" "
"	19....	6:21 p.m.	Feeble, distance 12 miles, felt on east slope of Mauna Loa.
"	20....	7:22 p.m.	Very feeble.
"	21....	7:53 p.m.	" "
"	22....	4:07 a.m.	" "
"	22....	6:16 p.m.	" "
"	24....	6:32 a.m.	" "
"	24....	11:34 p.m.	" "
"	25....	5:53 p.m.	" "
"	26....	8:35 a.m.	Slight, distance 40 miles, felt in Kohala.
"	26....	10:23 p.m.	Very feeble.
"	27....	12:52 a.m.	" "
"	30....	12:21 a.m.	" "
"	31....	12:20 a.m.	" "

Teleseisms.

January	1,	9:30 a.m.	Moderate.
"	4,	10:00 p.m.	Very slight.
"	16,	5:53 p.m.	Moderate, distance 2300 miles.
"	21,	5:06 p.m.	Moderate.
"	22,	8:44 a.m.	"
"	25,	11:04 p.m.	"
"	31,	2:54 a.m.	Strong, distance 2800 miles.

Spasmodic Microtremor.

This type of tremor, by weeks, beginning December 31, was registered as follows:

Dec. 31—Jan. 6.	Slight to moderate.
Jan. 7-13.	Moderate to slight.
Jan. 14-20.	Slight.
Jan. 21-27.	Slight to moderate.
Jan. 28—Feb. 3.	Slight.

Harmonic Microtremor.

This type of tremor was very slight.

Microseismic Motion.

Amplitude of microseisms was as follows:

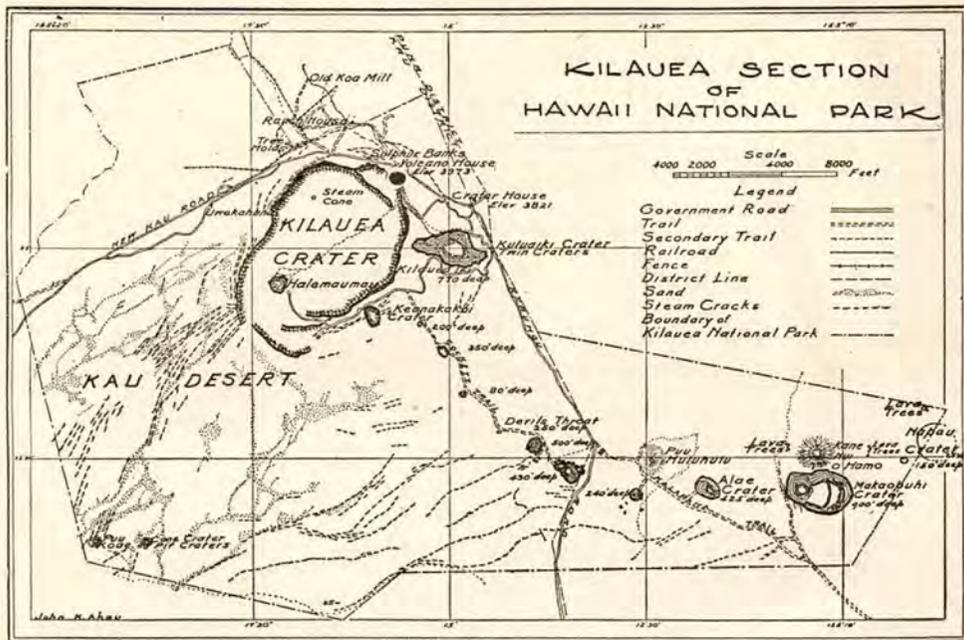
Dec. 31—Jan. 6.	Slight.
Jan. 7-13.	"
Jan. 14-20.	"
Jan. 21-27.	Slight, some increase January 27.
Jan. 27—Feb. 3.	Slight.

Tilting of the Ground.

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

Dec. 31—Jan. 6.	3.2	seconds S.
Jan. 7-13.	1.9	" NW.
Jan. 14-20.	1.9	" SSE.
Jan. 21-27.	3.1	" NNE.
Jan. 28—Feb. 3.	3.2	" SSW.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges should be addressed to

HAWAIIAN VOLCANO OBSERVATORY,

Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismometric instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of local earthquakes; one optically recording seismograph for distant earthquakes; one clinograph registering E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete piers in a closed basement room having practically constant temperature, beneath the chief Observatory building near the hotel. Time is referred to a rated chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. $19^{\circ} 25' 54.2''$ N.; Long. $155^{\circ} 15' 39.2''$ W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun," a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Sword (*Argyroxiphium*). Thirteen volcanic cones lie wholly within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvelously beautiful.

Wailuku is the point of departure, automobiles taking the traveler to Olinda, a summer residence settlement 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of $3\frac{1}{2}$ hours. Here is a fine concrete rest house, built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa, a vast dome 13,675 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bril-

liantly colored lava slopes, has a summit crater 3 miles long by $1\frac{1}{2}$ miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jetted 500 feet into the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaii National Park, if not in the world. The pit of fire, Halemaumau, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overridden by the lava slopes of Mauna Loa on the west, so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solfataras and a strange desert where lava flows have poured out of cracks as recently as 1920.

The live pit of Halemaumau is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvelous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory, which stands on the brink of the greater crater within the Kilauea Park.

U. S. DEPARTMENT OF AGRICULTURE
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GENERAL MAP, KILAUEA NATIONAL PARK.

VOLCANIC CONDITIONS IN FEBRUARY.

Activity of Halemaumau.

The end of January at Halemaumau pit showed a rising lava column, chiefly characterized by trickling and oozing liquid lava depressed about 300 feet below the rim when the month of February opened. The rise of the liquid portion was followed during the first week of the month by a corresponding lift of the craggy hills and islands which lay among the crusted lakes. The rising movement was slow, one or two feet per day, and the gas pressure was confined largely to expanding and lifting the lava column, so that there were visible only four or five fountains at a time, playing at the borders of crusted lava pools.

January 31 had been a day of strongly rising liquid lava, so that the platforms bordering the lakes were obliterated, and glowing floods streamed over the talus heaps around the margins of the circular floor area. The crags stood as island masses in the flood, and their former bases were submerged. Only two fountains were visible. The fume was excessively thin so that the whole interior of Halemaumau was plainly visible.

After that the new border channels and the main lakes became heavily crusted, lava puddings oozed through cracks, jostlings of the rising crag masses shook the walls of the pit so as to dislodge some loose rock, and hissing cones formed on the frozen surfaces of the lakes.

Sheets of white steam, occasioned by heavy rainfall, rose from the 1919 and 1921 flows on the floor of Kilauea crater, and the rift wells southwest of Halemaumau sent up hot steamy gas.

During the second week of the month slow rising continued, the crags and lakes alternating in their gains of higher level. The liquid lava reached a stand 290 feet below rim of pit and the tallest crag stood 110 feet higher. Four or five fountains were commonly in sight, the lakes overflowed the platforms, and occasionally the pit became brilliant when the entire crust of one or more of the lakes broke up and sank. Hissing of gas through crust was audible. The rift wells of March, 1921, remained hot.

The third week was characterized by thin fume and good seeing at the pit, and the crags and shore benches were being lifted more in the center of the pit than elsewhere, and more than the liquid lakes. The highest peak came up sixteen feet in ten days, the lava lakes rising one-half as much.

During this rapid lift of the crag peaks there were avalanches. Then the lakes took a spurt, overflowed the benches, and added width to a ring of crusted lava pools around the margin of the floor area. The lakes mostly remained quiet, with small flames at cracks in the crust. Quick breaking-up spells occurred, however, from time to time.

Down the hot rift well live lava could now be seen. There was still red heat to be seen in cracks along the north rim of Halemaumau, where there is new lava dating from March, 1921.

An earthquake was felt strongly all over the island of Hawaii about 8 a. m. February 21. Avalanches of rock fell from the high bluff west of Kilauea.

Gradual rising continued in the fire-pit. February 22 the lava lakes had been rising more than two feet per day and were 275 feet below rim of pit. The highest crag was 116 feet above lake level, and the crags had been slower than the lakes in their rising.

The lakes were now crusted roundish pools or coves mostly level with platforms of overflow adjacent to their margins. Ordinarily five fountaining places could be counted. Some central islands had risen and split open, standing seven feet above the lake. There was much hissing and flaming of gas, and fresh overflows around the lake margins showed festooned skins in some places, and lumpy dribble forms in others. Rusty rock fragments lay where they had been jarred off the walls by the earthquake, and occasionally falling rocks were seen. Great cracks formed where the crag matter was in motion.

JOURNAL.

February 2. After a heavy rainstorm lasting several days, sheets of white steamy vapor were rising from the 1919 and 1921 flows, notably along the edges of the flow areas.

At 3 p. m. the liquid lava in Halemaumau appeared to be still rising, though not much change was observed in the crags. Flooding had connected the east pond and southeast arm along the wall-valley, entirely burying the talus. The southeast arm had overflowed and submerged its banks. There were three fountains in east pond and one in west pond. On the crust of southwest bay were hissing cones. The small south peak was nearly surrounded by pools. Pahoehoe lava was oozing up through cracks in the crusted lakes. The rift cavern was low and the rift wells remained hot with blue fume rising. Glow over pit was dull at night.

February 4. Rain and steaming continued. At 2 p. m. extensions of the trickle flows on the floors were noticed. There were two fountains in east pond, one in west pond, and a fountaining pot was active at southwest edge of south-

east arm. The east and west ponds showed tendency to form border benches. New falls of rock lay under southeast and southwest bluffs of pit rim. Hot gas rose from the rift wells and fume was thin.

February 7. At 11 a.m. the mean liquid level was 295 feet below rim and the south crag was 113 feet high above the lava lake at its base. The liquid lava had been extending the flooding of the platforms. Six fountains were in action. Flaming cones were hissing, a large one standing on west side of west cove pool. The central island appeared higher. Fresh lava was visible inside the rift cavern. A new northern pool had been created by extension of the west pond along the northwest wall-valley. Five terraces of uplift were now discernible on the northwest crag mass along the eastern side of the west pond. The east pond had extended itself north and south. The ground was upheaved and cracked in the northern and northeastern regions. Fume was very thin and the rift wells were scorching hot, depositing pale yellow flaky sublimates. Except during occasional breaking-up spells, the glow at night was dull.

February 9. The lake was now rising two feet per day and the south crag one foot per day. At 10 a.m. the central island was found to have collapsed toward the southeast leaving only a small ridge a few feet above the lake. The lakes were higher and nearly flush with their banks. New festooned flows were trickling and adding to the annular floor along the wall-valley. The longest stretches of this wall depression still occupied by talus were on the northeast and southwest sides of pit. Five fountains were seen, all in the east pond and southeast arm. Some new talus had fallen near the rift cavern southwest.

February 11. At 9 a.m. fume was thin and an avalanche was seen to fall from east crag mass. Another avalanche at 9:19 a.m. fell from the Kilauea wall northwest of Halemaumau. A small overflow from east pond poured towards the south. The crags appeared lifting relative to the liquid lava, and notably so in the center. The new northern pool had collapsed. There were no central fountains, and five border fountains were building spatter ramparts.

February 12. At 2 p.m. the liquid lava appeared rising faster than the crags. There were recent overflows southward from southwest arm and east pond. A vigorous overflow from the west arm pond was in process of extending itself toward the rift tunnel. A trickling flow appeared to originate in the wall-crack just north of the rift tunnel. Noise of gas hissing had increased.

February 14. Fume was now very thin over the pit, notably so on the 13th. At 9 a.m. the 14th there was found evidence of considerable flooding along the base of all the walls. Crust cracked and foundered rapidly in central lake leaving a peninsula extending out from the south crag about one foot high. Entrance to rift tunnel was smaller by reason of the filling from below. Remains of central island showed uplift away from center toward the east. The filling along the wall-crack had left three pools along the north and northwest sides of the pit.

At 10 p.m. live lava could be seen in the depths of the rift oven well making a faint glow on the walls above. In the pit many small flames issued from cracks in crust and vents on banks of lakes. There was a continuous fountain in the central lake and four fountains in action in east pond. In the northern fill some red heat appeared in the cracks but the pools had distinctly crusted and cooled off.

February 15. At 9 p.m. lakes were crusted except where fountains played along northeast border of east pond. There was little fume. Some gas hissing was heard. A fountain broke out at the west base of east crag mass. Glow appeared in the north pool region and under the northeast wall of pit. Fume at rift wells was thin and very hot.

February 17. At noon lakes were 287 feet below rim and had been rising less than a foot a day, whereas the bench magma had risen twice as fast. Now, however, lakes appeared high within their cups, and east pond was overflowing towards the north and fresh overflows toward base of walls were numerous.

There were four or five fountains in all. There was a small islet opposite south crag mass in central lake, and a peninsula protruded from east crag mass. South crag had tilted over until its south face was steeply inclined, and the southwest bay was extended into the region of southern wall-crack talus. Southwest rift tunnel was now low. A large flow filling that followed the north wall-valley had been extending itself westward into the west pond from a source at the north pool.

February 18. At 10:30 a. m. the pit was very quiet and the air clear. Trickle overflows were creeping from the east pond. The islet in central lake was now connected to south crag mass. The border fill was everywhere widening. The lakes were crusted but a rapid break-up was seen in the west pond. The rift wells were very hot and making a mild blowing noise, their interiors covered with pale yellow-green coatings.

February 19. At 5 p. m. cracking and foundering of crust was seen at both ends of the east pond, there was much hissing from under crusts, fountaining was confined mostly to the east and west ponds, and ordinarily only five fountains could be counted. Lakes were high within their banks and gradual rising continued. The central island remnants had been rising and the piece adjacent to east crag mass had split along a north-south line. The two peninsulas were now 7 feet high.

February 21. About 8 a. m. there was a strongly felt and prolonged earthquake making avalanches at both north and south ends of Uwekahuna Bluff. The northern slide was noisy.

February 22. At noon the central, west and southeast lakes were all flush with their banks and the east pond one foot below its bank. Festsions of fresh overflow lay at southeast end of southeast arm, six border fountains were seen to break out at east pond. New dribble flows had poured from the southwest bay. A fountaining grotto was in action at west pond. The southeast wall-pool was freshly filled and hissing noises were heard. New talus lay at the base of east wall of the pit, and rock falls were heard at the northeast. The west crag fragment was surrounded by new floor matter. Southwest rift cavern was about 7 feet high. Fault cracks due to uplift of the crags extended from their faces east and west of the southeast arm southeastward across the wall-valley fill. The southeast crag appeared to be lifting independently of the east central crag mass along a fault fissure following the valley between the two crags.

Measurements now showed that the lakes had been rising between two and three feet per day and the crags only half as fast. This alternation from week to week in speed of rising of crags and lakes is a persistent habit of Halemaumau.

February 25. At noon only two fountains were in action, gas was hissing through cracks in crust and lakes were nearly flush with their marginal platforms. Spells of breaking-up of crusts were frequent. In the evening the illumination from pit was dull. Rift wells were sending up hot gas as usual.

February 27. At 4:30 p. m. lakes were overflowing their banks and the fill along the wall-valley had joined through from southwest bay to southeast arm. Fresh glowing pools lay along the west and south walls. Two fountains played in the east pond and a small vent in the southwest floor emitted a flowing stream. The east pond was overflowing northward. Southwest rift wells were hotter, their interior coatings changing from yellow to brown.

February 28. From 9 to 11 p. m. Halemaumau was quiet with one fountain in west pond and several in east pond. Cracking and foundering spells occurred in east pond and southeast arm. The border fills were covered with glowing cracks, some of which were hissing. Fume was rather thicker than it had been. In the rift oven dark cherry red glow was visible, but only at night.

LAVA MEASUREMENTS.

Measurements of depression of the mobile lava column, made with transit, referred to northeast station on rim of Halemaumau pit (3727 feet above sea-

level), for the month ending February 28, 1922, including crag peaks of bench magma, and mean liquid level of lake magma, were as follows:

	Mean Lake Level	South Crag	Northwest Crag
Jan. 30, 10 a. m.....	312 feet	189 feet	202 feet (Jan. 28)
Feb. 7, 11 a. m.....	295 "	182 "	...
" 9, 10 a. m.....	290 "	180 "	...
" 14, 9 a. m.....	295 "	170 "	190 "
" 17, 12 noon.....	287 "	166 "	182 "
" 22, 12 noon.....	275 "	159 "	173 "
Mar. 3, 11 a. m.....	259 "	143 "	155 "

Progressive changes were as follows for the liquid lava:

Jan. 30-Feb. 9	10 days, lake rose 22 feet, averaging per day	+2.2 feet.
Feb. 9-17	8 " " " 3 " " " "	+0.4 "
Feb. 17-22	5 " " " 12 " " " "	+2.4 "
Feb. 22-Mar. 3	9 " " " 16 " " " "	+1.8 "

Progressive fluctuation in level of south crag summit was as follows:

Jan. 30-Feb. 9	10 days, crag rose 9 feet, averaging per day	+0.9 feet.
Feb. 9-17	8 " " " 14 " " " "	+1.7 "
Feb. 17-22	5 " " " 7 " " " "	+1.4 "
Feb. 22-Mar. 3	9 " " " 16 " " " "	+1.8 "

Fluctuation of northwest crag summit was as follows:

Jan. 28-Feb. 14,	17 days, crag rose 12 feet, averaging per day	+0.7 feet.
Feb. 14-17	3 " " " 8 " " " "	+2.7 "
Feb. 17-22	5 " " " 9 " " " "	+1.8 "
Feb. 22-Mar. 3	9 " " " 18 " " " "	+2.0 "

Relief of peaks above lake was as follows:

Jan. 30	south crag 123 feet	(Jan. 28) northwest crag..	108 feet
Feb. 7	" " 113 "	" " "	" "
" 9	" " 110 "	" " "	" "
" 14	" " 125 "	" " "	.. 105 "
" 17	" " 121 "	" " "	.. 105 "
" 22	" " 116 "	" " "	.. 102 "
Mar. 3	" " 116 "	" " "	.. 104 "

The following table shows comparative monthly changes of level for mean lake lava and mean crag lava beginning with July, 1921:

July	liquid lava - 22 feet, bench lava - 14 feet
August	" " +119 " " " +118 "
September ..	" " +138 " " " +158 "
October	" " -259 " " " -253 "
November ...	" " - 18 " " " - 21 "
December ...	" " + 16 " " " + 18 "
January	" " + 25 " " " + 29 "
February	" " + 40 " " " + 40 "

SEISMOMETRIC RECORD.

During the month ending midnight February 28, 1922, 20 local earthquakes and no distant quakes were registered at the observatory. These and other

earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W., 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

February	1	....	3:40	p. m.	Very feeble.
"	3	....	12:33	a. m.	Slight, distance 18 miles, azimuth SW-NE.
"	4	....	7:06	a. m.	Very feeble.
"	6	....	3:19	p. m.	Very feeble.
"	8	....	8:28	a. m.	Very feeble.
"	10	....	11:38	a. m.	Very feeble.
"	12	....	11:09	a. m.	Very feeble.
"	12	....	4:48	p. m.	Very feeble.
"	13	....	2:11	a. m.	Very feeble.
"	14	....	10:14	a. m.	Very feeble.
"	14	....	1:45	p. m.	Very feeble.
"	16	....	5:15	p. m.	Very feeble.
"	17	....	10:46	p. m.	Very feeble.
"	19	....	4:26	a. m.	Very feeble.
"	21	....	7:55	a. m.	Moderate, distance 20 miles, azimuth WNW-ESE. Felt over E half of Hawaii.
"	21	....	2:56	p. m.	Slight, distance 20 miles. Felt locally.
"	21	....	6:00	p. m.	Feeble.
"	21	....	6:58	p. m.	Very feeble.
"	22	....	1:11	a. m.	Very feeble.
"	24	....	10:21	p. m.	Very feeble.
"	26	....	4:33	a. m.	Very feeble.

Spasmodic Microtremor.

This type of tremor, by weeks, beginning February 4, was registered as follows:

February	4-10	.....	Slight.
"	11-17	.....	Slight.
"	18-24	.....	Slight.
"	25-March 3	.....	Moderate.

Harmonic Microtremor.

This type of tremor was very slight.

Microseismic Motion.

Amplitude of microseisms was as follows:

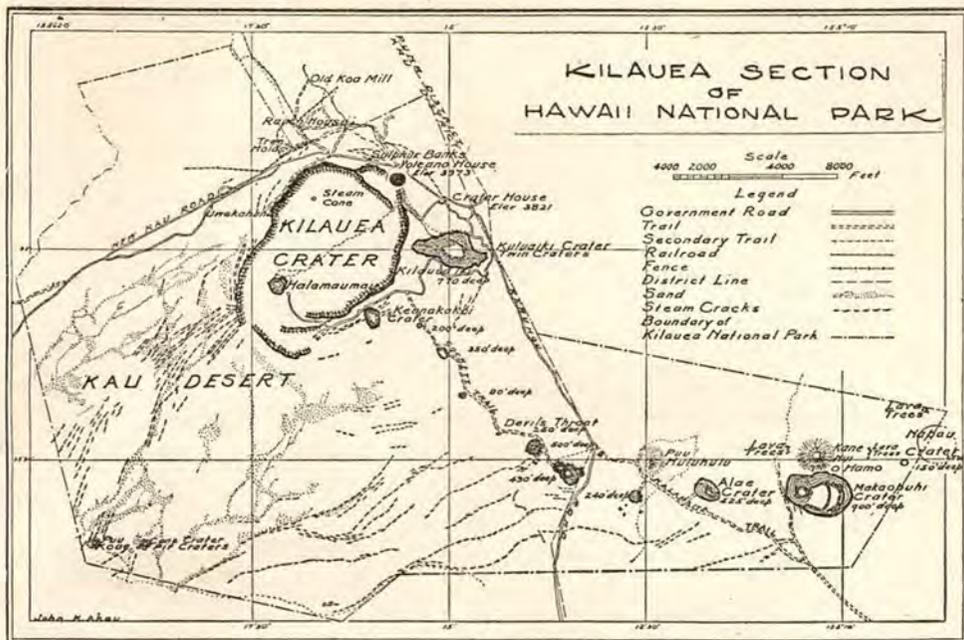
Slight until the 26th and moderate thereafter.

Tilting of the Ground.

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

February	4-10	.....	1.3	seconds	NNE.
"	11-17	.....	4.5	"	SW.
"	18-24	.....	0.8	"	SE.
"	25-March 3	.....	1.2	"	NE.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges should be addressed to

HAWAIIAN VOLCANO OBSERVATORY,

Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismometric instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of local earthquakes; one optically recording seismograph for distant earthquakes; one clinograph registering E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete piers in a closed basement room having practically constant temperature, beneath the chief Observatory building near the hotel. Time is referred to a rated chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. 19° 25' 54.2" N.; Long. 155° 15' 39.2" W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun," a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Sword (*Argyroxiphium*). Thirteen volcanic cones lie wholly within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvelously beautiful.

Wailuku is the point of departure, automobiles taking the traveler to Olinda, a summer residence settlement 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of 3 1/2 hours. Here is a fine concrete rest house, built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa, a vast dome 13,675 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bril-

liantly colored lava slopes, has a summit crater 3 miles long by 1 1/2 miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jettied 500 feet into the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaii National Park, if not in the world. The pit of fire, Halemauau, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overridden by the lava slopes of Mauna Loa on the west, so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solfataras and a strange desert where lava flows have poured out of cracks as recently as 1920.

The live pit of Halemauau is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvelous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory, which stands on the brink of the greater crater within the Kilauea Park.

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, CHIEF

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GENERAL MAP, KILAUEA NATIONAL PARK.

VOLCANIC CONDITIONS IN MARCH.

Activity of Halemaumau.

The first week in March showed the rising lava in Halemaumau pit about 260 feet down and increasing its rate of uplift as equinox approached. Two crag peaks standing among others as conspicuous landmarks between the lava lakes stood above the liquid respectively 104 and 116 feet. As these were part of the live lava column, rising simultaneously as a whole with the fluid lava, it will be seen that the highest point of the column was only 143 feet below rim of pit.

The main marks of activity were overflows of the pools across border benches so as to fill in the marginal valley between the bunch of crags and wall of pit. This had created border pools of still, crusted, live lava that every now and then broke up with spectacular effect. Fountains were few, but the number had increased from two to eight between February 25 and March 5. The fume from pit had become excessively thin.

The tunnel at southwest rift in wall-rock of pit, and inside the pit at base of wall, was now nearly obliterated by the risen lava. The wells leading down to this tunnel outside the pit were seen at night to be glowing and sending up very hot gas.

In the second week of the month the lava lakes rose 12 feet and the sharp steeple of the northwestern crag rose 15 feet, the crag standing 104 feet above the liquid and the latter 247 feet below rim of pit. The number of splashing fountains had increased to ten or twelve, and occasionally some of the crusted lava pools would break up with rapidity and show strong effervescence, making a brilliant bubbling surface that lighted up the fume cloud at night. Small grottoes and flaming cones were forming at the lake edges. Lava welled up around the edges of the floor area and was flowing most of the time. Sometimes the lakes overflowed their banks, making trickle flows that resembled molten lead. In one place little grottoes formed in a line where gas was escaping at the edges of a pond, and these became evenly spaced.

Avalanches were common owing to the disturbance made by new fills of live lava all around the base of the pit wall, especially along the zone of the northeast-southwest rift that crosses the pit. The mouth of rift cavern leading from lake level into southwest wall of pit was now totally covered and in its place there was a fresh tumble of debris from the crumbling wall rock along the rift zone. Another fresh tumble lay on opposite side of pit. The two live rift wells glowed cherry red at night, and in daytime they were seen to be hung with brown stalactites and ejecting scorching hot gas.

The approach to equinox (March 20) was marked by increase of occasional fountaining and stronger rising from a rate of a foot and a half a day to four feet per day. The liquid lakes reached a depression of 217 feet, incessantly flooding their margins. The number of fountains varied from four to fifteen in action at one time, and blowing cones at edges of lakes replaced the fountains in some places. Here and there lava "gushers" were seen where a vent in crust at the edge of a pool vomited up the molten fiery fluid, the torrent flooding the stagnant border fills.

There were increasing spells of strong breaking-up of crust. These were spectacular, the movement spreading from one side of a lake to the other, and making a brilliant flare as the incandescent matter bubbled up from below. All the older debris slopes had been buried under the border floods. The crags rose almost as fast as the lakes, tipping back from the central region. The rift wells glowed brightly and sent up blue fume.

The rise continued past the equinox at 4 feet per day, the lakes reaching a level 189 feet below rim of pit. The liquid gained on the crags, the two highest standing about 100 feet above the live pools. Every detail of interior of pit was plainly seen, and the number of fountains in action varied from three to ten. Spells of breaking up of crust and sinking of slabs in the glowing melt became more frequent and spectacular, the whole situation strongly recalling the rising episode of the September equinox of 1921, and correspondingly suggesting a period of subsidence to follow. The flooding of the space around the margin of the pit became excessive March 25. Hot overflows of all the lakes created a wide ring pool of puddled glowing lava between the precipice bounding the pit and the cluster of crags in the center. A big cone with a pot full of splashing lava was formed at the base of the wall. Puffing spatter cones tended to form at the outer edges of the lakes where they overflowed. There was a curved fault valley full of tumbled red rocks athwart the eastern crag mass, and these masses were moving so rapidly that big avalanches fell from them. At the end of the month the liquid lava was only 175 feet down, and gas escaped with hissing noise through a few vents. The southwestern rift wells were now glowing brightly in daylight. The fifth perceptible earthquake felt during the month occurred during the early morning of March 27.

Discussion of Special Features.

The rise of lava in Halemaumau from December, 1921, to the March equinox of 1922 was similar to the rise that culminated at the September equinox of 1921, and both occasions produced similar scenes within the pit, the same general grouping of crag peaks and lakes, and the same welling up of liquid lava around the edges of the floor area. In the autumnal crisis the high level lasted past the middle of October and then was followed by strong subsidence. The vernal rising was destined to reach its maximum rate at the end of March, but to continue at decreasing rates, with some spurting, until May, when excessive subsidence occurred.

The gas action of this rising spell was singularly sluggish compared with the March culmination of 1921. Violent cauldron action was absent; slight cauldron effervescence occurred once or twice in the north pool, but almost no spatter grottoes formed, fountains were few, and the usual method of gas release was by swelling a crusted pool to the rupture point and then emitting the gas by gentle breaking up of crust, engulfment of the slabs, and short-lived bubbling.

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March 2. At 7:30 a. m. the pit was moderately fummy from vents at the northwest crag, the southern end of the east crag, and one in the northeast region. A trickling flow poured from the southeast arm toward wall of pit and central lake was heavily crusted. Entrance to rift tunnel southwest was now nearly filled. Heat at the rift wells was increasing.

March 3. Measurements now showed that the lakes were about 260 feet below rim and both lakes and crags were rising two feet per day. At 11 a. m. a small jet of dense fume was rising from a vent in broken rock at north end of east crag mass. There were four fountains, central lake remained crusted, and the liquid lava appeared no higher than on the previous day. There were frequent breakings-up of crust in southeast arm. A fountain in east pond was noisy.

March 4. At 7:30 a. m. fume over pit was notably thin in contrast to what it had been, and in spite of the presence of considerable floor vapor outside of pit.

March 5. This condition continued remarkably, for despite rainy weather the pit was quite free from fume. At 3:30 p. m. the liquid lava was flooding, nine pools were counted among the crags, and eight fountains were in action. A large wall-pool was in process of cracking and foundering on north-northwest side of pit. This process was observed in east pond also, which remained the most active of the lakes. Small blowing-cone grottoes had formed. The bench magma was rising more in the center than elsewhere, notably at the central island remnants. The floor of the eastern valley east of southeast arm had risen so as to make bench 10 feet high above that pool. Two small pools were observed in the north cove region and another between southeast arm and central lake. The southwest wall-valley had become a large floor flooded with flows from both east and west sides. The motion of south crag mass had produced fresh breaks on its face. The small south peak next west was nearly isolated by the floods. The only part of the ring valley that now remained tumbled and broken was at the northeast. Southwest rift tunnel was now a low arch about 5 feet high.

March 6. Rainy conditions and thin fume continued. There were trickling overflows from the lakes, some cracking and foundering occurred at the central lake, there was hissing noise and at 11 a. m. a cone broke into action with spurting lava flings at southeast end of southeast arm. The arch of rift tunnel was still more buried.

March 7. At 4 p. m. the lakes were generally and voluminously overflowing. The arch of southwest rift tunnel was now covered. Trickle flows were in motion on all the floors. There was high gas pressure arching the crusted pools and making hissing noise. The active spots were at seven fountains, two bright flowing streams, and numerous trickling toes. On the north and east sides of east pond five or six evenly spaced openings indicated where small fountains and bursts of gas tended to form a row of small grottoes. Floor of southeast wall-valley was arched up, and a new fill had welled along the wall-crack.

At 4:45 p. m. an avalanche fell from the east wall. There was much crushing action along the east central valley. Cracks had formed in north-eastern flat ground inside the pit where bench magma as a whole was swelling. Fume was thin and its odor was more acid to leeward. At southwest rift wells hot gas was rising, brown and yellow stalactites lined the walls, and matches would ignite when thrown into the openings.

March 8. At 8 p. m. purplish red light was visible in the two rift wells and the fume was acid with sulphurous gases. In the pit there were seven spurting and spraying vents at the edges of the crusted lakes. Along the wall-valley lay fresh glowing fills heavily crusted. Some slight cracking and foundering was observed. Flames were seen in crust cracks and the noises were of hissing and spraying.

March 11. At 11 a. m. the lakes were 247 feet below the rim. Ten fountains were in action, some of them forming small grottoes and border cones. A live dribbling fill of lead-colored pahoehoe followed the northwest wall-valley. A recent flow had welled up a crack in the arched floor of southeast wall-valley. The bench at lake border was progressively higher from southwest bay toward center of pit. The bank of east pond was two feet high on west side and overflowed by fresh lava on east side. Evidently the central crag matter was rising. This was shown also by the string of islets which now formed a continuous partition separating southeast arm from central lake, and extending from east central crag to south peak. Rather rapid spells of cracking and foundering were observed in west cove pool and southeast arm.

New talus heaps lay on floor of pit at southwest rift and in southeast wall-valley. Rocks were seen sliding from upper part of south pressure ridge along the pit rim, and another fall of rocks occurred at northwest side of south peak, the material tumbling into the lake.

After excessive rains on the Kilauea floor clouds of white vapor were concentrated over the 1919 and 1921 lava fields, indicating greater heat at those places. There was rain vapor also over the rift belt near the wells, but the wells themselves sent up transparent gas with a tinge of bluish fume condensing.

March 12. Lakes and crags were now rising over a foot and a half per day. At 11 a. m. seven fountains were in action and the banks of southeast arm and east pond were three feet high. Southwest arm and western ponds were brimming full on the wall side. Around base of wall of pit there was a fresh upwelling of dribble lava resembling molten lead, especially conspicuous southwest, west, northwest and north. A small open pool in the southeast arm showed bubble fountaining. There were fountains also in north cove pool. Fume had increased.

March 14. At 11 a. m. the end of southwest bay was found built up and overflowing the floor so as to flood the talus. From five to eight fountains were in action. Rapid cracking and foundering occurred in the central lake. The accumulation of new pahoehoe in the wall-crack formed a heap next to the wall all around the pit. A fresh flow from the east wall-crack had moved westward through southeast wall-valley. East pond had been overflowing all

its edges and was flush with its rim on all sides. Fresh overflows had poured west from west pond. North cove pond was fountaining.

All that was left of west crag now was a red rock 4 feet high. All three crag masses had been tilting up centrifugally. The southeast and south crag masses had both broken away from the floor bordering southeast arm along big crevasses. Northwest peninsula and the crag separating central lake from north cove pool had been lifted and tilted as a unit towards the northwest, along with the northwest crag mass. The group of small crags at the central island locality was now higher and formed a unit connecting south peak and east central crag mass. This last had been tilting eastward, but the southeast crag more so, so as to increase the jumble of fragments along east central valley.

Rocks were still sliding from the upper southeast pressure ridge, and much fresh talus lay on the floor of pit southeast and southwest.

March 16. At 5 p. m. there were two fountains in east pond and one each in southeast arm, west pond and north wall-pond. There had been recent flooding over most of the south floor. A gas vent at south margin of southeast arm was hissing loudly. There was some noise of escaping gas through cracks in crust at the place where rift tunnel had been submerged.

March 17. At 2 p. m. fifteen fountains were in action and a flow was in motion from southwest bay to wall of pit. Recent talus heaps were drowned under fresh lava. East pond had a line of spurting fountains at its edge and was overflowing. Central crags had lifted and a shelf had been raised along shore of southeast arm on south crag side.

A heavy rainstorm had produced notable clouds of vapor on the Mauna Iki flow heap in Kau Desert, where remnant heat from 1920 activity is strong. The same phenomenon was observed on the 1919 and 1921 flows in Kilauea crater.

March 18. Lakes and crags were now rising 3 to 4 feet per day and the lake level was 221 feet below rim of pit. At noon the bottom area was quiet with only four fountains in action, the others being replaced by hissing and flaming cones. Lakes were flush with their margins, trickle flows pushed through cracks and there was cracking and foundering in the southwest wall-valley fill. There were fresh deep fillings along this valley south and southeast. Blue fume was abundant. The glow was not yet perceptible by daylight in the rift wells, and the gas from the wells condensed to blue fume above. Some noise of an indefinite character could be heard in the southwestern wells.

March 19. At 11 a. m. four fountains and three cones were counted in the pit. A gushing cone at west edge of west cove pool sent a flow over the floor. Pahoehoe lava was trickling, the fills were snapping under the cooling strains of freshly chilled lava surfaces, and the wall-valley fills were obviously becoming wider. The west crag rock and all the southern talus heaps were now completely submerged. Cracks southwest of lower rift well were hot enough to burn paper; at the well a breathing noise could be heard.

March 21. Equinox was now passed, the general rapid rise continuing throughout the equinoxial season. On this day at 3 p. m. no important changes were observed. About ten fountains were in action, most numerous at east pond. There were some spurting fountains. Pahoehoe trickled around edges of floor. South crag surface was now a gigantic slab tipped up very steeply. Ponds were brimming full, live lava moved along the northeast wall-crack and the fills were growing wider.

March 22. The liquid lava was now 200 feet down and the crag peaks stood 100 feet higher. At 4 p. m. there were eight fountains in the pit, and a big cone had formed in the northeast wall-crack with lava splashing from a pot in its summit. Lakes were still overflowing into the wall-valley fill, the platform margins standing usually a foot or two high in the central region.

At 8:30 p. m. a smart rain shower was coincident with a strong breaking-up of crust at the pit, which produced bright flaring.

March 23. At 5 p.m. there was heavy rain making tails of steam all over floor of pit and a violent fountain was in action at the edge of southeast arm pool. There was loud hissing and the pit was full of vapor.

March 25. At 3 p.m. there were hot floods of lava at the edges of the floor on all sides of pit. Cracking and foundering of crust were seen to spread rapidly across southeast pool. A similar process progressed slowly eastward along south wall-valley fill. Six fountains were in action. The northeast cone had disappeared and was replaced by a hot glowing hole. The liquid lava had everywhere gained on the crags. Blowing cones had formed on the western sides of southwest arm, west cove pond and west pond. A small pot was open on the north side of north cove pool. All the pools were overflowing and the wall-valley had become a complete ring of flat lava outside of the group of craggy hills, recalling the condition of September 20, 1921. The air was very clear and free from fume.

March 26. At 10 a.m. the hot overflows of the previous day were found to have subsided, and their surfaces showed crusts which had sagged to a trough along the wall-crack. Three fountains were in action. An avalanche started rapid cracking and foundering at the west pond. At 10:50 a.m. an avalanche fell from the west side of northwest crag. Some fresh avalanche debris was observed at base of pit walls. Hissing was audible. The rising of the crag masses was now beginning to obstruct the view. A long tumbled valley full of broken rock followed the east central crag mass on the east and north sides, showing the line of motion whereby this mass had risen differently from the southeast crag.

March 27. At 3 p.m. there were fresh floods around the margin, about nine fountains were in action and rapid cracking and foundering were seen to spread across southeast arm. Three terraces had formed on the east side of this arm where the southeast crag had lifted and tilted eastward in stages. The southeast wall-valley was occupied by a flat sagging fill with a smooth surface that showed crack-and-founder pattern. It was evident that rising still continued.

March 29. At 9:30 a.m. the marginal floods appeared higher and only two fountains were in action. These were in the eastern pools. The south and southeast crags had risen and lifted with them the southeast bank of southeast arm pool, and the ground there was swollen and cracked. The bank around this pool was 5 feet high, whereas the western and eastern pools were flush with the flood level. Floods of lava had joined across from the west cove pool to the central lake, leaving an isolated crag north of the southwest arm. At 9:30 a.m. this arm was overflowing strongly and a fountain broke into action at the place of overflow.

There was considerable fume from the central crags, and fresh tumbles lay under the northwest and south crags. The northwest peak had lost its former summit. The central island and northwest peninsula were higher. The whole semicircle of crag matter east of the east valley had risen and tilted east. The east central crag had also risen and tilted east, but separate from the eastern crescent.

Purple red glow could be seen in daylight inside the southwest oven, and bright blue smoke rose from the wells.

March 30. At 4:30 p.m. there was heavy crust and seven fountains were counted, mostly pots in cones and border grottoes. Lava welled up cracks. The whole top of northwest crag had fallen and made a big talus. Fume had increased. Liquid overflows were seen at east pond, southeast arm and southwest arm. The southeast crag and crag north of southwest arm were encroached upon by flow lava. The cup of north cove pool had lifted, leaving a four-foot rim around the liquid. Both the rift walls were glowing, and the fume was brown against the western sun, but blue in reflected light.

March 31. In the evening a portion of the south crag cracked off and toppled northward into the central lake.

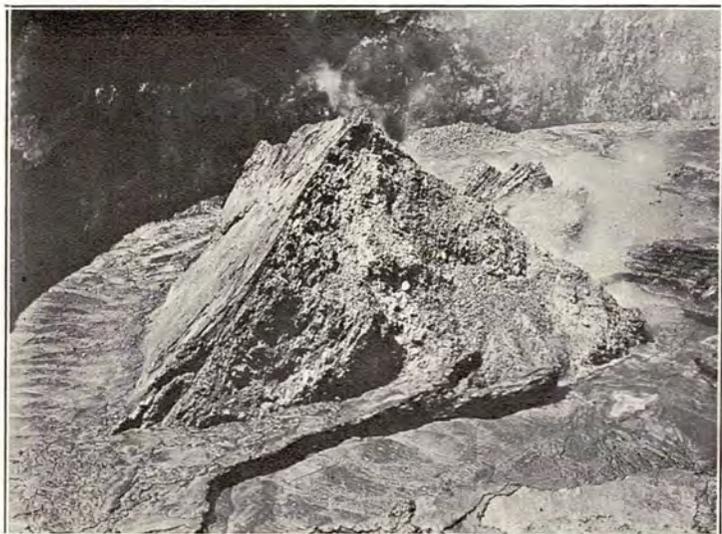


Fig. 1. March 12, 1922, Halemaumau looking west from southeast rim of pit. Shows southeast arm pool and south crag, the latter separated by wall-crack fill from wall of pit.



Fig. 2. March 26, 1922, Halemaumau looking south from north shelter. Shows northwest crag peak, west pond and wide wall-valley fill. Photos Jaggar.

LAVA MEASUREMENTS.

Measurements of depression of the mobile lava column, made with transit, referred to northeast station on rim of Halemaumau pit (3727 feet above sea-level), for the month ending March 31, 1922, including crag peaks of bench magma and mean liquid level of lake magma, were as follows:

	Mean Lake Level	South Crag	Northwest Crag
March 3, 11:00 a. m.....	259 feet	143 feet	155 feet
“ 11, 11:00 a. m.....	247 “	130 “	140 “
“ 18, 11:30 a. m.....	221 “	111 “	116 “
“ 22, 4:00 p. m.....	203 “	102 “	104 “
“ 26, 10:00 a. m.....	194 “	90 “	89 “
“ 29, 9:00 a. m.....	178 “	77 “	84 “

Progressive changes were as follows for the liquid lava:

March 3-11	8 days, lake rose	12 feet, averaging per day	+1.5 feet.
“ 11-18	7 “ “ “	26 “ “	+3.7 “
“ 18-22	4 “ “ “	18 “ “	+4.5 “
“ 22-29	7 “ “ “	25 “ “	+3.6 “

Progressive fluctuation in level of south crag summit was as follows:

March 3-11	8 days, crag rose	13 feet, averaging per day	+1.6 feet.
“ 11-18	7 “ “ “	19 “ “	+2.7 “
“ 18-22	4 “ “ “	9 “ “	+2.2 “
“ 22-29	7 “ “ “	25 “ “	+3.6 “

Fluctuation of northwest crag summit was as follows:

March 3-11	8 days, crag rose	15 feet, averaging per day	+1.9 feet.
“ 11-18	7 “ “ “	24 “ “	+3.4 “
“ 18-22	4 “ “ “	12 “ “	+3.0 “
“ 22-29	7 “ “ “	20 “ “	+2.9 “

Relief of peaks above lake was as follows:

March 3	south crag	116 feet,	northwest crag	104 feet
“ 11	“ “	117 “	“ “	107 “
“ 18	“ “	110 “	“ “	105 “
“ 22	“ “	101 “	“ “	99 “
“ 26	“ “	104 “	“ “	105 “
“ 29	“ “	101 “	“ “	94 “

The following table shows comparative monthly changes of level for mean lake lava and mean crag lava, beginning with July, 1921:

July	Liquid lava	- 22 feet,	bench lava	- 14 feet
August	“ “	+119 “	“ “	+118 “
September ..	“ “	+138 “	“ “	+158 “
October	“ “	-259 “	“ “	-253 “
November ..	“ “	- 18 “	“ “	- 21 “
December ..	“ “	+ 16 “	“ “	+ 18 “
January	“ “	+ 25 “	“ “	+ 29 “
February ...	“ “	+ 40 “	“ “	+ 40 “
March	“ “	+ 92 “	“ “	+ 80 “

SEISMOMETRIC RECORD.

During the month ending midnight March 31, 1922, seventeen local earthquakes and two distant shocks were recorded at the observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W, 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

March 5	.....	1:21 p. m.	Very feeble.
"	7	.....	5:12 p. m. Very feeble.
"	9	.....	2:33 p. m. Very feeble.
"	12	.....	11:47 a. m. Feeble.
		2:33 p. m.	Moderate, distance 20 miles, azimuth WNW-ESE. Felt locally and in Hilo. Dismantled instruments.
		4:55 p. m.	Slight, distance 20 miles.
		5:04 p. m.	Feeble.
		5:05 p. m.	Feeble.
"	15	.....	9:52 p. m. Very feeble.
"	16	.....	5:13 a. m. Very feeble.
"	17	.....	3:40 p. m. Slight. Felt in Hilo.
"	18	.....	11:22 a. m. Slight. Felt in Hilo.
"	25	.....	12:05 a. m. Very feeble.
"	26	.....	6:30 a. m. Very feeble.
		9:35 a. m.	Very feeble.
"	27	.....	3:24 a. m. Slight. Felt locally and in Hilo.
"	30	.....	7:06 a. m. Very feeble.

Teleseisms.

March 4	.....	2:40 a. m.	Slight.
"	9	.....	9:00 p. m. Slight.

Spasmodic Microtremor.

This type of tremor by weeks, beginning March 4, was registered as follows:

March 4-10	.....	Moderate, decreasing on March 7.	
"	11-17	.....	Slight, increasing on March 15.
"	18-24	.....	Slight.
"	25-31	.....	Slight.

Harmonic Microtremor.

This type of tremor was slight throughout the month with a maximum on the 8th.

Microseismic Motion.

Amplitude of microseisms was as follows:

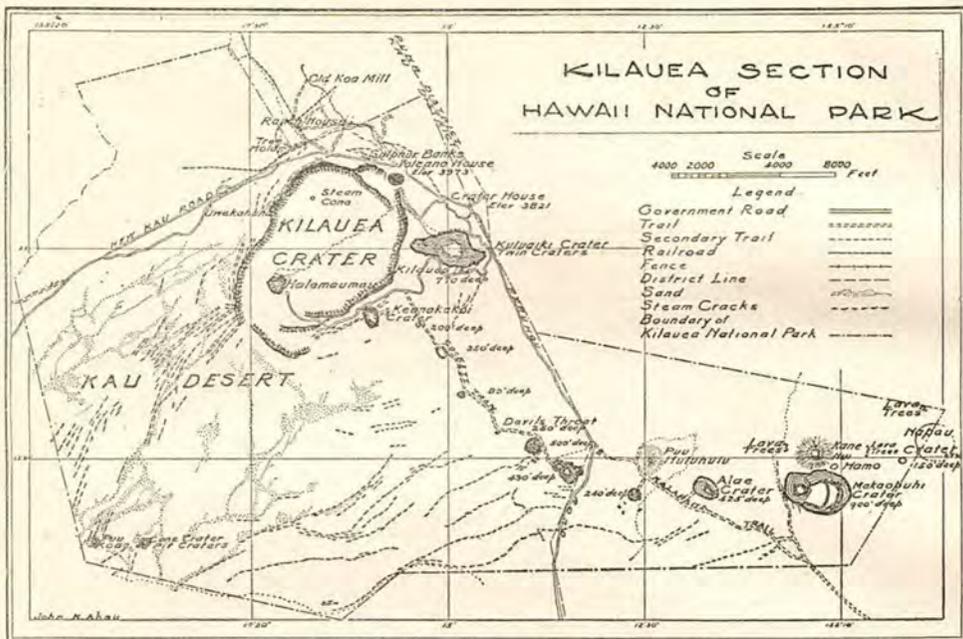
March 4-10	.....	Moderate.	
"	11-17	.....	Slight, with some increase March 15.
"	18-24	.....	Moderate.
"	25-31	.....	Moderate.

Tilting of the Ground.

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

March	4-10	.....	2.9	seconds	S.
"	11-17	.....	3.1	"	SSW.
"	18-24	.....	1.5	"	N.
"	25-31	.....	1.9	"	WSW.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges should be addressed to

HAWAIIAN VOLCANO OBSERVATORY,

Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismometric instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of local earthquakes; one optically recording seismograph for distant earthquakes; one clinograph registering E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete piers in a closed basement room having practically constant temperature, beneath the chief Observatory building near the hotel. Time is referred to a rated chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. 19° 25' 54.2" N.; Long. 155° 15' 39.2" W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun," a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Sword (*Argyroxiphium*). Thirteen volcanic cones lie wholly within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvelously beautiful.

Walluku is the point of departure, automobiles taking the traveler to Olinda, a summer residence settlement 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of 3½ hours. Here is a fine concrete rest house, built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa, a vast dome 13,675 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bril-

liantly colored lava slopes, has a summit crater 3 miles long by 1½ miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jettied 500 feet into the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaii National Park, if not in the world. The pit of fire, Halemaumau, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overridden by the lava slopes of Mauna Loa on the west, so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solifatares and a strange desert where lava flows have poured out of cracks as recently as 1920.

The live pit of Halemaumau is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvelous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory, which stands on the brink of the greater crater within the Kilauea Park.

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, CHIEF

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VOLCANO RESEARCH IN HAWAII, 1922.

By T. A. Jaggar.

Address at annual meeting of Hawaiian Volcano Research Association in
Honolulu, April 3; 1922.

Ten Years of Work Finished.

The Hawaiian Volcano Research Association was founded ten years ago. It is now an incorporated society devoted to scientific and educational work in this Territory. From the start the leading spirit, counsellor and friend of the society has been Lorrin A. Thurston. From the start it has been the privilege of the writer to be scientific director of the work of investigating, recording, compiling and experimenting, with the island of Hawaii, containing the volcanoes Kilauea and Mauna Loa, as a vast natural laboratory.

Ten years of work and of publication have determined critical discoveries and critical turning points. The discoveries need not be reviewed here except

as they affect plans for the future. They have shown that Mauna Loa is a prime center of activity sympathetic with Kilauea; that earthquakes cluster around the Mauna Loa center; that both mountains split open and throw out lava along definite rift lines; that gas is the dominant heating and impelling agent in eruptions; that the heat may even increase toward the surface through the burning of the gas and that the lavas may add to this heat by oxidizing in the air; that chemistry, therefore, is a vitally important science adjunct to volcanology; that tidal movements make the lava rise and fall systematically, day and night, spring and summer, decade and century; that these risings and fallings, heatings and coolings, tiltings and tremblings, all work together under inexorable law which gives new interest to the passage of time upon an active volcano, whether reckoned in seconds, minutes, days, months or years. Each of these units of time may be quite as important in revealing scientific discovery through the medium of an instrument actuated by delicate clockwork set up and anchored at one place, as any of those units of space made much of by the explorer or astronomer. Depths, distances and distributions are matters of interest in volcano study also. But it must not be forgotten that the ultimate aim of geology is earth history, and this, like human history, can be clearly deciphered only by studying minutely the history of the present.

Turning Points of Progress.

The critical turning points of progress in Hawaiian volcano research were (1) the proposal to have an observatory in 1909; (2) the gift of an observatory building by Hilo and of money by Honolulu and the Massachusetts Institute of Technology in 1912; (3) the publication of a regular bulletin after 1913; (4) the experiments, photographs, gas analyses, soundings, tide surveys and temperature measurements made possible by the great activity of the years 1916-21; (5) transfer of the observatory to United States Weather Bureau in 1919, and lastly the adoption of a new five-year program of experimental research by the Hawaiian Volcano Research Association in 1920.

The past decade has thus founded the keeping of a permanent record of volcanic activity in Hawaii by creating a government establishment for the purpose. It has started experiments investigating the depth, temperature, composition and viscosity of Hawaiian lavas in the field, and the earth motions which pass through the lands adjacent to those lavas. It has started a new experimental spirit in dealing with the origin and progress of the mountains, soils and shorelines of these mysterious and beautiful islands that from time immemorial have been slowly rising and falling in the midst of the world's greatest ocean. And in the train of this experimental adventure, entered into with such vigor and fine cordiality by the men and women of Hawaii, there has come a new influx of travellers, a revival of Polynesian exploration by the Bishop Museum, the creation of a great volcanic national park and a succession of international congresses called hither by the indomitable energy and vision of Mr. Alexander Hume Ford. The scientific congress of 1920 stimulated Pan-Pacific volcano research as never before and the new program of the Volcano Research Association was partly financed under that stimulus.

A Program For the Future.

This program supplements and expands the government work of the Hawaiian Volcano Observatory. Your members at home and abroad have provided special funds. Mr. P. G. Gates of Pasadena provided \$1000 wherewith to safeguard our records, and the people of Hilo so supplemented the gift that a serviceable iron and concrete office building is now in process of erection. Mr. John Brooks Henderson of Washington gave \$3000 towards boring experiments, and this fund has been raised to \$8000 by generous additional contribution from citizens and firms in Hawaii. Your directors have discussed six other subjects now in progress or to be given attention in the immediate future. They are (1) maintenance of auxiliary seismograph stations; (2)

securing the services of chemists; (3) publishing back records; (4) creating a volcano museum at Kilauea; (5) propagating the gospel of volcano observatories in other Pacific lands, and (6) building a station on the summit of Mauna Loa. The year 1921 produced from Hawaii a fund to create auxiliary earthquake recorders, and stations in the hands of paid observers are now equipped with instruments in Hilo, Kona and Hilea. Already most interesting seismograms or earth autographs have been written in different places on papers moved by clockwork, showing a great difference of intensity for the same quake on opposite sides of Hawaii. Kona on the west and the observatory on the east are registering the way the ground tips or tilts from hour to hour, and the study of these papers will yield new information about the swelling up and sinking down of Mauna Loa. To Dr. Arnold Romberg, professor of physics in the University of Hawaii, our Association owes a debt of gratitude for the devotion and skill he has put into the making of these instruments, built with his own hands in the shops of the university.

The Geophysical Laboratory of the Carnegie Institution has done much to help volcano research in Hawaii. Dr. E. S. Shepherd has prepared elaborate gas analyses for us, showing extraordinary results from collections made with vacuum tubes on Mauna Loa and Kilauea. Although collected in the midst of live flames these gases appear greatly burned, and water vapor is the principal product of the burning as though hydrogen were the principal gas of the flames. Dr. H. S. Washington has analyzed our rocks and salts, and has discovered rare minerals identical with some of the volcanic deposits of Italy, containing traces of copper. He is keenly interested in the project to make borings into Kilauea, and proposes to bring up, at a European scientific congress this coming summer, the question of boring into other volcanoes. Dr. A. L. Day, director of the Geophysical Laboratory, has enlisted the interest of the president of the Carnegie Institution, so that money has been allotted for sending a party of skilled chemists and spectroscope experts about September, 1922, the men selected being Dr. Babcock of the Mount Wilson Observatory and Drs. Allen and Zies of the Washington laboratory. This will go far towards solving some of our chemical problems at Hawaiian volcanoes. I am greatly indebted to Dr. Ripperton, chemist of the U. S. Department of Agriculture, for analyses of some of the solfataric deposits and cementing agents which form the crusts and white coatings on the ash beds of 1790.

Thus the new program provides a fireproof office for the archives, enlists the interest of chemists, harnesses Hawaii with delicate seismographs, and starts experiments dealing with underground heat, by drilling into the rock. The national park administration will take care of a better track up Mauna Loa and of a museum for tourists at Kilauea. The Research Association funds of next year and thereafter may be looked to for provision of attractive publication of results of the scientific work, and it is hoped an agency for financing volcano observatory propaganda will be found eventually. Today I want to harp on two strings—the drilling project and the station for Mauna Loa.

Drilling Project.

When Mr. Henderson handed me his cheque he said: "Use it for making a beginning in boring at Kilauea, do whatever will make for progress. We must start finding out about underground conditions at the volcano." This, then, is the keynote, to make a start, to experiment, to break ground in a new venture. The entire history of the past ten years has involved roughing out what needs elaborate treatment later, and one of the best achievements of your society has been the rough draft of a volcano observatory which you have written into the past decade of human history. You have rough hewn a monument that the American government has thought worthy of perpetuating.

The small sum of money available for first drillings into Hawaiian lava may do an interesting bit of pioneer work if we use it for path-breaking, and refrain from grandiloquent talk and intoxicating dreams. First of all, we want to know how hot the ground is. That means measurement of temperature

in fifty places at depths not exceeding 100 feet. It is not enough to take the temperature at surface cracks, for these are full of air, of many widths and at all angles to the wind. We must survey and map the temperature of the rock itself, and it cannot be sounded like a lava lake, for it is a hard solid. Borings a hundred feet deep in a land where cracks opened and poured out floods of hot lava one, two, three, four, six, eight and fifteen years ago are of fascinating interest. The result will be a lot of profile sections across crater and across rifts showing changes of temperature at each place 25, 50, 75 and 100 feet down, and changes of temperature across country at like depths a half-mile apart. The lava of 1919 filled one side of the big crater floor for a depth of 50 feet, and clouds of steam rise there every time it rains; possibly the rock is red hot 40 feet down, and cooler 60 feet down; or possibly the lava blanket has raised the temperature of the rock below. Experiment will give the answer. The Alika flow buried forests and made charcoal of the wood; the lava is not very thick and is still warm; a shallow core-drill boring will show the various substances and the thermometer will tell how hot it is. This is of especial interest because a substance resembling cannel coal was found among the lavas at Olaa mill in a well-boring 200 feet below sea-level.

Advantages of Shallow Boring.

If several shallow, small holes are secured by rapid and cheap drilling processes, they become assets of the observatory for repeated measurements of temperature in future years. Oxidation processes or gas action have been known to heat up certain cracks. It is possible that this might happen to artificial holes. Or some of the holes might show a seasonal or tidal heating and cooling. Or possibly the approach to a coming eruption might exhibit in the holes a rise of temperature. In short, the acquisition of this honeycomb into the top of the mountain will provide the scientific workers with an array of new knowledge similar to what we got in 1917 by thrusting steel pipes, thermometers and chemicals into the lava lakes. When I then wrote Dr. Day that we had struck lake bottom 40 feet down, he replied: "It is many long moons since anything so overwhelming as your recent letter has come into our atmosphere." That was the result of a very simple experiment. Boring a short distance down is also simple, whereas deep boring is complicated and expensive. Therefore, after two years of study of this question, I unhesitatingly recommend for a beginning shallow borings at many places, with temperature measurement as the main object.

Field Already Prepared

Let me say that the field is magnificently prepared for this work by the late volcanic history and the contour mapping recently done by Mr. Burkland and his associates of the U. S. Geological Survey. The great activity of both Mauna Loa and Kilauea in 1916, 1919 and thereafter has left a land plastered with fresh lava and rifted open along hot zones. These places have been newly mapped on a scale of two inches to the mile in 1921. On these maps the bore-hole sites may be laid off, and the nature of the country for moving the equipment and placing camps is all freshly studied by the survey workers. After we have determined the change of temperature of the ground at say five points on a line three miles long, across the Kau Desert rift that erupted in 1920, it will be keenly interesting to take temperatures at holes across the extension of that rift towards Pahala, farther south. In the same fashion we can eventually examine the underground temperature across the 1840 rift that extends eastward from Kilauea towards Kapoho, in Puna, or the great southern and north-eastern rift zones of Mauna Loa which trend respectively towards Kahuku and towards Hilo. Is there still heat underground in the 1881 flow back of Hilo? There certainly is in the mountain region at its source. Is there still heat underground in Hualalai and Haleakala? Borings may tell. Is there hot ground in the direction of Napoopoo, in Kona, where a submarine erup-

tion from Mauna Loa occurred in 1877? You will see from these questions that this boring proposition is concerned with geography and history, and that much may be learned without entering the field of deep drilling, always an expensive enterprise.

I am greatly indebted to engineers in Hawaii and to twenty manufacturers of machinery on the mainland, for advice concerning the possibilities of hammer, churn, rotary and core drilling in dealing with the peculiar rocks of a dry volcanic land. The experimental attack here suggested will reveal much concerning method as well as concerning scientific results. Each process involves new features, the working of the rock, transporting machines over lava, providing water and devising suitable thermometers. After three months of actual work with the aid of skilled drill runners we shall know much more about the whole subject than we do now, and the results attained by making a temperature map of the ground will show where it may be profitable to put down a few deeper holes to depths of several hundred feet. This subject, and the study of the rock by core-drilling, may be left to the teachings of experience.

Mauna Loa Station.

For some years past an extension has been discussed of the work of volcano research, along with study of the upper atmosphere, having in view continuous occupation of a station near the summit of Mauna Loa in the summer months, and some maintenance of self-recording instruments there even during the winter. The past decade has revealed the importance of Mauna Loa and has roughly outlined the nine-year cycle of eruptions wherein both Kilauea and Mauna Loa play a part. Of the earthquake movements on Mauna Loa we know nothing. A road up the mountain is now talked of, but, road or no road, we need shelter, fuel and water at the summit and an improved route up which a tractor or some such vehicle can pull supplies and instruments. To finish a road may take several years, and the next summit eruption is likely to occur in 1923 or 1924. The distress due to storms, cold and altitude, and the need for staying at the summit long enough to become acclimatized, make it imperative that a rough but passable track and a wooden camp be built at Mokuaweoweo soon if any scientific work is to be done there during the next outbreak.

Here again the experimental spirit is called for, and the sum of \$5000 would rough out a track and a summit camp. This would be the entering wedge for getting more travellers to the mountain, carrying in road supplies, making road labor less expensive, and easing the work of the United States topographers so as to get good maps promptly. This mapping should certainly be done in the summer of 1922. An outbreak is not likely to occur before midsummer of 1923, but thereafter it is possible winter or summer, with magnificent frothing, fiery fountains hundreds of feet in height.

The Nine-Year Interval.

When speaking of a nine-year interval it should be understood that an eruptive period is not a single event, but a succession of phases lasting years, and each phase is about nine years after the corresponding phase of the last eruptive period. Thus the first phase of the last period was at Mokuaweoweo, in November, 1914. A line of gigantic fountains spurted up through the floor of the summit crater, but no one saw the commencement. No one has ever seen a Mauna Loa eruption at the start, because the start is always at the summit region. We want to see the next one start and the only way to organize for it is to prepare a good trail, a house and suitable supplies at the summit. The preparation would be worth the \$5000 if only for the photographs and moving pictures that may be taken.

The apparatus that we shall set up on Mauna Loa includes earthquake recorders, meteorological instruments and thermometers for ground temperatures. The methods used at Kilauea may be usefully applied to prepare one or two bore-holes for continuous temperature measurements at the Mauna Loa

summit. It is possible to equip such holes with self-registering instruments that write the temperature changes automatically.

Road Improvement Needed.

I would be unfaithful to my trust in entering upon the second decade of volcanological work on Hawaii if I did not accent this need for added facilities upon Mauna Loa. The greatest and most voluminously productive active volcano on the globe, Mauna Loa, still defies the approach of science. The slopes of the mountain are easy grades, much of the lava is smooth and easily traversed, motor tractors have been used on Haleakala, and it is merely a matter of camping a few weeks on the mountain with a gang of trail-makers to build a rough track through to the summit which can be used for hauling in supplies. When this is done, the construction of a hut is easy. A local contractor has offered to improve the upper stretch of trail, from the Puu Ulaula house to the summit, for \$500. If this will make a good horse trail, then ten times the amount will widen the trail sufficiently to give passage to a tractor, and leave something over for a camp.

In conclusion I beg to express my keen personal aloha and gratitude to the members of this Association who have always been ready to give time and money to the cause of volcano research for ten years past. May I also express the appreciation of the Association for the way in which the United States Weather Bureau, through the Hon. Charles F. Marvin, has aided volcanologic progress in every way possible. And finally I want to thank Mr. Henderson and Mr. Gates for their substantial contributions to the progress of science in Hawaii.

PREPARATIONS FOR BORING EXPERIMENTS.

The Board of Directors of Hawaiian Volcano Research Association voted on April 6, 1922, to authorize the Volcanologist to proceed with experimental borings at Kilauea, as part of cooperative program of work done jointly by Association and Weather Bureau. Mr. A. H. Hobart was engaged as drill operator to furnish competent drillers, using an impact or "churn" drill for three months, beginning work in May. Furthermore a shot core drill was purchased for use after August 1. The plan of operations is set forth in the foregoing address, and in April it devolved upon the Observatory staff to complete surveys for location of wells to be bored, to arrange tractors and other devices for hauling water and machinery across lava fields, and to prepare a suitable water-supply and such rough roadways as were necessary. A large part of the expense and labor of such test borings in dry, hard volcanic country, without any water except that from rainfall and roof drainage into storage tanks, with no underground water supply expectable in the wells, and the rock a porous cracked lava incapable of holding water, consists in transportation and track-making.

Preliminary tests during the preceding year had shown (this Bulletin, Vol. IX, No. 5, p. 91), that a small motor car is capable of traveling over sands, gravels and pahoehoe lava surfaces of Kau Desert. Improvements suggested by experience were made by doubling each rear wheel and fitting a pair of wide non-skid pneumatic tires to each doublet; this gave to each rear driving roller eight inches of grooved rubber traction surface, including a small air space between each pair of wheels. The double wheels were made by bolting two ordinary wheels together with a wooden disc between. A rear axle planetary gear system was added, giving three extra low gear ratios in addition to the usual two forward speeds and one reverse. All unnecessary weight of fenders, steps and doors was removed, and at rear end of car was placed a drawbar and shackle and an extra heavy spring. This converted the car into a general utility vehicle for use both as tractor and conveyance for men and supplies, devised to travel over any ordinary rough lava or on the surface of deep gravels where a common truck would dig in and be stalled.

April 14 this car was tested on the rounded crisp pahoehoe flows which had poured out of Halemaumau across the roadway to the east in 1918 and 1919. From the road terminus to the edge of the pit the car climbed the foot trail without any trouble by means of the lowest gear (gear ratio 26:1). Another test was made across the 1921 flows in south bay of Kilauea crater, along the flow that had penetrated a gap in wall of crater, and thence to Kau Desert where a run was made for several miles, returning to Kilauea by a different route. There was no heating of engine and the car carrying three persons went over much deep sand and gravel.

A small caterpillar tractor was purchased as a power plant, and for hauling water and machinery. April 10 the traction of this machine was tested on a rocky road and found defective for such surfaces owing to side-slip due to rear steering and breakage due to impact of steel on stone. The tractor was remodeled and furnished with forward steering gear, wheels and rubber tires. Thereafter it was useful particularly for hauling sleds with water-barrels, for skidding irons over rough ground, for road haulage especially in narrow ways, and as a stationary engine.

During the month surveys were made to locate places desirable for drill holes. It was determined to place the first wells at Sulphur Bank flat near Volcano House where temperature is high, gases are interesting, and where water supply was kindly offered for use by the hotel company. The place of next interest is the floor of Kilauea crater, where there are recent flows dating from 1894, 1918, 1919, 1920 and 1921, of a variety of thicknesses and unknown temperatures. In order to give symmetry to the profile along which first boring-temperatures might be measured, in relation to the Kau Desert rift of 1920 and its extension northeast through Halemaumau, a point was located practically central for the greater crater and in line of the 1920 rift so extended. A line was now surveyed across the crater northwest-southeast at right angles to the rift azimuth, and three stations flagged respectively in center of crater and 3000 feet from center on each side along this line. The center of crater lies on a thin semi-aa flow of March 1921, 1800 feet northeast of Little Beggar cone. The first crater flag to be made accessible for boring was the one southeast of center, lying on 1894 lava midway between Keanakakoi crater and Center Flag.

April 20 a route was prospected from the Halemaumau road terminus toward Center Flag and the motor car was taken a half-mile. The ground was bad. A few days later a better route was found following southeast edge of Kilauea crater northward from Halemaumau roadway. This route followed contact of lava and gravel and then traversed smooth lava. April 25 and thereafter a volunteer crew of road builders was hired at Kilauea Military Camp and these soldiers under the direction of Mr. R. H. Finch, meteorologist at the Observatory, beat down a rough track in four days. This with subsequent improvements sufficed in June for hauling the drill rig in to the Southeast Flag. It was tested with motor car April 30.

VOLCANIC CONDITIONS IN APRIL.

Activity of Halemaumau.

At the beginning of April the lava in Halemaumau pit had been rising steadily for three weeks four or five feet per day, and at the end of the first week of the month stood 122 feet below the precipitous rim where visitors stand. The crags and portions of the crater floor had risen faster than the molten pools, the highest peak standing 117 feet above the liquid and only five feet below rim of pit. Two of the inner peaks came into the distant view from the Observatory during the afternoon of April 5.

Avalanches falling from the crags would sometimes strike a crusted lake, letting loose the gas below and starting rapid foundering of crust slabs while waves of fiery melt surged from bank to bank. Flooding of the floors was

often brilliant. Hissing of gas became noisy at times and the number of fountains simultaneously active was occasionally as low as two. The rise of the crag masses now prevented the seeing of the entire floor from any one point on the rim. The glowing rift wells southwest were emitting much fume.

By the middle of the month the liquid lava was less than 100 feet below the verge and the giant crags rose well above rim of pit. As seen from Uwekahuna Bluff the interior jumble of smoking craggy peaks was the most conspicuous feature of the lava column, the lakes appearing as floors between and around the rocky hills. Much of the time there was hardly any fountaining to be seen, but southwest of the center a large rhythmic dome fountain had developed with outbursts once a minute. Sometimes spurting fountains formed, flinging up incandescent spray.

The cluster of crags occupied the central region, split up by gorges occupied by the three arms of the lava lake, the peaks surmounting a platform of overflow which was swelling and cracking like a vast cake or pudding in its circular pan. All around the edges the curved surface sloped downward to a fissure next the wall of Halemaumau, and up the fissure rose thick liquid lava in trickling streams. Some of the ponds amid the crags had their entire cups lifted high by swelling action of the floor lava. The crags rose two to four feet per day, this being slower than before. The decrease in rate of rising checked with the decrease in numbers of fountains and both of these decrements occurred soon after the equinox. Also the outside rift over southwest was darkening at times, though still glowing when seen by evening light.

By the third week in April the main lava column of the fire pit was in full view of Volcano House settlement, all three of the great crag masses standing high above the rim. The liquid lava was 75 feet down at the level of October 1, 1921. The entire scene at the lava pit was almost a duplicate of the October condition. The central lava lake occupied a deep canyon amid the clustered crag peaks, with an open liquid pool near the middle where a big fountain was exploding regularly. All around the outside of the crag cluster there was an annular swollen floor of hot lava with many trickling streams and some oval ponds. These ponds when covered with crust resembled plateaux or plains raised above the surrounding slopes and falling off at the edges. There are similar features on the surface of the moon. Sometimes the crust on one of these pools broke up angrily with explosive violence, and big fountains of boiling orange-colored slag would play for several minutes while the hot melt spread out and engulfed the neighboring surface shells for several hundred feet. Then only could the definite outline of the pond be seen, for it would sink a little before the surface again cooled and hardened. The rate of rising of the whole lava column was diminishing, both crags and lakes gaining one or two feet a day. The rift oven had cooled greatly, the stalactites losing incandescence and turning brown and yellow, bearded with Pele's hair.

At the end of April the lakes and fields of crusted lava were 60 feet down and quite accessible to adventurous climbers. The cluster of crags formed a central rugged ring swollen above the general level of floor of pit, with peaks 100 or more feet above the lava lakes and considerably above the rim of pit.

The fountaining activity so increased that the pit was brighter at night, largely owing to the frequent cauldron action of the border pools when an explosive outrush of gas rent and engulfed their crusts. Out in the central lake there was continuous fountaining and inflation of the skin so that big balloons were lifted, torn, and so forced to collapse. Spatter cones formed in many places, seen flaming with burning gas at night. One pool maintained an open area where the regular dome fountain burst once a minute. Avalanches continued to fall from the crags. The lakes could now be seen from Uwekahuna Bluff. Down the rift oven lava could be heard splashing, seemingly at a lower level than the lakes in the pit. The latter were now standing at various levels and there were eight or nine separate ponds.

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April 1. At 10 a. m. fume was thin and lakes were crusted except for four fountaining patches and a spatter cone at end of southeast arm. Rift oven was glowing by daylight.

April 2. At 4 p. m. inspection showed that crags and central floor were rising faster than liquid lava. Four fountaining patches were counted, one of these at a border grotto north of the east pond. This pond was seen to break up. The partition between central lake and southeast arm had been widening. Even in daylight there was bright glow in southwest rift wells.

April 3. At 3 p. m. the pit was dull but there was evidence of recent flooding around edges of floor. The elevated bench next to southeast arm pool had been cracking and a block had crashed down on the cone below. The floor lava appeared to be gaining on the liquid lava. Southwest rift well was hotter.

April 4. At 7 p. m. lakes were quiet and heavily crusted. From the edges of west cove pool and central lake small flows were pouring over the floor. Seen by night the rift wells glowed brightly with a pink color.

April 5. At 9 a. m. measurement showed the lake to be 134 feet down and there was one fixed fountaining vent in southeast arm pool and one blowing vent in southwest arm. Otherwise fountains were sporadic, dependent upon a slight outbreak of cracking and foundering of crust in each of the lakes. There was an avalanche of rocks from the northwest crag to the central lake, and a small fall from south crag. A lava flow poured for a few minutes from a driblet spire along the wall under the west station. On this day the higher crag peaks first came into view above rim of pit as seen from Observatory.

At 9 p. m. the lower rift well was of much darker incandescence than on the previous night.

April 8. At 10 a. m. rising was still in evidence and gas was hissing loudly at the border grotto north of east pond and at vents around the central lake. There were small trickling flows in the debris of the cracked floor along the wall-crack.

South crag and adjacent floor were now so tilted westward as to lift a high scarp above south corner of southeast arm. The southeast floor had been recently flooded and from the north end of east lake a vigorous overflow was seen to break out. Occasional avalanches fell from the crags. The wall crack northwest had opened.

April 9. At 3:30 p. m. lakes were heavily crusted and no fountains were in sight from southwest stations. The live lava rising along the wall crack had in several places made swollen puddings emitting lava trickle through the cracks. The southeast arm was now extended to the wall of the pit in T-shape by union with the wall-crack pool. The east pond had enlarged and flames were playing through cracks in the crust. No fountains were seen during a visit to the pit but in the evening spells of bright flaring gave evidence of spasms of breaking up of crust.

The northwest and south crag peaks were now plainly visible from Observatory. Rising was taking effect chiefly on the beach magma, the lakes holding their own. Northwest and south crag masses were evidently heaved up along the axis joining southeast arm and north cove and tilted westward en masse. This had lifted the east side of west pond cup and the floor at the east base of the south crag. The latter had become a new crag. The whole jumble of island and south peak masses was upheaved as part of the south crag mass along with the floor west of the crag, and the whole unit was tilted westward. The floor was swollen and cracked both here and at the north side of the pit, giving evidence of massive swelling of the whole central region. A remnant of the small crag north of the southwest arm still persisted. Some large tabular masses of floor had risen west of northwest crag, and a deep crevasse between these tables extended out to the wall of the pit. Floor of pit now appeared accessible from the north. Cracks in the north shelf region

were still excessively hot. Southwest rift oven was glowing brightly by daylight and apparently flaming as seen at night from the Observatory. The farther southwestern well had lost its brightness and showed no perceptible glow by daylight. Hot blue fume rose from both wells.

April 12. At 2:15 p. m. the scene at Halemaumau strongly resembled that of September-October, 1921. There was floor swelling in a dome curve around margin of floor southwest and north, leaving a depressed and cracked wall-valley where lava puddings were discernible. From the west, northwest crag appeared to be a sharp spire with talus tumble at its base. West of west cove pond a sector of floor had risen to create over the pond a 30-foot wall. The ground between this crag and central lake was cracked. Central lake and southwest bay now formed an elongate lake with cracking and foundering crusts, one continuous fountain, and banks 6 feet high.

Craggy blocks and a platform had now risen athwart the central lake between northwest peninsula and south crag mass. In the midst of uplifted crag matter a small high round pond lay at the northern base of the south crag. The northern end of the northwest crag mass was again becoming conspicuous as a separate north crag. The east central crag mass had lifted the cliff that bordered the central lake on that side so as to create a new peak. All the eastern crags were tipped east.

There were cracking and sliding noises and much thin blue fume rose. The crag masses were now divided into three pronounced sectors, and the liquid lava into seven principal pools as follows: Southeast arm, southwest central lake, west cove pond, south crag pond, west pond, north cove pool and east pond.

The region northeast of north cove pool was occupied by an uplifted mass with broken rocks on its summit and radial cracks down its northeast slope. East of the eastern valley stood a steep peaked mass.

A most remarkable uplifted plateau lay in the region of the west pond and the west cove pool, with a steep crevassed slope extending to the northwest wall-valley. This broke down into a west-facing cliff at the western wall-crack. A gushing vent was filling with liquid lava the northwest wall-valley.

Hissing was heard in the northeast region, but the pit was otherwise very quiet. The view from the north was almost identical with that of last October. The whole central cake of bench magma constituted a dome nearly up to the level of the October shelf. The wall-crack fill was still 50 or 60 feet below that shelf. There was a tumbled narrow valley between the southeast crag mass and wall of pit. The region north of east pond was a swollen mass of trickle fillings separated from the wall by a distinct valley. The east pond was now a crusted fill or platform with definite shoreline only on the crag side, and trickling overflows on the wall side. A crack extended westward from the west side of east pond separating the southeast and northeast crags. The marginal bench of both these crags showed northeasterly tilt. This tilt was by block faulting and affected the north-northeast and east central crag blocks as well. Similarly the southern and western masses were all tilted westward. The platform surrounding west pond was lifted highest of all, although its surface remained horizontal.

April 14. At noon the pit was very quiet and no fountains were visible from east rim. East and southeast pools were not outlined by definite banks but appeared to be a mass of rough swollen lava with some trickling. There was some smoke. The crags were now slow in their rising, only two feet per day. The eastern wall-crack fill appeared to lie 40 feet below October shelf. In afternoon rift oven was reported to be dark.

At 9 p. m. seven fountains were in action. Crack-and-founder action was seen to spread across central lake. About once a minute a large rhythmic fountain was seen to burst near center of pit, and an explosive spattering vent had broken through the crust of southwest bay. Glowing flows and fills could be seen all around wall-crack. There was flaring at east pond and occasional fountaining occurred in a pool under north wall. In the west fill a stream was trickling. There was some hissing. Southwest oven was glowing



Figure 3. April 23, 1922, northern side of Halemaumau from north-northeast rim. Shows northwest erag mass, domed and crisscrossed floor, and live annular fill of wall-crack.

with diminished brightness, an orange red, and lower well appeared dark though lava could be seen 70 feet down.

April 15. At 9 p. m. there was very regular rhythmic action at central fountain once a minute, other fountaining was slight, some of it in a pool at base of north wall. Flames played through shore vents and cracks in crust. The west pond cup had high margins. The crags were rising most on north side of pit.

April 18. At 10 a. m. there was much fume from central region and rising had continued. There were three fountains respectively in central lake, north wall-pool and east pond. Northwest side of lava column had risen the most, the fill there standing 10 to 15 feet below October shelf, whereas that shelf on northeast side stood 40 feet above floor of wall-crack. Southeast arm was quiet. Central lake was seen to break up its crust rather rapidly, starting at the rhythmic fountain. Latter retained its 60-second interval. North wall pool was oval and its crust cracked up and foundered; a marginal grotto was active on its northeast side. Cracking and foundering occurred also in east pond, which had high west banks, and the heat was great radiated during and after the break-up. On south side of pit the October shelf was 20 feet high. Much debris lay at base of northwest crag. A flat pool occupied southwest wall-crack.

Only broken stones could be seen on the bottom of lower rift well, the oven showing fume and dark red glow.

April 20. At 1 p. m. crags were rising but little, and some of them were stationary. Pools were crusted and hissing without fountains. A cone had formed on west bank of east pond. A new flat-surfaced pool had filled the northeast wall-valley, the October shelf there standing 15 feet above it, whereas at the south this shelf was 10 feet high. Lakes had been rising more than crags. South shore of east pond showed westerly tilt.

April 21. From 3 to 5 p. m. lakes appeared about 80 feet below rim. Fountains were seen in central pool, at a cone which was rapidly growing on east bank of north wall pool, and at north bank of east pond. Fume in forenoon had been thin, but the oven vent at southwest rift was smoking and showed less heat. Rising was still in progress. The marginal pools were still 5 to 10 feet below the October shelf, the higher ones northwest and southeast, the lowest north-northeast. In general the rise was a swelling with little gas activity, and faint hissings. The scene at Halemaumau resembled October, 1921, in every respect, with its clustered crag matter in the center, sloping floors, and puddings of lava trickling up the wall-crack. The crags were slowly changing in shape. Southwest oven no longer glowed by daylight, and its stalactites were covered with brown filaments.

April 22. At 5 p. m. a swollen plateau was found in the northeast wall valley, with trickle flows making out from its margins. Blowing cones were developing along northwest edge of east pond. In southwest pool the rhythmic fountain continued its pulsations and in the central pool open fountains were more or less continuous. The west pond was now much higher than central lake. October shelf was now partly submerged on northwest and southeast sides of pit, but 5 to 10 feet high elsewhere. The wall-crack fill was everywhere hot and trickling. Three fountains were seen, and grottoes were forming. The crags had been rising two to three feet per day, first on the northwest, then on the south. An open pot had formed against the southwest wall of pit near the rift locality, and the rift oven appeared hairy and yellow.

April 23. At 11:30 a. m. there was strong hissing from border cones of east pond, and the wall-valley fill was hot and trickling about 80 feet below rim. On northeast and southwest sides of pit the October shelf was 5 feet high. On northwest the fill had just overflowed the shelf. An oval pool southwest of south crag was seen in process of cracking and foundering, and at noon the northern wall-pool broke up violently by means of a hot cracking and foundering of its crust, a process which was seen to spread to the fill west of this pool.

Central lake had become a deep irregular canyon. Rise of the crags had become slower. The only open pool was at the rhythmic fountain. Everywhere else the pools were crusted and swollen except for occasional spells of cracking and foundering. The east pond surface had become a plateau, and at 12:20 p. m. it was squeezing trickle flows out from under its northern margin.

April 25. The crags had been rising very slowly and the lakes faster. The October shelf was now submerged and the north pool was accessible by way of the easy slopes and shelves on that side of Halemaumau. There was much diffuse smoke. At 11 a. m. there were four hissing cones at western edge of east pond and the hissing noises in the pit were loud. No fountains were visible from east rim. Eastern lakes were heavily crusted. At night two localities were seen to keep up a glow, near central fountain and north pool.

April 26. At 9 a. m. lakes were crusted. A cone south of south crag was splashing lava to the adjacent floor. A small cone on southwest floor was hissing and making coarse Pele's hair; there had been recent flooding there. Dense fume rose from a small vent between wall of pit and west pond. In the oven well deep rumbling from splashing lava below could be heard.

April 28. At 3 p. m. there were flagree cones along inner border of east lake and under the northeast crag, hissing noisily. Another hissing cone had formed in the northwestern wall pond. Trickling flows poured from the north pool towards wall of pit. Smoke rose from a crack in the north floor and from near west pond. After twenty minutes of quiet the north pool became inflated, the crust heaved, cracked and gave vent to a rush of gas through a crack several inches wide. This with the vigorous fountain that followed resembled the cauldron action of March, 1921. There were two fountains in central lake. The lakes appeared to have gained on the crags. Splashing of lava could be heard in oven well at the southwest rift, seemingly at a lower level than the lakes in Halemaumau.

April 29. At 3 p. m. lakes appeared about 60 feet down, and crags were rising about 1.3 feet per day. The night before had shown brighter glow due to much breaking up of the border pools and fountains in the central and southwest pools. Now there was much cracking and foundering of crust in southeast, east, northeast and north-northwest wall pools. Superficially the northeast pool appeared continuous with east pond. A north-northwest pool had replaced the north wall-pond by a migration of the cup westward. Over the north pond site there remained a large spatter dome. Central pool was open and making huge balloons of inflated skin, alongside a big dome grotto on its north bank. This pool lay adjacent to east central crag separated by a crust partition from southwest arm pool. The latter was also open with the rhythmic fountain at its eastern end breaking once a minute.

An avalanche from east side of northeast crag mass showed that centrifugal tilting was in progress. Southwest pool showed a fixed rim 4 feet high, the other pools had rims revealed after breaking-up spells one or two feet high. These spells were now very frequent as though gas pressure increased as the lava surface approached the rim level of Halemaumau. The crusts would crack in long slabs that tilted down into the melt beneath, pushed over by a cascade-like rush of lava from under the crust surface remaining.

April 30. At 4 p. m. pit was dull and lava was rising. Only central and southwest pools were active. There was much smoke and the night glow was dull.

LAVA MEASUREMENTS.

Measurements of depression (—) and of elevation (+) of the mobile lava column, made with transit, referred to northeast station of rim of Halemaumau pit (3727 feet above sea-level), for the month ending April 30, 1922, including crag peaks of bench magma and mean liquid level of lake magma, were as follows:

	Mean lake level	South crag	Northwest crag	East central crag
March 29, 9 a.m.	-178 feet	-77 feet	-84 feet	
April 5, 9 a.m.	-134 "	-22 "	-27 "	-58 feet
" 8, 10 a.m.	-122 "	-5 "	-14 "	-52 "
" 12, 2 p.m.	-111 "	+10 "	+4 "	-33 "
" 18, 10 a.m.	-84 "	+30 "	+21 "	-13 "
May 2, 11 a.m.	-58 "	+56 "	+46 "	

Progressive changes were as follows for the liquid lava:

Mar. 29-April 5,	7 days, lake rose	44 feet, averaging per day	+6.3 feet.
April 5-12,	7 "	23 "	+3.3 "
" 12-18,	6 "	27 "	+4.5 "
" 18-May 2,	14 "	26 "	+1.9 "

Progressive fluctuation in level of south crag summit was as follows:

Mar. 29-April 5,	7 days, crag rose	55 feet, averaging per day	+7.9 feet.
April 5-12,	7 "	32 "	+4.6 "
" 12-18,	6 "	20 "	+3.3 "
" 18-May 2,	14 "	26 "	+1.9 "

Fluctuation of northwest crag summit was as follows:

Mar. 29-April 5,	7 days, crag rose	57 feet, averaging per day	+8.1 feet.
April 5-12,	7 "	23 "	+3.3 "
" 12-18,	6 "	17 "	+2.8 "
" 18-May 2,	14 "	25 "	+1.8 "

Fluctuation of east central crag summit was as follows:

April 5-12,	7 days, crag rose	25 feet, averaging per day	+3.6 feet.
" 12-18,	6 "	20 "	+3.3 "

Relief of peaks above lakes was as follows:

Mar. 29.	south crag	101 ft., northwest crag	94 ft.	
Apr. 5.	" "	102 "	" "	east central crag 76 ft.
" 8.	" "	117 "	" "	" " 70 "
" 12.	" "	101 "	" "	" " 78 "
" 18.	" "	114 "	" "	" " 71 "
May 2.	" "	114 "	" "	" " ..

The following table shows comparative monthly changes of level for mean lake lava and mean crag lava, beginning with July, 1921:

July	liquid lava	-22 feet, bench lava	-14 feet.
August	" "	-119 "	+118 "
September	" "	+138 "	+158 "
October	" "	-259 "	-253 "
November	" "	-18 "	-21 "
December	" "	+16 "	+18 "
January	" "	+25 "	+29 "
February	" "	+40 "	+40 "
March	" "	+92 "	+80 "
April	" "	+104 "	+106 "

SEISMOMETRIC RECORD.

During the month ending midnight April 30, 1922, 11 local earthquakes and three distant shocks were registered at the Observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W., 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

April 1,	1:42 a.m.	Feeble.
" 3,	2:40 a.m.	Very feeble.
" 9,	11:23 a.m.	" "
" 10,	7:17 p.m.	" "
" 12,	12:50 a.m.	" "
" 16,	2:10 a.m.	" "
" 17,	11:18 a.m.	" "
" 23,	11:45 a.m.	" "
" 25,	4:07 a.m.	Slight, distance 3 mi. azimuth SE-NW. Felt locally.
" 25,	11:36 a.m.	Slight, distance 6 mi.
" 29,	1:30 a.m.	Very feeble.

Teleseisms.

April 2,	9:00 a.m.	Slight.
" 25,	11:10 a.m.	Slight.
" 25,	5:30 p.m.	Slight.

Spasmodic Microtremor.

This type of tremor by weeks beginning April 1 was registered as follows:

April 1-7.	Slight.
" 8-14.	Slight, with increase on the 11th.
" 15-21.	Slight, except moderate on 19th and 20th.
" 22-28.	Slight.

Harmonic Microtremor.

This type of tremor was very slight throughout the month.

Microseismic Motion.

Amplitude of microseisms was as follows:

April 1-7.	Slight.
" 8-14.	Slight.
" 15-21.	Slight, except moderate on 17th and 18th.
" 22-28.	Slight.

Tilting of the Ground.

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

April 1-7	2.3 seconds	SSW.
" 8-14	2.3 "	ENE.
" 15-21	1.0 second	NNE.
" 22-28	3.5 seconds	WSW.

T. A. JAGGAR,
Volcanologist.

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, CHIEF

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No. 5

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PROGRESS OF BORING EXPERIMENTS.

Hole No. 1.

May 12 to 14 the contractor, Mr. A. H. Hobart, brought his drill rig and crew of four men from Honolulu. May 15 the drill was set up at east corner Sulphur Banks flat, near Volcano House. The site of Hole No. 1 is between a large steaming crevasse and the main bank of red clay and sulphur, the latter following a curved fissure emitting scalding hot steam at 96° C., the boiling point of water for this elevation (3940 feet above sea-level). The bank is covered with yellow crystalline sulphur deposited about steam holes. This is the largest permanent solfataric action at Kilauea. The rock is basalt, siliceous and whitened by solfataric action, bedded horizontally in lava flows, its upper surface under eight or ten feet of altered volcanic ash and agglomerate.

Boring began May 16. The machine was a cable rig with cam shaft and treadle operated by kerosene engine and delivering 40 or 50 strokes per minute. In this hole a bit 6 inches in diameter was used, of blunt chisel form. This tool heavily weighted is lifted and dropped rhythmically, and turned by hand at the cable. The drillings are reduced to powder except for occasional small chips

of rock. The harder the rock the finer the powder. Water is supplied to the hole by hand and the "sand-bucket" is used for occasional cleaning out of the sump, or bottom. This bucket consists of a tube with trap in lower end which when churned up and down catches the muddy debris. The upper earthy layers were cut away rapidly, showing sulphur and some fume. At 9 feet of depth a crack emitting scalding sulphurous steam was penetrated and thereafter came hard rock and the drilling was very slow. Steam rose steadily with gentle purring, but without marked pressure. It was necessary to wrap sacking around mouth of well to protect drillers and machine from hot acid fume, and to paint cable and other steel parts with crude petroleum. Eventually a plug was made for the casing at mouth of well, consisting of a wooden stopper in two halves grooved to let cable pass.

Water was kindly supplied by Volcano House. The impact method was selected because of its economy of water. This first hole consumed 10.4 gallons water per foot of drilling. Water in barrels lashed to sleds was hauled by tractor. Tractor and special motor car were used for skidding and hauling casings and other tools to the work.

The following shows record of drilling Hole No. 1:

Date	Machine	Hours		Progress (feet).	Depth hole.	Water hauled (gallons).	Notes
		hours.	other work.				
May 16	4	4		10.0	10.0	35	Boring begins afternoon.
17	4	4		0.5	10.5	50	Rock dulls the bit.
18	3	5		3.7	14.2	105	Hole caving in.
19	4	4		5.8	20.0	..	Drill sticking.
20	2	6		1.5	21.5	..	Broken cam shaft.
22	0	8		0.0	21.5	..	Repairs.
23	2	6		0.5	22.0	40	Hole crooked.

Machine hours are those when machinery was in operation. Besides drilling this involves much hauling up and lowering tools and casing, jarring tools that stick in hole, working the sand-bucket, and idle running while tackles and tools are being adjusted. Omitting first day through soft soil, the rock drilling averaged 0.8 feet per machine hour. The muddy bottom of hole held water much of the time but the hot tool dulled and showed surfaces worn by the hard rock. Attempt to place a long casing in hole May 23 showed that hole was going crooked and pitching to southwest, perhaps guided by underground fissures. Casing was necessary to keep rock fragments from falling in and wedging the tools, therefore drilling here was discontinued. The hole was capped with steel over a short casing cemented in the orifice, and so preserved for chemical and physical investigation. Iron pyrite occurred in all the rock of this hole.

Temperatures were measured as the work progressed with Centigrade maximum mercurial thermometer, lowered into the well at times when bottom was known to be free from any fresh inpouring of drill water. Thermometer was exposed five minutes. No cooling effect from such water was detected anyway, as the hole was scalding hot and water in sump was heated very rapidly to the temperature of bottom.

The following is the record of temperature measurement at Hole No. 1:

Date and Time.	Depth (feet).	Air		Bottom		Notes.
		Temperature Cent.	Fahr.	Temperature Cent.	Fahr.	
May 17, 8 a.m..	10.5	14°	57°	98°	208°	This reading 98° C. on May 16 also.
19, 3 p.m..	20.0	17°	63°	96°	205°	Two readings in succession.
23, 9 a.m..	22.0	14°	57°	96°	205°	Inside of casing 19 feet long.

A general temperature of 96° is a constant here. The reading 98° by two different observers, when the hole was first opened to the rock under the overburden, is questionable. The same thermometer was used throughout. When the long casing was withdrawn readings of thermometer both 10 feet down and inside mouth of well May 23 gave 96° C. A similar measurement at this hole June 11, 10 feet down, gave 98° when maximum thermometer was read while immersed in the steam column, the mercury receding to 96° when withdrawn into open air. It is possible that in first measurements the observers read quickly and did not observe subsequent shrinkage. Presumably a maximum thermometer reading is calibrated for reading after removal from exposure to heat, and not for reading while mercury above constriction in tube is itself expanded by heat. Moreover the 96° readings check with later measurements made in August by means of alumel-chromel thermo-element and potentiometer, and repeated with another maximum thermometer of different make.

An experiment was made May 18 at this hole to determine whether water in the steam column would boil. A sealed pipe of one inch internal diameter 6 feet long was filled with water and hung in the well. The water simmered and gave off small bubbles but did not boil. A similar test using a shallow pan produced the same result. The atmospheric pressure diminishes upward so as to lower boiling point of water about 1° C. for each 1080 feet of elevation. Hence mean boiling point at elevation 3940 feet should be 100° minus 3.65° equals 96.35°. The actual records at depths 20 and 22 feet in Hole No. 1 were 95.7° and 95.8°, reading thermometer to tenths. This if correct checks with experiment in showing that steam in well is half a degree below boiling point.

Hole No. 2.

The drill May 24 was moved 140 feet west from Hole No. 1 to the flat ground 50 feet in front of the large sulphur bank. This is in the basin traversed by steam cracks which lies a quarter mile northwest from Volcano House. It appears to be a corner of the old Kilauea Crater floor dating from some very ancient period, before the down-faulting that created the cliffs and fault-benches surrounding the present crater. The whole basin differs from the regions round about in the hotness of the ground and the large number of steam-cracks. Hole No. 2 was started in the surface covering of 1790 ash and rain-wash alluvium, ground that is warm but giving no sign of the scalding heat below. The hole was started 12 inches in diameter, some hard material was encountered 3 feet down, but the main ledge with steam cracks was reached at a depth of 7 feet. Six feet down the temperature was 53° C. (127° F.) in green sulphurous earthy material; the temperature rose to 96° C. (205° F.) in the course of the next 2 feet (May 26). Thereafter the drill was surrounded by scalding sulphurous steam and went through mineralized basaltic lava with much iron sulphide (pyrite), the mud and water sometimes disappearing in crevices, and in other places being recovered by sand-bucket or iron ladle. Below 7 feet a bit 8 inches in diameter was used, producing a hole about 9 inches across. The hole was drilled 20 feet deep in May and carried farther in June. Consumption of water in May on this hole was 14.9 gallons per foot; average consumption of water on both holes was 12.6 gallons per foot.

The following is the May drilling record for Hole No. 2:

Date	Machine	Hours other work.	Progress (feet.)	Depth (feet)	Water hauled (gallons).	Notes.
1922.	hours.					
May 24	1	7	3.5	3.5	..	Drilled with tube bit.
25	3	5	2.5	6.0	30	Reach rock.
26	7	1	4.2	10.2	40	Mud disappears in steam-cracks.
27	3	5	2.9	13.1	40	Bit shows wear.
29	2	6	2.6	15.7	..	Two men only; three men off.
31	6	2	4.4	20.1	140	Put in casing.

The average drilling in rock for this period, omitting upper 6 feet, was 0.78 foot per machine hour. The mean for all rock drilling for the month including Hole No. 1 was 0.79 foot per machine hour. The average drill operation accomplished for both holes from May 16 to May 31, thirteen working days (not including four days of travel, transportation and assembling rig) was 3.15 machine hours per 8-hour day. This makes the daily footage 2.49 feet at the rock-drilling rate, the actual footage (including rock and overburden) averaging 3.2 feet per day. These results show that basaltic lava sheets are hard rocks to drill.

VOLCANIC CONDITIONS IN MAY.

Activity of Halemaumau.

The scene at Halemaumau fire pit was now very spectacular and the lava was accessible. The activity of splashing and spurting fountains increased during the first week of the month so that fifteen or twenty centers of effervescence were sometimes in action. The liquid lava of the marginal pools came up to within 57 feet of the mean level of rim of pit, and the great crags out in the center stood over 100 feet above the lakes. The rate of rising, however, was decreasing to little more than a foot per day. Most of this was registered as motion of the flat platforms that surrounded the lakes, and of the craggy peaks surmounting them, for the liquid lava at times distinctly subsided, making valleys of slumped crust along the edges of the floor area. Furthermore the separate ponds of which there were nine, so retreated within their cups as to show banks 4 to 8 feet high, with overhanging edges enclosing fiery grottoes. Smoke at the pit was fairly thin.

In the two rift wells outside of Halemaumau the lava rose so as to be plainly visible as a floor where gas was hissing through glowing cracks about 50 or 60 feet below the openings. Occasionally some spurting or fountaining was seen down the wells, but the upper walls hung with stalactites were no longer glowing.

During the second week the liquid lava rose to a point less than 50 feet below rim in some places. The crags rose spasmodically but at times were nearly stationary. Fountaining and splashing activity varied, some new cones and open grottoes were forming and the outer pools along the border valleys were generally brimming full and often overflowing their banks. Some of the border fills swelled into irregular hummocks. The tilt of the crags made showers of broken rock spill from the ledges. Usually six or seven fountains could be counted. Flames were abundant where burning gas rushed up through cracks in crust. The lava in the southern rift wells ceased its activity, but the oven cone continued to show live melt from 40 to 75 feet down, the liquid sinking markedly at one time and revealing a glowing cavernous hole.

This sinking at the rift well was the signal for a crisis which was reached May 13 and the third week of the month was the most spectacular and interesting culmination which had occurred at Kilauea since the March eruption of 1921. The rise which had started in November, 1921, continued with slight fluctuations until May 13 when portions of the liquid lava reached a level of less than 50 feet below the rim. By May 21 the lake level had dropped 300 feet, the subsidence in one week nearly equaling the rise of five and a half months.

The sinking was steady but majestic, most of the crags, lakes and adjacent floors maintaining their identity. More molten lava was visible than during the rising period. Fume remained thin and seeing good. Avalanches from crags and walls were numerous and the crash of tons of rock falling 300 feet was awesome. Pasty flows were frequently seen trickling from the veneer that covered the pit walls.

The southwest rift tunnel inside the pit again became visible as an opening at the base of the precipice with a molten lava pool at the entrance. At once the admission of air through this blast furnace brought about a roaring updraft through the oven well, and the interior surfaces became brightly incandescent as the fresh supply of oxygen was mingled with the uprushing volcanic gas.

The week ending May 28 at Kilauea witnessed one of the great historic subsidences of the lava which will be remembered for years to come. This was expected as the closing episode of the cycle of Mauna Loa and Kilauea eruptions that began in 1914. The collapse of Halemaumau pit continued after the end of the month, accompanied by incessant roar of avalanches falling into a tremendous void more than 800 feet in depth.

The rapid subsidence after the middle of the month continued at about the same rate until May 25. Swarms of earthquakes were registered by the seismographs, many of them felt at the volcano, and finally some of these were reported from Hilo, Honoumuli and Waiohinu. The shelf of new lava clinging to the Halemaumau wall gradually caved away making glowing avalanches. The crags and lava lakes were drawn down bodily and enveloped in debris slopes, but on May 26 some of these features could still be identified over 600 feet down. The huge cavern of the 1920 rift became an enormous black tunnel half as high as the pit wall, with a lava pool below and incandescent rock falls from its ceiling. This tunnel appeared also on the opposite side of the pit at a much lower level, and here also liquid lava could be seen in its depths.

About 2 p. m. May 26, and in the early afternoon of the two succeeding days, spells of general caving in of the pit wall took place, sending up cauliflower clouds of brown and salmon color hundreds of feet, and making a thunderous roar heard several miles away. All of the surveying stations and "danger" signs were carried away, and also many portions of the trail around the pit. The tunnel southwest and the two rift wells fell in, making a smoking canyon extending Halemaumau 500 feet in that direction. On other sides the rim caved in for a width of about 100 feet. The new pit was therefore a pointed oval in plan with the point directed toward the Kau Desert, 2000 feet long on that diameter by 1500 feet wide.

By May 31 Halemaumau had entered upon a dormant period, becoming an immense vacant cauldron bottomed with slide-rock and steaming mostly at the southwest corner where the rift tunnel of 1920 lay buried under talus. After May 30 there was no glow at Halemaumau, the sliding and avalanching gradually lessened, and the depth to the bottom of the talus funnel was found by later measurements to be 861 feet. It is certain that the top of the lava column subsided at least 1000 feet.

Activity of Puna Craters.

In view of the supposed drainage underground of the liquid lava of Halemaumau, the Kau Desert was explored for outflows May 28 and nothing new was found, nor was any distant smoke seen. A swaying earthquake about 8 p. m. heralded the appearance of bright glow at Makaopuhi crater. This crater had been visited that morning by tourists and had shown nothing unusual. The evening outbreak was found to be occasioned by cascades of stiff lava that poured from the top of the talus on the north side of this pit and made a pool in the bottom. Cracks had opened a foot or more for four or five miles west-southwest from Makaopuhi. May 29 this eruption dwindled, but a new eruption broke out on the north edge of Napau crater farther east. Noisy explosive lava cones formed here making small areas of lava flow on the floor of the crater and on the plateau above, and cascades down the cliff. This eruption also lasted only a day. There was a slight lava flow also at a small pit crater northeast of Napau. All of this Puna lava was a scoriaceous pahoehoe with aa phases.

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Activity of Halemaumau

May 2. At 11 a. m. crag and bench lava were found to have risen so that the several pools had banks 2 to 4 feet high and the liquid was open and showed surface streaming. Measurements made lake level 58 feet below rim and both crags and liquid were rising 2 feet per day. Around wall-crack V-shaped de-

pressions showed slumping, especially marked northeast and northwest. There were eight or nine border fountains and some central fountaining in central lake. The east, southwest and north ponds had sharply marked outlines. There was some smoke and increased flaring at night.

May 3. At 1 p. m. pools showed banks 4 feet high excepting east pond which was nearly brimming. There were two fountains in southeast pool and two in southwest arm. Latter was separated by an isthmus from central lake. A hissing cone stood near south wall. North pond showed one fountain and rising lava. Conspicuous cracks extended northward across the swollen north floor.

May 5. At 10 p. m. eighteen fountains were visible, also flames through cracks in crust of lakes, and liquid lava showed around wall margin everywhere except southwest. A peculiar explosion was observed over the inner bank of north lake, making a sharp report and producing bluish sparks for about two minutes after the detonation. On two occasions this pond sank about six inches without any breaking up of crust and with only one fountain in action. Molten lava was splashing in upper southwest rift well and was visible in the lower well.

May 7. At 11:30 a. m. large lifted platforms were conspicuous around west side of pit and an evenly sagged crust along the southwest wall-valley. Wall-crack fill was depressed also northeast and northwest. There were fountains in south, northeast and northwest wall cracks, in north and east ponds, in central lake and at the locality of incessant outbursts of rhythmic fountaining in southwest pool. Interiors of southeast pool, north cove pool and west cove pool were not visible. The group of crags was rising by steady swelling of bench magma. Rocks were falling along the crevasses, notably where northwest platform of uplift was breaking away from the wall-crack. Banks of southwest pool and west pond were respectively 6 and 4 feet high, but the wall-crack pools had raised banks on the crag side and overflowing margins on wall side. A breaking-up spell occurred in southeast arm with streaming southeastward. Eight fountaining places were counted in the whole pit. At the two southwest rift wells there were lava floors about 50 feet down, the northern or oven well showing glow in a crack, the other a flat yellowish floor with a hissing vent.

May 8. At 3 p. m. there was fountaining in southeast arm and central lake, hissing from under crusts, new fills occupied the wall-valley, there was a fountaining puddle in northeast pond, and the lava of east pond was brimming level with banks, crusted over, and making a hissing sound at glow cone on bank. The north pond had overflowed extensively along wall-valley and buried a spatter cone that had been uncovered on the previous day. Rocks were seen to fall from northeast crag mass and Observatory measurements showed maximum rising at south crag.

May 10. At 11 a. m. seven fountains and six blowing cones were counted. Southeast arm had now developed T-shape, the cross-piece being made by wall-valley pool; at west end of this pool was a cove enclosing a splashing pot. Crust of this pool broke up at 11:45. Swollen floor west of south crag exhibited a downward bend to wall-valley with concentric cracks. In the wall-crack were trickle flows over 50 feet below rim of pit.

The writer descended to north wall-valley fill which was very hot, glowing and hissing. This was crossed to the north crag slope, but the latter was found badly crevassed and inaccessible. A new wide northern fill had a swollen plateau surface that showed signs of recent cracking and foundering. It was now thickly crusted, with gas hissing through cracks.

May 11. At 10 a. m. the northern wall-valley fill was found to be higher and more humpy. Northeast pond broke up and sent out hot overflows. Only two or three fountains were observed. Southwest arm lay 10 feet below its banks. There was much smoke.

Southwest oven showed a break in the lava shell 40 feet down through which a glowing void could be seen where lava was heard splashing and surging at least 20 feet lower. In second well the floor was yellow, broken and dead, and wet yellow patches of salts had formed on the walls.

May 12. Crags continued to rise but lakes were rising only half as fast. At noon a perpetual fountain was in action at east end of southeast wall pool. A fountaining grotto with half-dome over it was seen in east pond. Swollen domes had formed in northern regions. Fragments were falling from raised platform about 4 feet high around west pond. The liquid lava in rift oven appeared lower than the lakes in Halemaumau.

May 13. Only one fountain was observed, the gas expending itself at vents loudly hissing. Some of these along inner bank of east pond were glowing and above lake level, while the outer bank on wall side was not marked. Escape of burning gas through cracks in crust of southeast arm was sufficiently violent to blow away small chips of crust and to heat the cracks red. This day was the end of the prolonged rise.

May 14. At 8 p. m. ten fountains were in action, flames were common and subsidence had begun. Some of the crags were lower. The border lakes showed lowering within their banks revealing caverns at the ends. Most of the pools were open and free from crust, the central lake fountains flinging the melt high, and the southwest arm exhibiting its dome fountain at intervals. Northwest wall-crack pool had lowered 4 feet leaving a new bench on wall side and a cavern at its east end. Northeast region showed flaming clefts and the pool there had cavernous overhang at its ends. East pond showed curtained grottoes and southeast arm was streaming voluminously against south wall of pit.

In forenoon probably an upward gushing of lava occurred in oven cone of southwest rift. The lava in the well was credibly reported to have stood only a few feet down. Now in the evening it showed a glowing shell 40 feet down and a bright quiet void below hung with big stalactites.

A visit to Mauna Iki in Kau Desert on this day showed that all was quiet in that region.

May 15. Crags were distinctly lower but the fume and night glow remained as before.

May 16. At 10 a. m. general lowering was remarkable, especially in central region amounting to from 5 to 10 feet for the crags. Gas was hissing, lakes were crusted except in border pools, and a fountain in north wall pond was building a spatter rampart on the crust. A tunnel was seen under south crag mass opposite the rhythmic fountain in southwest arm.

At 8 p. m. eighteen fountains were in action and lakes appeared about 75 feet below rim. North wall-crack pool had greatly lengthened. There were falls of rock from the marginal shelf left by subsidence, this shelf appearing over 20 feet above east pond on the wall side, while on crag side the bench above pond was low as crag and pond sank together. East pond appeared lower than south wall pool and a partition separated them. These pools showed cracking and foundering and some flames were seen.

May 17. At 6:30 p. m. lakes appeared 90 to 100 feet down and avalanches of glowing material fell from the wall veneer. Aa paste was visible, glowing in the debris slopes. Thirteen fountains were counted. Topography of lava column was only slightly changed, cracks had appeared in the platforms and the general movement was like October, 1921, the circle of crags lowering steadily and the annular lake leaving a vertical veneer against wall of pit. This veneer was capped by a bench 20 feet wide and the wall below showed successive shore markings.

Southeast crag exhibited glowing cracks. A large platform was attached to northeast crag, while part of the ring pool occupied the wall-valley. There were many glowing cracks. Fume was thin.

May 18. At 10 a. m. lakes were 118 feet below rim and only south and northwest crags were still visible from Observatory. These also disappeared

during the day and rate of lowering was estimated two feet per hour. Two earthquakes occurred during the previous day, one of them felt and swarms of small quakes were now in progress.

The lakes were sluggish and the wall veneer was interrupted by an avalanche scar southeast. Central and southwest pools stood 10 feet below their platforms. Northwest crag mass had sunk relative to platform west of it, leaving the latter in high relief relative to the pools against it. The bench lava was breaking down and revealing red hot surfaces, and debris fills lay in the wall-valley southwest, northwest and north. An avalanche fall broke up the surface of the east pond. Fume was very thin.

May 19. At 5 p. m. lakes appeared over 200 feet down. Wall crack was becoming choked with scarlet glowing aa paste, pahoehoe crusts and talus. There were pressure heaps in south wall-valley. The large dome fountain burst rhythmically in southwest arm. The even horizontally corrugated shelf veneer all around was broken below only in those places where the sinking crag matter was becoming crowded against the funnelled wall of pit. Numerous trickle flows had developed where the sinking bench magma was displacing liquid lava. A cascade poured from southeast arm into fissures east of it. Ten fountains were counted. Central region was going down so much faster than the border region as to make central lakes flood their banks, while the marginal pools receded within their cups.

At 11 p. m. cheesy material was seen issuing red hot from cracks in the wall plaster and at one of these places near the northeast continuation of southwest rift in Halemaumau wall a flowing took place lasting over two minutes, and shorter flows were seen there on two other occasions, seemingly coming out of the wall of the pit.

May 20. Lava column was now going down 12 feet per day and the rate of lowering was increasing. Earth shocks were numerous and were felt. At 9 p. m. the lakes appeared to be 300 feet down. Pit appeared to be a vertical cylinder with high black plaster shelf five times as high as the 50-foot cliff above. There was a slope of glowing aa debris at base of wall west and south. This was slipping and trickling continually with tinkling and crashing noises. The top of these heaps was marked by a glowing band which widened when the material slipped down. The black ledge had many glow cracks. The southwest rift tunnel was again open at base of pit wall and the rift oven had resumed brilliant glowing up to its orifice and was again blowing noisily owing to indraft of air into tunnel below.

The pit had increased in brightness and twelve fountains were in action including the rhythmic fountain. New fills of glowing and trickling lava occupied the east central valley. Eight pools were visible. No big avalanches occurred at this time.

At 11 p. m. avalanches were falling from wall and crags and there were many granular glowing flows from the black ledge. The glow in rift oven extended to outer edges of the cone, but the second well remained dark.

May 21. At 11 a. m. avalanches at the pit were continuously sending dust to leeward. A large section of the new plaster fell from the west wall. A small avalanche from roof of rift tunnel at its entrance fell into the lava pool inside the tunnel. Lakes were now 340 feet down. Big falls of rock occurred both north and south sides of pit.

In the evening southwest rift oven showed diminished glow and little fume. The rift tunnel doorway leading out of the pit in its southwest wall now appeared as a great arch 90 feet high and 30 feet wide with a quiet glowing pool inside showing heaving surface covered with thin skin and extending far beyond the pit as an underground passage.

There were nine fountains, the rhythmic dome fountain making large flaring effects. Cascades poured from cones in central valley amid the crags. Bottom edge of northern black ledge was falling and glowing. Glow was seen elsewhere in the ledge but not much glow remained in the talus below.

May 22. Subsidence with earthquakes and avalanches was now continuous. At 10:30 a. m. the pit wall measured by height of inner black ledge appeared over 400 feet deep. This ledge southwest was stripped away from top to bottom. There were several fountains and the crag topography appeared as before except for some crushing and burial around edges. The pit, however, appeared big and cylindrical all the way down. Where the crags came against the plaster they scored it vertically; elsewhere it showed horizontal shore marks.

May 23. At 11 a. m. fume had greatly increased and the southwest rift zone had evidently been moving. Rift oven had ceased to glow, showed interior debris 20 feet down where small black hole on the southwest side gave vent to hot air rising in a transparent cauliflower cloud. The stalactites in the oven were brown. The lower rift well was sulphur stained, shallow and gave out very little gas. Rift tunnel inside pit appeared 150 feet high with fountaining pool inside. Black ledge veneer had peeled off from the entire rift crack zone north of tunnel.

Southeast crag showed a hooked peak at its eastern end. Pools were trickling and fountaining with much overflow of crusts and with banks 2 to 4 feet high. There were small sudden noisy falls of rock and some of the avalanche dust was gray rather than red. Southwest arm extended to wall of pit, there was some spatter building on the banks and a fall of rock was seen at the northwest crag.

May 24. Subsidence continued, accompanied by avalanches and earthquakes. At 9 a. m. the southwest cavern appeared to have its roof one-third of the way from bottom to top of wall and a lava pool could be seen inside. Twenty fountains were counted, including the large rhythmic outbursts near center of pit. There was much trickling lava and the lakes appeared distorted and high in their cups. Fume was abundant.

May 25. The lake was now 487 feet down and earthquakes were felt about 11:45 a. m. and 2:45 p. m. The last was somewhat remarkable, dismantling seismograph pens and producing an east-west rocking motion without any jarring or rattling.

At noon bottom of pit appeared much lower. Top of southwest cavern stood at a height three-eighths that of wall of pit; the crusted pool in its bottom was broken up by frequent falls from the roof. Transparent fume rose from the oven and some smoke from the second well. A ridge of debris had formed in front of the cavern and liquid lava streamed through this ridge into the cavern.

At the rhythmic fountain spatter crescents were forming and lava streams were trickling against southern talus, in east central valley and at northeast wall crack. There was much new talus, partly in motion, and the lower walls of pit were scored vertically. Lower part of the fresh plaster was falling or had fallen. A small island lay in western part of central lake. Northwest platform was breaking up and sloping toward center of pit.

A big avalanche at 10 a. m. made an arch of red dust clouds. Big falls from inner roof of rift cavern about noon threw out dust at the oven well. The falling material caused pool inside cavern to swash back and forth. Three fountaining puddles were seen in the cavern.

May 26. Big cauliflower clouds of avalanche dust shot up from the pit during the forenoon.

At 1 p. m. fumes of sulphurous acid were strong at the northeast solfataras near Halemaumau and in the vicinity of oven well southwest rumblings could be heard in the tunnel below. There were also perceptible vibrations and a noise of splashing lava was heard down the well. At 2 p. m. there was incessant roaring and crashing of sliding rock, especially from roof of rift tunnel. The inner black ledge was nearly intact south, east and north, but it was gone from the west wall leaving brightly colored solfataric rock.

At 2:15 p. m. a tremendous maximum of general avalanching was reached and enormous red-brown cauliflower clouds boiled up to a great height over the

entire area of whole pit. Showers of dust fell to leeward and the brown cloud hung over Kau Desert for an hour. Recurrent intense avalanching continued for a half-hour. Glimpses of southwest rim showed that thick vertical slabs were scaling off, the maximum collapse occurring along the broad outcrop of the rift belt.

A survey during partial clearing after 2:30 p. m. made the lakes 660 feet down. A new large talus covered entire west side of bottom area, burying northwest crag mass and west pond. Still identifiable were the central lake and southern and eastern crags. A pool at base of northeast wall occupied a tunnel presumably in the rift belt. The eastern black ledge and plaster were still in place.

Examination of southwest rift wells showed smoking ground between pit and oven, and rim of pit was completely changed on the west. Southwest, west and northwest stations had fallen in as well as much of the trail. The oven cone was now close to Halemaumau rim, which had formed a deep embayment in direction of the rift.

Immediately after the great avalanches, scores of bubble fountains were seen in southwest arm, the debris reaching edge of lake. Thereafter lake crusted over and the rhythmic fountain became the principal center of activity.

The new tunnel northeast, seemingly a continuation of rift tunnel, had its top over 400 feet down, whereas southwest rift tunnel now appeared only about 100 feet down and its lower part was so filled with talus as to leave only a small height of cavern entrance visible. New hot cracks, probably glowing by night, had opened parallel to rim of pit along north and west sides. Small slides and some great ones occurred all the afternoon and night, especially about 6:45 p. m. when the northeast tunnel was completely buried. The fresh plaster material of these avalanches was red hot. During the night northeast and south-southwest stations fell in. The south pressure ridge persisted except at its eastern end.

Violent explosions occurred through cracks in the east central valley during the afternoon, sending up sheets of lava in umbrella form so as to create a slag heap. There were also explosions and puffs of dust from the vicinity of northeast tunnel.

May 27. There were slight earthquakes and heavy avalanches about 6:15 a. m.

At noon the convergent talus slopes inside Halemaumau were continually sliding and the rim had everywhere fallen away except at south pressure ridge. Top of southwest tunnel appeared higher than before and rocks were falling from its roof. What appeared to be a vertical dyke 2 feet wide extended up the face of the cliff above the mouth of the tunnel. Some of the recent veneer still clung to southeast wall of pit. A small puddle of liquid lava with trickling streams was still discernible in center of pit where the talus slopes met. Clouds of dust hung over the pit and reddish jets from avalanches were frequent. These became big cauliflower clouds again between 1 and 2 p. m. Roaring noises accompanied the avalanches and in one case the rock-falls seemed to migrate from south to north along east edge of pit.

At 6 p. m. there was continuous roar of sliding stones mostly from southwest rift region, which had now completely caved in so that the tunnel was an open chasm. In front of it a craggy outlier of the cliff stood as a group of pinnacles incessantly crumbling and sending showers of rock to the talus below. Edge of pit had changed everywhere including west end of pressure ridge, which had fallen taking with it portions of the trail. The ground southwest of pit was steaming. Hot cracks back of north rim were wider open than before.

A clearing spell revealed immense talus slopes converging to bottom of pit, the only patch of live lava lying in the region of southeast wall-crack, where also some aa substance was sliding in powdery incandescent streams.

May 28. During night pit was dark. At the Observatory a loud roar was heard from the pit at 1:20 a. m. and two lesser noises during the following hour.



Figure 4. May 18, 1922. Halemaumau during subsidence. Southeast wall-valley and plaster shelf or black ledge. Shows southeast crag and east pond going down together. Photo Jaggar.

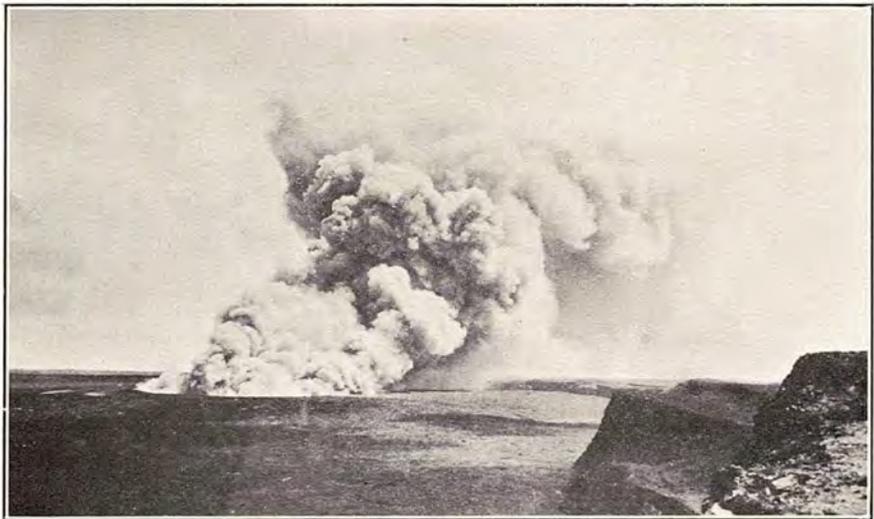


Figure 5. May 26, 1922, early afternoon. Halemaumau from Uwekahuna Bluff during big avalanche.

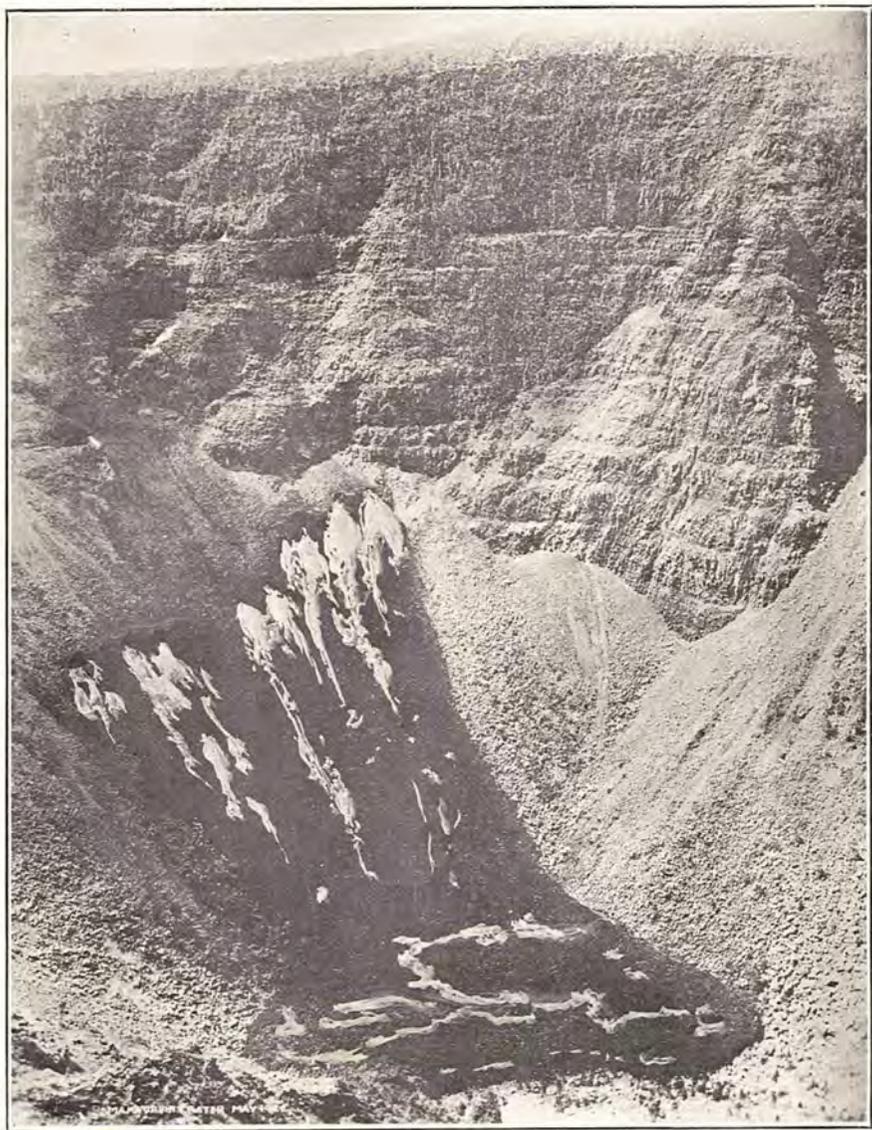


Figure 6. May 29, 1922. North wall of Makaopuhi Pit during lava flows from upper part of the talus filling bottom area. Photo Morihiro.

At 9:30 a. m. the pit was overhung with salmon-colored dust and white fume. Talus was sliding most of the time and small soft clouds of dust rose. Bottom of pit showed two principal convergent talus slopes from north-northeast and from west sides; the south and east sides were rock surfaces, the former sloping inward at a high angle and covered with a mask of fine debris. The east wall was very steep and showed rounded projections below. Rock face of north wall contained small ragged dykes, one of these trending east and west and dipping about 80 degrees northward. Below it there was a rounded mass of massive rock sharply contrasted with the bedding of the flows. In the forenoon no trace of molten lava was visible but it made its appearance in afternoon at base of southeast wall.

The great rift chasm southwest of Kilauea crater showed no changes except an unusual quantity of hot vapor. No activity was discernible in the desert to the south. Pink dust from recent avalanches was abundant in the desert and on southwest floor of Kilauea. During a shower the raindrops were found to be stained with pink dust, noises and puffs of avalanches coming from Halemaumau at the time.

Inspection of the rift zone near Halemaumau showed that the subterranean tunnel had become a chasm 40 feet wide and widening where it joined the pit. It was over 100 feet deep and floored with rock debris. It ended at what had been the lower rift well. The upper surface tunnel was still in place opening at the chasm, its entrance piled with debris. Hot sulphurous fume rose from the chasm. There was no sign of a tunnel extension along the rift from the lower well and no cracking in that direction on the floor of Kilauea crater. A large rectangular block several hundred feet long lay adjacent to the chasm on its southeast side, itself part of wall of pit and separated from the ground south of it by a crevasse which narrowed to a small crack in the direction of the south pressure ridge. This crack was very deep and emitted hot air.

About 1:45 p. m. an enormous general collapse took place inside the pit sending up red cauliflower clouds. The same thing had happened about this time of day on the two preceding days, as though the daily tidal subsidence of the lava below augmented the sliding in early afternoon. At 2:15 p. m. a black spot on southeast wall of pit broke away and allowed a quantity of lava to pour among the talus blocks making a pool 20 feet in diameter. Red hot paste fell into this pool from time to time for several minutes. There were other heavy falls especially from northwest wall of pit during the following two hours. Seismic disturbances were still abundant and many of them were felt. At night the pit was nearly dark except for a flaring glow from the small remnant area of live lava.

May 29. At 9 a. m. seen from Observatory pit was clear with white vapor rising from southwest rift chasm, and a downsunken ledge was visible forming a step in west rim of pit. Shortly after nine a spectacular avalanche cloud shot up in great volume making gorgeous brown volutes of hard outline rising one after another from the entire area of pit.

At 4 p. m. the funnel of talus was sliding occasionally but large avalanches were infrequent. The lava pool of southeast corner was covered with talus but the wall rock there showed fuming chasms. South pressure ridge was falling away in its upper parts and the ground back of its western half was crevassed for a width of 50 feet. Rim of pit elsewhere was changed and showed much overhang. Cracks along north edge were very hot. Pit had enlarged enormously toward the west and an immense slab of the wall 600 feet long by 60 deep had slid down forming a bench in the region north of the southwest chasm. Back of this bench was a chasm giving up hot vapor along the entire line. The southern wall slab had dwindled to a narrow tabular mass which stood out as a tower inside of the pit. The opening of the tunnel gorge was no longer a narrow canyon, but had become a wide flaring valley with two or three pinnacles standing out from the wall and rapidly crumbling. The area

west of the pit was crevassed for a long way back, the cracks sending up dense clouds of steam.

Fume from the pit itself was thin and at night the pit was dark.

Activity of Puna Craters.

May 28. About 8 p. m. a slow swaying earthquake was generally felt at Kilauea. Red glow was observed a few minutes later in the direction of the Puna craters. At 11 p. m. a definite fume cloud was seen from Uwekahuna Bluff, with red illumination from lava below in the direction of Makaopuhi.

An Observatory expedition was at once organized and a party consisting of T. A. and I. P. Jaggar and R. H. Finch went in motor car by way of Keauhou road to the Kalapana trail. Thence the march was on foot, first by that trail and then through the forest in the direction of the glowing clouds. An old aa flow was crossed amid small tree growth and the edge of Makaopuhi pit was reached at 3:20 a. m., May 29. The new eruption was inside of the deeper or northern half of this pit.

Frothy semi-aa lava had welled up back of the talus at the fuming cracks on north side of crater. Here along a straight line about 500 feet long and 500 feet below rim of crater, the spouting melt at the top of the talus had formed twenty small cone pots giving vent to light frothy spatter which settled airily on the slopes below and bounced like spume blown by the wind. Flames were burning at the gas vents. From seven of these vents streams were trickling down the long talus slope in channels of their own substance from 2' to 4 feet wide. The material forked out below in leaf-like forms on the surface of a new pool 350 feet long making a new bottom to the crater. The largest vent near the western end of the line spouted continuously, the lava flowing out under a bridge of its own construction that later broke down and revealed a gushing sluiceway.

Flames were bluish and numerous both at the vents and through crevices in the slope. Around edges of pool the lava invaded bushes and small trees making yellow flames and some explosions. The larger stream showed some tendency to pahoehoe festooning. Elsewhere the flow was crumbly, making typical aa fragments, and a line of dark curdled matter was rafted down the middle of each stream. The material broke away and dripped in aa fashion.

The most notable odor from the lava was a foundry smell perceived over a mile away. Close at hand the smell was of sulphur dioxide and bluish smoke rose from the vents. Rain clouds of water vapor formed above. On the western edge of Makaopuhi the steaming cracks 50 to 100 feet back from the rim seemed hotter than usual but this vapor was odorless.

May 29. By daylight the fresh flow area inside Makaopuhi was blackish or reddish and showed surfaces partly pahoehoe and partly aa. Details of action in the flaming pots resembled in miniature the Alika source cones of 1919. Some of the vents were partially closed and exploding, others were flaming and appeared very bright inside, and more than one had its stream encased in a shell where bright windows revealed the melt inside.

During this day the number of open ribbons of flow dwindled and at no time during our visit was the gas pressure strong. The orifices were only about 3 feet across and the spray was jettied only a few feet. The shell of cascade lava over the talus left a few islands of debris revealed, showing that it was very thin.

On returning toward Puu Huluhulu at 9 a. m. May 29 fresh earthquake cracks were observed a mile away from Makaopuhi trending toward Kau Desert. They showed freshly broken soil and hot vapor, one of them 8 inches across. This crossed the Kalapana trail 3 miles south of Puu Huluhulu.

The activity of Makaopuhi dwindled during the day, three of the streams keeping up their flowing. C. Stanley of the drill crew went to the bottom area by way of southwest wall of pit and verified the texture of semi-aa lava and rough pahoehoe festoons.

Mr. Mudd of the U. S. Geological Survey, in camp at Keaouhou, was at Makaopuhi about 9 a. m. and saw smoke in direction of Napau crater. His party completed a trail through the jungle to Napau from the Kalapana trail along southeast boundary of National Park. They heard the rumble of the eruption at some distance from the crater and found noisy thunderous spouting lava at northeast edge of Napau mostly along the wall-crack, but partly on the plateau above pit on that side. Their route went N. 23 E. to small pit crater west of Napau, then to south border of Napau and across bottom to the place of activity.

Mudd by later surveys determined that another crater of Napau type lying farther to the northeast had in it fresh lava of this eruption. The Makaopuhi eruption apparently came to an end soon after these craters broke out.

May 30. The Observatory staff went to Napau by way of the Mudd trail. Time occupied: to Puu Huluhulu, 45 minutes (motor); to Mudd trail 3 hours; trail to Napau, 2 to 4 hours by different individuals.

This track was a rough traverse line through fern jungle full of fallen logs, with holes in the mat of vegetation revealing ancient aa. The small crater is a deep wooded pit; Napau proper is a large shallow circular saucer 150 feet deep with flat floor and wooded slopes, the bottom partly covered with small growth and moss.

From the south rim a small patch of active lava was visible against northeast wall consisting of three black cascades down the wall, the small rough flow below, a field of lava at the source of the cascades, and a smoking chimney cone against the wall north of the cascades built up steeply of driblet lava 100 feet high.

Activity had almost ceased but there was abundant smoke smelling of iron and organic matter and suggesting a pork slaughter house.

The trail led down a steep wooded cliff on southeast side of crater and across the mossy bottom. A line of ancient cones was found crossing north side of bottom along a rift zone trending N. 50 E. The same rift had opened for the present eruption making a fresh fissure and talus on west side of crater, a steaming vent in the middle of the line, the active lava at northeast wall, and another steaming place in high ground a quarter mile farther northeast. The old vents had made loose aa which it was necessary to climb for a height of 10 feet, this was covered with moss. The new flows were piled on top of this old flow.

The new flow at the foot of the bluff consisted of aa about 6 feet thick forming a walled area lying against the cliff 300 feet long. In front of this there were three pronounced lobes of pahoehoe, very hot and glowing in the cracks. This flow had been fed by the chimney cone against the bluff. Southeast of this cone the three driblet cascades of pahoehoe had come straight down the bluff, now all frozen and black, and leading from a source consisting of one big cone at the edge of the bluff and a lava field beyond not visible from below.

Messrs. Stanley and Silverspar visited this upper area and found four cone vents and a lava area 200 yards across, larger than the area at the foot of the cliff. The only sign of activity was a breathing noise from the lower smoking cone. The pahoehoe flow was still slightly in motion as indicated by crunching movements and snapping sounds.

The night was spent in bivouac at Napau.

May 31. Observatory party left Napau at 5:30 a. m. and reached the Observatory at 3 p. m. Messrs. Silverspar and Stanley had returned the previous day by following the 1840 flow west of Napau, traveling the length of this flow on smooth lava, then traversing a very bad strip of jungle by compass to the south corner of Makaopuhi crater where they emerged on the trail.

The harmonic tremors which had been marked during the Puna eruption, had now nearly ceased. Some earthquakes had been felt in Panau, but not at Kalapana and not at Kapoho.

LAVA MEASUREMENTS.

Measurements of depression (—) and of elevation (+) of the mobile lava column, made with transit, referred to northeast station on rim of Halemaumau pit (3727 feet above sea-level), for the month ending May 31, 1922, including crag peaks of bench magma and mean liquid level of lake magma, were as follows:

	Mean Lake Level.	South Crag.	Northwest Crag.	East Central Crag.
May 2, 11:00 a. m..	—58 feet	+56 feet	+46 feet	—13 feet (Apr. 18)
“ 12, 11:30 a. m..	—49 “	+73 “	....	+30 “
“ 18, 10:00 a. m..	—118 “	+3 “	—20 “	—41 “
“ 23, 10:00 a. m..	—439 “	—306 “	—351 “	....
“ 25, noon.....	—487 “	—363 “	—444 “	....
“ 26, 2:30 p. m..	—659 “	....	....	....

Progressive changes for the liquid lava were as follows:

May 2-12, 10 days, lake rose.....	9 feet, averaging per day...	+0.9 feet.
“ 12-18, 6 “ “ “ lowered... 69 “	“ “ “	—11.5 “
“ 18-26, 8 “ “ “ ...541 “	“ “ “	—67.6 “

Progressive fluctuation in level of south crag was:

May 2-12, 10 days, crag rose.....	17 feet, averaging per day...	+1.7 feet.
“ 12-18, 6 “ “ “ lowered... 70 “	“ “ “	—11.7 “
“ 18-25, 7 “ “ “ ...360 “	“ “ “	—51.4 “

Northwest crag summit subsided as follows:

May 18-25, 7 days, crag lowered.....	424 feet, averaging per day...	—60.6 feet.
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Relief of peaks above lake was:

May 2, south crag 114 ft., northwest crag 104 ft., east central crag .. ft.		
“ 12, “ 122 “ “ “ “ “ “ 79 “	“ “ “	“ “ “
“ 18, “ 121 “ “ “ “ “ “ 77 “	“ “ “	“ “ “
“ 23, “ 133 “ “ “ “ “ “ ..	“ “ “	“ “ “
“ 25, “ 124 “ “ “ “ “ “ ..	“ “ “	“ “ “

Details of the great subsidence after May 26 were not measurable as the lava column disappeared in dust and talus and the surveying stations were destroyed. The average daily rate of subsidence shown above as from 51 to 68 feet was not regular; the record of lake and south crag May 18-23 was about 62 feet per day but only 26 feet per day May 23-25; the next day the lake lowered 172 feet and the diminishing relief of northwest crag shown in above table indicates that it was going down faster than the lake. The next survey early in July made the bottom of the convergent talus 872 feet below where the old northeast station had been (3727-foot datum level), and all the lava column had long since disappeared under debris heaps. May 29 the lava flowing at Makaopuhi and Napau was at elevations 2500 and 2700 above sea-level; on May 12 the lava flowing in Halemaumau pit had been at elevation 3678. As the Puna crater unquestionably drained Kilauea, it seems reasonable to conclude that the lava column under Halemaumau subsided not less than one thousand feet. A rate of 100 feet per day from May 26 to May 30 would agree with this conclusion, and heavy avalanches, occasioned by general collapse in center of pit, occurred throughout this period, only slightly smaller than those of May 26; as the measured rate of subsidence on that day had been 172 feet before the tremendous collapse of the afternoon, a rate of 100 feet for the succeeding four days may be considered a minimum. Slower subsidence went on in June as evidenced by avalanches in the pit, but the convergence of talus in relation to rock funnel appeared to hold a fairly constant position. Even rough measurement is difficult and dangerous under these conditions, as vertical angles are over 50 degrees and edge of pit is everywhere cracked and overhanging. To measure depth with such angles the horizontal triangulation must be precise.

The following table shows comparative monthly changes of level for mean lake lava and mean crag lava, beginning with July, 1921, (May figures assuming 1000 feet subsidence after May 12):

Month	Liquid lava	Bench lava
July	-22 feet	-14 feet
August	+119	+118
September	+138	+158
October	-259	-253
November	-18	-21
December	+16	+18
January	+25	+29
February	+40	+40
March	+92	+80
April	+104	+106
May	-990	-970

SEISMOMETRIC RECORD.

During the month ending midnight May 31, 1922, 589 local earthquakes and one distant shock were registered at the observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W, 10h. 30m. 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; Δ=distance in miles.

May	May	May
1 6:45 p. vf.	5:27 p. vf.	6:36 p. s Δ 11.
3 3:51 p. f Δ 12.	8:15 p. vf.	6:44 p. f.
3:53 p. vf.	8:35 p. vf.	6:47 p. vf.
10:20 p. vf.	9:06 p. s Δ 3½.	7:06 p. vf.
4 11:45 a. f.	10:42 p. s Δ 2.	7:14 p. s Δ 2½.
4:30 p. vf.	11:30 p. f.	7:20 p. vf.
6 8:40 p. vf.	11:15 a. f.	7:21 p. vf.
10 8:35 a. vf.	5:14 a. vf.	7:22 p. f Δ 4.
11 10:17 p. vf.	5:39 a. vf.	7:35 p. vf.
15 11:42 a. f Δ 3.	5:44 a. vf.	7:59 p. vf.
17 6:13 a. vf.	5:47 a. vf.	8:07 p. vf.
11:14 a. vf.	6:56 a. vf.	8:08 p. vf.
2:05 p. f Δ 4.	8:56 a. f.	8:16 p. vf.
6:50 p. vf.	9:27 a. vf.	8:18 p. vf.
9:49 p. vf.	11:58 a. f.	8:36 p. vf.
10:07 p. vf.	12:14 p. f.	8:38 p. f.
10:51 p. vf.	1:31 p. vf.	8:39 p. s Δ 3.
10:52 p. vf.	2:24 p. s Δ 2½.	9:05 p. vf.
11:10 p. vf.	3:43 p. vf.	9:30 p. vf.
18 12:03 a. vf.	4:11 p. vf.	9:49 p. vf.
2:07 a. vf.	4:20 p. vf.	10:22 p. vf.
2:46 a. vf.	4:21 p. vf.	10:29 p. vf.
2:47 a. vf.	4:22 p. vf.	10:39 p. vf.
2:48 a. f.	4:39 p. vf.	10:41 p. vf.
3:19 a. vf.	5:11 p. vf.	11:48 p. f.
3:34 a. vf.	5:14 p. vf.	20 12:09 a. vf.
4:32 a. vf.	5:15 p. vf.	12:29 a. vf.
7:10 a. s.	5:18 p. s.	12:33 a. vf.
7:15 a. vf.	5:19 p. vf.	1:43 a. vf.
8:40 a. vf.	5:24 p. vf.	2:49 a. vf.
11:23 a. vf.	5:30 p. vf.	2:54 a. vf.
11:47 a. vf.	5:43 p. f.	4:32 a. vf.
11:49 a. vf.	5:47 p. vf.	5:26 a. vf.
1:12 p. vf.	5:48 p. vf.	7:01 a. vf.
1:25 p. vf.	5:49 p. s Δ 3½.	8:55 a. s Δ 4½.
1:32 p. f.	5:54 p. vf.	8:59 a. s Δ 4½.
2:04 p. vf.	5:58 p. vf.	9:13 a. m Δ 4½.
2:26 p. vf.	6:04 p. f Δ 3½.	10:47 a. vf.
3:21 p. vf.	6:25 p. s.	12:59 p. vf.
4:20 p. f.	6:28 p. vf.	1:48 p. vf.
4:27 p. vf.	6:29 p. vf.	2:30 p. vf.

May

4:53 p. vf.
 4:54 p. vf.
 5:22 p. vf.
 5:27 p. vf.
 5:37 p. s Δ 4½.
 7:10 p. s.
 7:12 p. vf.
 7:13 p. s.
 7:14 p. vf.
 7:16 p. vf.
 7:17 p. s.
 7:18 p. s.
 7:19 p. s.
 7:20 p. m. d.
 7:23 p. f.
 7:26 p. s.
 7:30 p. s.
 7:31 p. f.
 7:38 p. f.
 7:39 p. f.
 7:42 p. s.
 7:43 p. s.
 7:48 p. f.
 7:49 p. f.
 7:51 p. s.
 7:52 p. f.
 7:53 p. m. d.
 7:57 p. f.
 7:59 p. f.
 8:00 p. f.
 8:02 p. f.
 8:07 p. f.
 8:11 p. s.
 8:12 p. s.
 8:18 p. s.
 8:19 p. f.
 8:27 p. s.
 8:28 p. f.
 8:29 p. f.
 8:31 p. s.
 8:34 p. f.
 8:40 p. f.
 8:49 p. s.
 8:53 p. s.
 9:01 p. s.
 9:09 p. f.
 9:32 p. f.
 9:35 p. s.
 10:04 p. f.
 10:05 p. f.
 10:41 p. f.
 10:44 p. s.
 10:54 p. s.
 11:18 p. s.
 11:48 p. s.
 21 3:23 a. s.
 8:56 a. vf.
 9:56 a. vf.
 9:58 a. vf.
 10:13 a. m Δ 10.
 10:50 a. f.
 10:58 a. f.
 11:05 a. f.
 11:25 a. vf.
 12:20 p. s Δ 10.
 12:29 p. f.
 5:07 p. f.
 6:32 p. vf.
 7:06 p. vf.
 7:10 p. vf.
 8:29 p. vf.
 8:33 p. f.
 8:40 p. vf.

May

9:02 p. vf.
 9:27 p. vf.
 9:39 p. vf.
 11:16 p. vf.
 11:46 p. vf.
 22 12:18 a. f Δ 4½.
 12:57 a. vf.
 2:39 a. vf.
 2:45 a. vf.
 2:58 a. vf.
 3:34 a. vf.
 4:02 a. f.
 4:34 a. f.
 6:39 a. vf.
 7:20 a. vf.
 9:38 a. vf.
 9:54 a. s.
 10:13 a. vf.
 11:58 a. vf.
 12:13 p. vf.
 2:28 p. s Δ 6.
 2:43 p. f.
 3:15 p. vf.
 4:31 p. f.
 4:53 p. m. d.
 5:20 p. f.
 5:36 p. s Δ 5½.
 6:00 p. f.
 7:37 p. vf.
 8:32 p. s Δ 9½.
 8:38 p. f.
 8:45 p. s Δ 9½.
 9:24 p. s Δ 5½.
 9:26 p. s Δ 9.
 9:37 p. f.
 10:12 p. f.
 10:15 p. vf.
 10:23 p. vf.
 10:24 p. m. d.
 10:49 p. s.
 11:06 p. s.
 11:26 p. s.
 11:31 p. s.
 11:35 p. f.
 23 12:49 a. f.
 1:34 a. f.
 1:39 a. f.
 2:44 a. f.
 5:19 a. f.
 9:10 a. vf.
 9:59 a. vf.
 2:45 p. vf.
 4:05 p. vf.
 8:19 p. s.
 8:48 p. vf.
 10:18 p. f.
 10:46 p. f.
 10:25 p. vf.
 24 12:45 a. vf.
 2:47 a. s Δ 6.
 12:26 p. s Δ 14.
 12:46 p. vf.
 1:14 p. vf.
 1:26 p. vf.
 3:11 p. vf.
 3:33 p. vf.
 4:17 p. s.
 5:45 p. f.
 6:15 p. f.
 6:37 p. vf.
 6:45 p. f.
 6:48 p. vf.
 6:54 p. vf.

May

6:58 p. vf.
 9:09 p. f.
 9:10 p. s Δ 4.
 9:42 p. s.
 9:44 p. s.
 9:45 p. s.
 9:47 p. s.
 9:50 p. s.
 9:54 p. s.
 9:58 p. m.
 10:05 p. vf.
 10:06 p. f.
 10:08 p. s.
 10:10 p. f.
 10:14 p. vf.
 10:15 p. s.
 10:17 p. vf.
 10:22 p. s.
 10:24 p. f.
 10:27 p. f.
 10:32 p. vf.
 10:53 p. f.
 11:11 p. f.
 25 12:09 a. f.
 12:43 a. m.
 12:55 a. s.
 2:00 a. m.
 2:08 a. f.
 4:45 a. f.
 5:09 a. f.
 5:15 a. vf.
 5:41 a. s Δ 9.
 5:54 a. f.
 6:04 a. vf.
 6:07 a. s.
 6:15 a. m. d Δ 10.
 8:24 a. vf.
 8:26 a. vf.
 8:34 a. f.
 9:02 a. s Δ 9.
 9:11 a. f.
 9:30 a. vf.
 9:33 a. vf.
 9:44 a. vf.
 9:53 a. f.
 9:54 a. f.
 11:33 a. vf.
 12:15 p. vf.
 12:59 p. vf.
 1:28 p. vf.
 3:06 p. vf.
 3:08 p. vf.
 3:34 p. vf.
 3:41 p. vf.
 3:59 p. vf.
 4:27 p. vf.
 4:37 p. vf.
 4:45 p. vf.
 4:51 p. vf.
 4:53 p. vf.
 5:03 p. vf.
 6:07 p. f.
 6:30 p. vf.
 6:41 p. vf.
 7:22 p. vf.
 7:54 p. vf.
 9:17 p. vf.
 9:26 p. vf.
 9:36 p. d. m.
 9:58 p. vf.
 10:13 p. vf.
 10:25 p. vf.
 10:41 p. m Δ 6.

May

11:13 p. vf.
 11:24 p. d. m Δ 9.
 11:26 p. m.
 11:43 p. m. Δ 11.
 26 12:06 a. vf.
 12:57 a. vf.
 1:13 a. vf.
 2:28 a. f.
 3:41 a. vf.
 4:14 a. vf.
 4:16 a. vf.
 4:20 a. vf.
 6:03 a. vf.
 6:46 a. vf.
 6:51 a. vf.
 6:52 a. vf.
 6:54 a. f.
 7:59 a. vf.
 8:21 a. vf.
 9:02 a. s Δ 9.
 9:23 a. vf.
 9:24 a. f.
 9:40 a. f.
 9:43 a. vf.
 9:44 a. vf.
 10:22 a. vf.
 10:26 a. vf.
 10:35 a. vf.
 10:40 a. vf.
 10:57 a. s.
 11:11 a. f.
 11:19 a. vf.
 11:26 a. vf.
 12:20 p. vf.
 12:33 p. vf.
 12:40 p. vf.
 12:47 p. f.
 12:54 p. vf.
 1:30 p. vf.
 1:46 p. vf.
 1:47 p. vf.
 1:48 p. vf.
 1:49 p. vf.
 1:50 p. vf.
 1:51 p. vf.
 1:52 p. vf.
 1:53 p. vf.
 1:54 p. vf.
 1:57 p. f.
 1:59 p. f.
 2:30 p. vf.
 2:35 p. vf.
 2:40 p. vf.
 2:44 p. vf.
 3:01 p. vf.
 3:10 p. vf.
 3:19 p. f.
 3:40 p. vf.
 3:43 p. s.
 4:24 p. f.
 5:00 p. vf.
 5:19 p. s Δ 6.
 6:01 p. f.
 6:09 p. vf.
 6:33 p. f.
 6:50 p. vf.
 6:51 p. vf.
 6:54 p. vf.
 6:57 p. vf.
 7:09 p. vf.
 7:11 p. vf.
 7:19 p. vf.
 7:20 p. vf.
 7:24 p. vf.

May

8:09 p. vf.
 8:10 p. vf.
 8:37 p. s.
 8:43 p. vf.
 8:57 p. vf.
 9:14 p. f.
 9:18 p. vf.
 9:20 p. vf.
 9:21 p. s.
 9:38 p. s.
 9:59 p. vf.
 10:14 p. f.
 10:23 p. vf.
 10:30 p. vf.
 10:39 p. f.
 10:55 p. s Δ 9.
 10:58 p. vf.
 10:59 p. vf.
 11:08 p. vf.
 11:36 p. f.
 11:51 p. vf.
 27 12:01 a. vf.
 1:52 a. vf.
 2:14 a. f.
 2:21 a. f.
 2:24 a. f.
 2:32 a. vf.
 2:36 a. f.
 2:42 a. vf.
 2:56 a. vf.
 2:57 a. f.
 3:07 a. vf.
 3:14 a. vf.
 3:36 a. vf.
 3:43 a. vf.
 3:48 a. vf.
 3:50 a. vf.
 3:58 a. f.
 4:03 a. vf.
 4:09 a. vf.
 4:10 a. f.
 4:11 a. f.
 4:12 a. f.
 4:13 a. f.
 4:17 a. vf.
 4:20 a. vf.
 4:21 a. vf.
 4:36 a. vf.
 4:53 a. vf.
 4:56 a. f.
 5:01 a. vf.
 5:06 a. vf.
 5:31 a. vf.
 5:43 a. s. Δ 6.
 5:51 a. vf.
 5:54 a. s. Δ 5.
 5:56 a. vf.
 5:58 a. vf.
 6:04 a. vf.
 6:19 a. vf.
 6:32 a. vf.
 6:45 a. vf.
 7:15 a. vf.
 1:09 p. f.
 1:13 p. vf.
 1:30 p. vf.
 1:35 p. f.
 1:40 p. vf.
 1:45 p. f.
 2:24 p. vf.
 2:30 p. vf.
 2:36 p. vf.
 4:36 p. f.
 5:32 p. vf.

May

5:54 p. f.
 6:23 p. vf.
 6:37 p. f.
 6:39 p. vf.
 6:44 p. vf.
 6:45 p. vf.
 6:46 p. f.
 6:47 p. f.
 6:48 p. f.
 6:49 p. s. d.
 6:51 p. f.
 6:52 p. s.
 6:54 p. m. d.
 7:04 p. vf.
 7:06 p. f.
 7:10 p. vf.
 7:11 p. f.
 7:26 p. f.
 7:56 p. f.
 7:58 p. s.
 8:00 p. f.
 8:04 p. m. d. Δ 5.
 8:27 p. vf.
 8:35 p. vf.
 8:44 p. vf.
 8:50 p. f.
 9:35 p. vf.
 10:01 p. vf.
 10:31 p. s.
 10:57 p. vf.
 11:11 p. s. Δ 6.
 11:26 p. f.
 11:47 p. vf.
 11:48 p. vf.
 11:49 p. vf.
 11:50 p. vf.
 28 12:58 a. f.
 1:54 a. vf.
 6:04 a. vf.
 6:11 a. vf.
 6:25 a. vf.
 6:50 a. vf.
 7:55 a. s. Δ 5.
 9:02 a. s. Δ 10.
 9:11 a. f.
 9:37 a. vf.
 11:33 a. vf.
 11:50 a. f.
 12:54 p. vf.
 1:49 p. vf.
 1:51 p. vf.
 1:58 p. vf.
 2:47 p. vf.
 2:49 p. vf.
 2:53 p. vf.
 2:55 p. f.
 2:56 p. vf.
 2:59 p. vf.
 3:01 p. vf.
 3:24 p. vf.
 3:36 p. f.
 3:39 p. f.
 3:40 p. m. d. Δ 11.
 4:24 p. vf.
 5:24 p. vf.
 5:42 p. s.
 5:45 p. vf.
 7:07 p. vf.
 7:10 p. s.
 7:36 p. vf.
 7:45 p. vf.
 7:57 p. d. m.
 11:17 p. vf.
 11:49 p. vf.

May	May	May
29 12:18 a. vf.	9:36 p. vf.	12:21 p. f.
1:30 a. vf.	2:01 a. vf.	3:19 p. f.
2:52 a. vf.	2:03 a. f.	5:55 p. vf.
7:04 a. vf.	12:46 p. vf.	6:51 p. vf.
7:27 a. f.	2:35 p. vf.	8:49 p. vf.
7:33 a. vf.	11:10 p. vf.	8:59 p. vf.
7:59 a. vf.	11:51 p. f. $\Delta^2 \frac{1}{2}$.	9:12 p. vf.
8:53 a. f.	31 3:23 a. vf.	10:23 p. vf.
12:20 p. f.	3:24 a. vf.	11:23 p. vf.
12:34 p. vf.	4:06 a. vf.	11:32 p. s.
2:48 p. f.	5:54 a. vf.	11:40 p. vf.
5:05 p. f.	10:34 a. vf.	11:55 p. vf.
9:03 p. vf.	10:37 a. vf.	11:57 p. vf.
9:30 p. f.	10:57 a. vf.	11:59 p. vf.

All of the moderate earthquakes and most of the slight were felt locally.
Teleseism.

May 11, 11:00 p.m. Slight.

Spasmodic Microtremor.

This type of tremor by weeks beginning April 29 was registered as follows:

April 29-May 5 Moderate.

May 6-12..... Slight.

“ 13-19..... Slight.

“ 20-26..... Slight.

“ 27-June 2. Moderate increasing to strong on 2nd.

Harmonic Microtremor.

This type of tremor was registered as follows:

April 29-May 5 Slight.

May 6-12..... Very slight.

“ 13-19..... Slight.

“ 20-26..... Slight to moderate.

“ 27-June 2. Moderate to strong.

Tilting of the Ground

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

April 29-May 5 3.1 seconds NE.

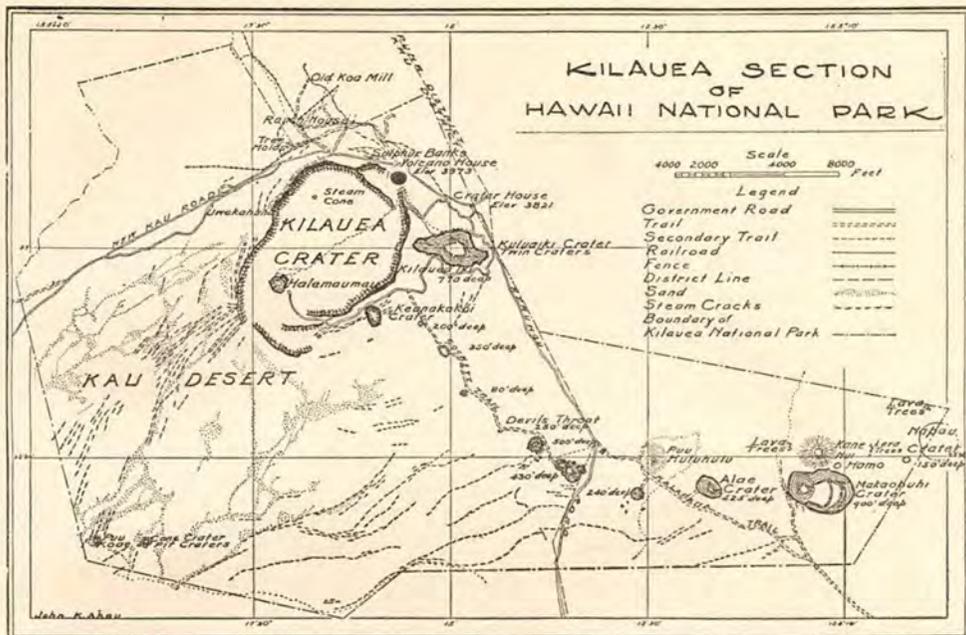
May 6-12..... 1.9 “ SW.

“ 13-19..... 4.1 “ NNE.

“ 20-26..... 5.6 “ SSW.

“ 27-June 2. 11.4 “ SSW.

T. A. JAGGAR,
 Volcanologist.



Black spot shows location of Observatory.

All exchanges should be addressed to

HAWAIIAN VOLCANO OBSERVATORY,

Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismometric instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of local earthquakes; one optically recording seismograph for distant earthquakes; one clinograph registering E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete piers in a closed basement room having practically constant temperature, beneath the chief Observatory building near the hotel. Time is referred to a rated chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. 19° 25' 54.2" N.; Long. 155° 15' 39.2" W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun," a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Sword (*Argyroxiphium*). Thirteen volcanic cones lie wholly within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvelously beautiful.

Waiuku is the point of departure, automobiles taking the traveler to Olinda, a summer residence settlement 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of 3½ hours. Here is a fine concrete rest house, built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa, a vast dome 13,675 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bril-

liantly colored lava slopes, has a summit crater 3 miles long by 1½ miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jetted 500 feet into the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaii National Park, if not in the world. The pit of fire, Halemauau, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overridden by the lava slopes of Mauna Loa on the west, so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solfataras and a strange desert where lava flows have poured out of cracks as recently as 1920.

The live pit of Halemauau is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvelous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory, which stands on the brink of the greater crater within the Kilauea Park.

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, CHIEF

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HONOLULU, HAWAII, JUNE, 1922

No. 6

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GENERAL MAP KILAUEA NATIONAL PARK.

PROGRESS OF BORING EXPERIMENTS.

Boring in June, 1922, continued with impact drill as before. A limit of 50 feet of depth was set for Hole No. 2 at Sulphur Bank and this was reached June 12. Mr. Hobart, the contractor, then returned to Honolulu, leaving his crew at work, and field operations were thereafter in charge of Mr. Jaggar, aided by Driller J. Waikoloa. The assistants were R. Kaili, C. Stanley (rigger), and R. Ingalls. The remainder of June was spent in roadmaking, hauling and starting Hole No. 3 on the pahoehoe lava floor of Kilauea crater, 3000 feet

southeast of center, about 0.9 mile east from Halemaumau. The rough track built for hauling water and machinery to this point left the Halemaumau road at the gravel flat a mile west of Keanakakoi, followed edge of gravel thence east for a half-mile, then turned north over flat pahoehoe for 0.4 mile.

Hole No. 2

Drilling at this steaming hole gave trouble, and five days out of ten spent in finishing the job were without downward progress. At 20 feet depth, the hole was cased and the bit reduced from 8 inches to 7 inches diameter. Here under-reaming was necessary to lower the casing. Heating and tempering the steel failed at the field forge, and bits were sent to blacksmith at Mountain View, thanks to cooperation of Olaa Sugar Company. The steel tended to flake off. At 42 feet depth, string of tools was wedged by infalling rock fragment, springing cam-shaft and breaking a gear wheel. Recovering tools used up three days. At this depth longer casing was installed which at first shut off much of the steam. Sulphides appeared to be decreasing. The bit was reduced to 6 inches diameter. At 43 feet depth, steam developed again. At 50 feet depth, all sludge and water disappeared in an east-west crack across bottom of hole.

The temperature of steam possibly increased from 96° minus to 96° plus in going down to 50 feet depth, but maximum thermometer is not trustworthy to fractions of a degree. The hole when finished was cased with 7-inch iron pipe 6 feet long set in concrete so as to protrude a few inches above ground, and covered with a screw cap. In a few weeks the inner surfaces of the iron were black with sulphide; and free sulphur crystals formed a yellow zone upward from the level where atmospheric chilling caused condensation on interior of pipe and cap. Whenever cap was removed steam rose under some pressure, smelling of spicy sulphur and sulphurous acid gas, and nucleating to thick vapor if subjected to contact with a smouldering brand such as burning rope or cigar. Hole No. 1, 22 feet deep, produced the same phenomena. At either hole if a cold steel bar was inserted in steam column, water condensed off bar in a steady stream. When drill tools were wedged in hole 42 feet down, a jet of cold water from hose allowed to fall on the tools made a bubbling rumble as though the water boiled on contact with the iron.

Consumption of water in June on Hole No. 2 was 18.6 gallons per foot. Drilling record was as follows:

Date 1922	Machine hours	Hours other work	Progress (feet)	Depth (feet)	Water hauled (gals.)	Notes.
June 1	5	3	0	20.1		Under-reaming casing.
2	6	2	6.0	26.1	95	Finished reaming.
3	6	0	8.9	35.0	190	Sludge lost at depth 30-34.
5	0	5	0	35.0		Dressing tools.
6	4	4	7.0	42.0	95	Tools stuck; machine broken.
7	0	8	0	42.0		Repairs.
8	0	8	0	42.0		Fishing for tools.
9	5	3	0	42.0	50	Recovered tools.
10	6	0	2.5	44.5	100	Set casing.
12	4.5	3.5	5.5	50.0	25	Finish 1:30 p.m. Sludge lost.

Average drilling in rock for this period was 0.82 foot per machine hour and drill operation was 3.65 machine hours per day. Footage averaged 2.99 feet per day.

Temperature of Hole No. 2.

Temperature measurement of Hole No. 2 with maximum Centigrade thermometer was as follows:

1922 Date and Time	Depth (feet)	Air Temperature		Bottom Temperature		Notes.
		Cent.	Fahr.	Cent.	Fahr.	
May 26, 8 a.m.	6	16°	61°	53.3°	128°	Sulphurous earthy bottom.
June 1, 10 a.m.	19	16°	61°	96.2°	205°+	Hole 20.1 feet deep.
3, 8 a.m.	26	15°	59°	{ 95.2°	203°	Exposure in mud.
				{ 96.0°	205°	Exposure in steam.
5, 9 a.m.	35	16°	61°	{ 96.3°	205.5°	Thermometer cased in pipe.
				{ 96.3°	205.5°	" " " "
				{ 96.0°	205—°	Bare bulb in mud.
6, noon..	20?	19.5°	67°	96.3°	205.5°	Top of tools in hole.
						Hole 42 feet deep.
10, 8 a.m.	40+	18°	64°	96.3°	205.5°	After lifting tools.
11, 10 a.m.	44.5	18.5°	65°	97.0°	206.5°	Reading at moment of leaving steam.
12, 11 a.m.	49	18°	64°	97.0°	206.5°	Reading in steam.
				96.0°	205—°	" outside steam after shrinkage.

Air temperatures are taken from thermograph at Observatory. Prior to June 5 mouth of well was covered with sacking during exposure of thermometer; thereafter it was left open. All readings were with same thermometer. Lowering and raising thermometer was done as rapidly as possible without jarring. Ten minutes exposure was used at first, but five minutes were found to be more than sufficient. Readings were made after withdrawing thermometer from the well. On June 5 thermometer was thrust in one of the steaming holes lined with prisms of sulphur at Sulphur Bank; while in hole the reading was 96°; after cooling thermometer in bucket of water the reading was 95.5°. Ordinarily the observed shrinkage of mercury in air was 0.2°. Thermometer immersed in mud of sump June 3 and 5 gave lower readings than when exposed in the steam; in both cases no fresh water had been put in well since the previous day; mud on bulb insulated instrument during raising; hence the mud reading was probably near the true temperature of bottom at depths 26 to 35 feet. The mean of these two readings was 95.6°; the mean of readings similarly made (after shrinkage of mercury) for depths 40 to 49 feet was 96.2°, and it was here that cold water on hot iron made an explosive rumbling. It will be profitable to bore this hole deeper and find out whether the temperature really rises. Evidence so far merely indicates that 96° is a constant for from 10 to 50 feet of depth at Sulphur Bank. If the temperature were to lower with depth, maximum thermometer would be useless for its measurement.

Temperature of Kilauea Floor.

Cracks in a lava mound near Site No. 3 were vaporizing at temperature 55° Cent. The ground where Hole No. 3 was started is smooth lava on a flat-topped spur of the Kilauea inner dome, dating presumably from the overflows of 1894, and not hot, though warm cracks occur here as everywhere in the crater.

A temperature survey made in the spring of 1912 in and near Kilauea crater resulted as follows, thermometer being thrust in so-called "steam cracks." The larger cracks are cooler than the smaller ones. The cracks commonly tested in this survey were from 1 to 3 inches wide and permitting downward insertions of thermometer from 1 to 3 feet. Since 1912, floor of Kilauea crater has been overflowed with fresh lava in many places, so that temperature distribution is somewhat different now. Table is arranged in order of maximum temperatures. The maxima are the hotter cracks, and the minima the cooler cracks for each district. The time was February 29 to March 4, 1912.

Temperature Survey Kilauea, 1912.

Districts.	Number of measurements.	Maxima		Minima	
		Cent.	Fahr.	Cent.	Fahr.
Vicinity of Halemaumau.....	6	145.5	294	64.0	147
Sulphur Bank	6	65.5	204	66.0	151
South margin near Keanakakoi.....	7	94.5	202	43.4	110
Northern floor Kilauea	11	89.0	192	36.7	98
Eastern floor Kilauea	7	84.0	183	39.0	102
Northeast floor Kilauea	5	81.7	179	57.8	136
Steam flats west of Volcano House.	13	80.5	177	47.8	118
South central floor Kilauea.....	2	73.3	164	66.6	152
North edge Kilauea	2	70.0	158	55.0	131
Observatory grounds	2	59.0	138	25.5	78

This table does not include the Postal Rift northeast of Halemaumau which maintained a temperature about 320° C. (608° F.) for many years and still asserts its presence as a superheated solfataric vent through the lava covering of 1919.

Hole No. 3.

Journal of road grading, hauling and assembling rig June 13-27 in preparation for Hole No. 3 follows:

1922

- June 13-15, Stowed tools and graded road southeast border Kilauea.
 15, Cemented Hole No. 2 and hauled 15 gallons water to Site No. 3.
 16, Hauled drill and engine to gravel flat.
 17, Hauled drill to Site No. 3 and bits to Mountain View for sharpening
 19, Hauled engine and 50 gallons water to Site No. 3, sleds and tools to gravel flat.
 20, Hauled tower, braces and tools.
 21, Repaired motor-car.
 22, Continued hauling and grading bad parts of road.
 23, Finished hauling and repairs to road.
 24, Assembled drill. Tested tractor on inner lava fields.
 26, Set up engine. Sent feed-wheel Mountain View for repair.
 27, Hauled casing and began drilling with 10-inch bit.

The following is the labor and drilling record for June in preparing and starting Hole No. 3:

Date 1922	Ma- chine hours	Hours other work	Prog- ress (feet)	Depth (feet)	Water hauled (gals.)	Notes.
June 13	0	8				Grading road, etc.
14	0	8				“ “ “
15	0	8			15	Dismantling and grading.
16	0	8				“ “ hauling.
17	0	4				Hauling.
19	0	8			50	“
20	0	8				“
21	0	8				“ and repairs.
22	0	8				“ “ grading.
23	0	8				“ “ “
24	0	4				“ “ assembling.
26	0	8				Assembling and repairs.
27	1	7	0.2	0.2		Hauling and drilling.
28	7	1	1.3	1.5	95	Drilling and hauling.
29	2	6	0.7	2.2		Bit broken at thread.
30	0	8	0	2.2		Hauling and repairs.

Moving rig was very arduous work and kept five men busy for twelve days. A platform trailer wagon was built using the steel wheels and axles of drill machine, and after depositing the latter this wagon was assembled and hauled by motor car. The tractor was serviceable on the main road, but too high-g geared and inflexible for the lava fields. A dump-cart was attached to motor-car and used partly for hauling dirt in grading road. From gravel flats to Hole No. 3 the rough road of 0.9 mile was about two-thirds flat lava in its original condition, the remainder being graded and filled very little, but enough to be barely passable. This road owing to its poor quality required much patching, and on the up-grade southward the hauling by motor-car was assisted by much pushing and occasional use of wire-rope in order to give the car traction on flat ground. Water was hauled partly in 100-gallon iron drum or wagon, partly in 50-gallon barrel mounted on rear end of car. It was stored at the drill in two barrels. The loads hauled were found to give least trouble when carried on the car, as the increased traction, vibration and difficulty in steering of trailers made haulage very slow and necessitated many stops for roping. The long loads especially, such as tower timbers, gave least trouble when they were lashed to sides of motor-car. At gravel flats the loose lapilli are deep and troublesome, with steep slopes; a motor truck with wide tires was tried here, dug itself in, and was extricated with difficulty; the special double wheels of motor car carried heavy loads easily over this material and the planetary low gear and flexible springs greatly facilitated driving in otherwise impossible rocky country. A water-tank of 2000 gallons capacity, formerly on the Mauna Loa trail, was set up at cantonier's hut near the Bench Mark south of Byron's Ledge, and this water will eventually be available for boring experiments in crater.

Shot Core Drill.

What is known as a Davis Calyx Drill, model BF4, made about 1912, was purchased from the Hutchinson Sugar Plantation Company at Honuapo, Hawaii. This machine is equipped to bore a 4-inch hole to a depth of 1000 feet taking a core about 3.25 inches diameter. The bit is a slotted tube rotated on the lower end of hollow rods so that water and chilled steel shot fed down the rods are brought under edge of tube, where the shot abrades the rock to form an annular groove. The water washes away the detritus, a core is left in the tube, and this is eventually broken off and lifted to the surface. Inventory of this outfit was checked at Honuapo by Messrs. Jaggard and Hobart May 20. By June 1 the machine in many boxes had been delivered at Observatory, including materials for steel tower 38 feet high, pulley, shafting, triplex pump, hoist, drill head, platform, core barrels, rods, bits, couplings, tools and abrasive. During June some of the drill crew were occasionally employed overhauling and oiling this apparatus in preparation for assembling it in August. A shed had been built for housing it and the Olaa Sugar Company kindly furnished a number of barrels for use in trapping extra rain water and arranging settling tanks. All the water used in this country must be accumulated from roofs.

Summary of June Drilling.

The average drilling in rock for June at Holes Nos. 2 and 3 was 0.69 foot per machine hour. Owing to time consumed in repairs and moving drill, operation for the month averaged only 1.79 machine hours per day. Omitting the 12 days of hauling, road-making and assembling, drill operation was 3.32 machine hours per day. On this last basis (omitting days of dismantled machine) the daily footage for 14 days of work at the bore-holes averaged 2.29 feet per day. The consumption of water per foot of drilling for the month was 22.3 gallons per foot.

What these figures demonstrate is that the cost in labor of repairs and moving in a remote region without roads is great. At the end of June it was beginning to be apparent that the churn drill is not an economical machine for boring shallow holes in hard basalt, though its economy of water was evident. The tendency for the hole to go crooked, for the string of tools to stick, for

rapid dulling of bits, and the necessity for much casing and reduction in size of bits downward, all made it apparent that some form of rotary drilling would probably succeed better. The rock specimens resulting from core-drilling are necessarily better for scientific purposes. In the work to date samples of sludge were bottled and preserved at the end of each spell of drilling; such material however is mixed and individual lava layers are not separated.

VOLCANIC CONDITIONS IN JUNE.

Activity of Halemaumau.

After the first of June the avalanching in Halemaumau diminished and there was left an enormous pit of oval form 2,000 feet long southwest-northeast and 1,500 feet wide. The bottom was a V-shaped meeting of two main talus slopes, the bigger on the southwest and the smaller northeast, both occasioned by major caving in along the 1920 rift line. Depth of pit was over 850 feet and rim of pit was everywhere lower than it had been by from 11 to 31 feet. On the western side of the pit everything had fallen in for 500 feet back carrying away the two rift wells and all the old landmarks. Away down the inside walls of pit there were dykes or fissure fillings of lava, and the rock of lower walls was notably earthy, oxidized and stained with solfataric salts. No puffing of gas could be heard and there was no further activity in the Puna craters.

The second week of the month showed stationary conditions, the tremors and earthquakes which had accompanied the recent subsidence died away and the volcano entered upon a repose period similar to the one which last occurred in 1913. It differed from that, however, in the notable absence of smoke.

Halemaumau had become a profound funnel with convergent slopes of reddish debris on its bottom. A long ledge trending north and south protruded from the lower part of the southeastern wall, and the southern wall west of this ledge was niched in an arc by excessive avalanching at that point, just over where the buried lava column was last seen. This wall was especially earthy and decomposed in its lower layers. Smoke rose from fissures on the steep western side of the ledge mentioned, and there was also smoke in the notch or chasm of the Kau rift tunnel southwest.

By the middle of the month Kilauea and Mauna Loa appeared completely dormant, the only signs of underground heat being solfataric activity in the floors and around the margins of the craters. The most interesting side of Halemaumau was the southwest corner where a buttressed pinnacle stood out from the wall, sulphurous smoke rose from the chasm where the lower rift well had been, and a crescent of the rim had subsided to make a sunken inner bench. The fume was so slight that from this corner the whole vast interior was easily seen at a flat angle.

About the solstice there were notable avalanches of debris, these sometimes sending up dust clouds sufficient to make showers of rock powder on Uwekahuna bluff.

On the north side of the bottom area of Halemaumau there was a smooth rounded wall consisting of a lava veneer left by the column of molten stuff that had subsided.

Avalanches during late afternoon June 19 were coincident with three small earthquakes that may have set the debris in motion. Air above the pit was dusty for several hours. In the calm weather rock falls at Halemaumau were heard two miles away in evening June 23, and again repeatedly during the next two days. Large dust clouds rose at 9 a. m. June 25 and were repeated at intervals for a half hour. The effect of the avalanching was to carry away portions of rim south and east and to create dangerous cracks there. Slight fume rose from three places inside the pit.

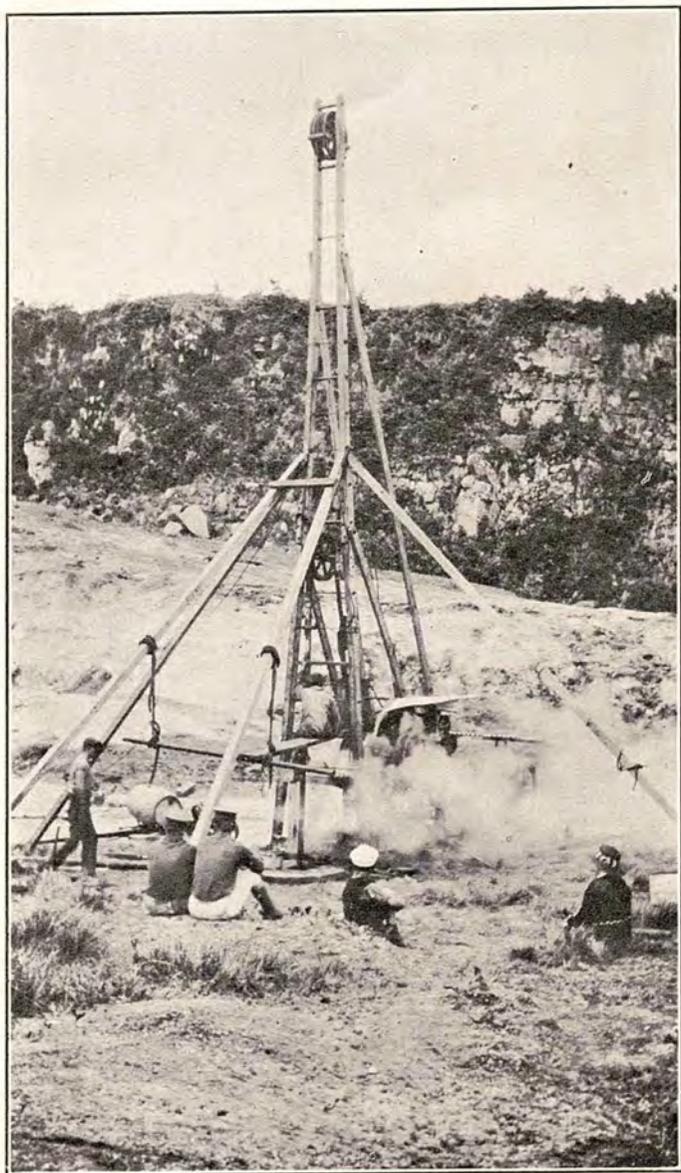


Fig. 7. Churn drill at Hole No. 2, Sulphur Bank. Photo Hobart.



Fig. 8. Motor car with double wheels and special gears hauling drill near Hole No. 3, Kilauea crater. Photo Jaggar.



Fig. 9. May 30, 1922, lava outbreak northeast side Napau crater, showing smoking cone and lava cascades on cliff. Photo Jaggar.

Discussion of Special Features.

The Puna eruptions manifested underground drainage of Halemaumau at the end of the eruptive cycle that began 1913. No such eruptions on the Puna rift of Kilauea had occurred since 1840. There was, however, activity at Kilauea Iki 1868 and at Keanakakoi 1877. There have been a number of features of the intense Hawaiian volcanic activity of the last four years to link this period with the two periods of major activity here respectively sixty-five and one hundred and thirty years before 1920. The years 1790 and 1855 were both times of unusual volcanic stress, and of these the 1855 period is best known to us. It was a long term of many years of intense lava outpouring from both Mauna Loa and Kilauea culminating in movements on both the southwestern and southeastern rifts of Kilauea. Probably something of the same sort occurred during the decades following 1790. The 1920 crisis resembled the period of 1855 and thereabouts in the series of Mauna Loa eruptions finally reaching the sea, in the outbreaks from both rifts of Kilauea, and in the upbuilding and collapse at Halemaumau. It should be understood that such an eruptive period merely centers around the year mentioned, and its term or duration may be decades long. We do not yet know whether the 1920 crisis is to have after effects for decades to come. The 1855 term produced enormous flows from Mauna Loa, great upbuilding at Kilauea and great collapse in 1868. The 1920 term so far as it has gone has produced three eruptions of Mauna Loa, beginning 1914, two outflows of Kilauea away from the central crater, much upbuilding and collapse there, and the succession throughout showing progressively lower vents from Mokuaweoweo, the summit crater of Mauna Loa in 1914, to Makaopuhi, the lowest of the outbreaks from Kilauea in 1922.

The nine-year interval that was noted by Green as representing a statistical average for rhythmic recurrences of like events in the Mauna Loa cycle has been strikingly confirmed since Green's time. The record of a decade at this observatory shows that Kilauea plays an equal part in that cycle. The 1913-22 cycle is one of these nine-year intervals, and it seems likely that the 65-year interval is somehow made up of about eight of these shorter cycles. In other words the Hawaiian volcanic system, in addition to the shorter term tides and rhythms, diurnal and seasonal, may have these compounded in terms of nine years, sixty-five years and still longer cycles that are measured in centuries.

JOURNAL.

June 1. At 5:40 p. m. the pit of Halemaumau contained convergent slides of talus still in almost continuous motion and there was increased fume from southeast wall cracks. Occasional avalanches made red clouds of dust. Abundant steam and fume rose from the upper western chasms. Table crag at southwest margin and western fault bench were still in place. Southeast pressure ridge on rim of pit was becoming shorter by caving in at both ends through the undermining action of avalanches, and its top was less jagged.

Dykes concentric with the pit, presumably representing old wall-crack fills, appeared in lower part of pit wall both north and south.

Not a trace of glow or live lava could be now seen in Halemaumau and no blowing noises were audible. The continued slumping of convergent talus suggested more subsidence of the subterranean lava, and as earthquakes and harmonic microtremors were pronounced on this day in spells lasting several hours each, the Puna rift belt was kept under surveillance by telephone communication with observers at Kapoho. A slight earthquake was reported there about the midnight preceding but nothing more developed.

June 2. The harmonic tremor decreased. At Halemaumau there was some settling of the western fault bench. At 6:15 p. m. a large avalanche cloud shot up from the pit.

June 3. Small avalanches fell from all sides, most numerous southeast. Fume in pit was thin, some rising at inner southeast ledge but at southwest chasm the fume was dense.

June 4. At 5 p. m. the pit was steaming southeast, but from northeast there was clear seeing. The long west bench was backed by steam jets along the chasm behind it. South-southwest table rock had lost its summit and become a buttress. Talus at bottom of pit was red and wet, and ledge outcropped near bottom on the east side. Bottommost points in pit lay in a crease trending north and south where slopes met. On the southeast side the wall projected in a buttress so as to present a vertical precipice with smoking cracks toward the west and rounded surface toward the east. Southeast wall of pit under the ragged pressure rim was very steep making a rounded bay at the bottom with freshly broken gray surfaces and small avalanches still falling from the wall itself. Otherwise the pit was very still and the air clear, and the talus slopes were not sliding.

Lower walls of pit were very red and mineralized to various colors. Criss-crossing dykes appeared in some places. There was much massive and finely laminated rock showing irregular rounded upper boundaries where the flow layers begin. Some of the dykes appeared to dip at high angles into the walls north and south.

June 6. Fume in pit was increasing. At 2 p. m. a red avalanche cloud rose from south side.

June 7. Fume was again thin and at 7 a. m. an avalanche fell from north side.

June 9. At 5 p. m. there were a few western slides and avalanche clouds, volcanic smoke rose from southeast corner and southwest chasm, but otherwise the pit was clear.

June 11. A strong avalanche at southeast wall made red cloud at 10:04 p. m.

June 13. At 4:30 p. m., south-southwest buttress was now becoming sharp like a steeple through a process of scaling off continuously and making small slides. Southeast wall was also scaling off, making pressure rim smaller.

June 15. A large avalanche cloud at 1:30 p. m.

June 16. At 4:30 p. m. fume at Halemaumau was moderate and some sliding was seen.

June 18. At 11 a. m. survey flags were placed and pit was clear. Southwest chasm was found to extend farther southwest than former second rift well, and the channel and tunnel of 1921 flow emerged on southwest rim of pit. In the chasm smoking debris stood only 80 feet down and this was continuous with the long inner talus slope of the pit. Rift cavern under this talus was totally buried. Slight rock falls were heard this day.

June 19. Avalanche clouds rose from pit at 4 p. m. and 5 p. m. Visible vapor, nucleated by the dust, increased for about three hours. Three earthquakes indicated on the seismograms probably occasioned the avalanches.

June 20. Places where rim had newly caved in were located south and east of pit. Rocks were still sliding occasionally.

June 23. At 11 a. m. the three fume sources were southwest chasm, under lower west pinnacle and at base southeast wall. Small avalanches fell from west wall and rock fragments occasionally elsewhere. The chasm back of west fault bench had widened since it was first formed. In the evening the air was still and a fall of rocks was heard at observatory, presumably at Halemaumau.

June 24. In forenoon there were several rock falls at pit. At 5 p. m. all was very quiet. Sulphurous blue-brown smoke at southwest chasm had slightly increased. Southeast upper rim had been caving in, making fresh cracks back from the rim. A flag station south had fallen in as well as some of the National Park signs.

Smooth rounded surfaces of plastered wall veneer formed wall of pit low down on north side. Tops of talus slopes were bordered with black dust separated by gravity. In north and south walls there were cracks in veneer remnants more or less parallel to the wall surface.

June 25. On preceding night there was rock sliding, and noises made by slides were heard in the morning and large dust clouds hung over Halemaumau

from 8:50 to 9:10 a. m. At 4:20 p. m. pit appeared as before but east and south rim had been scaling off.

June 26 and 27. A few slides.

June 28. Pit was very clear and fume from southwest chasm slight. Avalanche cloud at 5:20 p. m. was simultaneous with earthquake shown on seismogram.

June 29 and 30. No changes were observed in pit.

SEISMOMETRIC RECORD.

During the month ending midnight June 30, 1922, 101 local earthquakes and three distant shocks were registered at the observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W., 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

Abbreviations have meanings as follows: Vf=very feeble; f=feeble; s=slight; m=moderate; d=instruments dismantled; and Δ=distance in miles.

June 1	12:05 a. f.	June 4	9:52 a. vf.	17	9:59 a. vf.
	12:51 a. vf.		9:54 a. vf.		2:12 p. vf.
	12:54 a. vf.		11:08 a. s.	18	1:22 a. vf.
	1:00 a. vf.		11:47 a. vf.		2:23 p. vf.
	1:04 a. vf.		12:13 p. s.Δ2½.		7:04 p. vf.
	4:23 a. vf.		4:50 p. f.	19	3:43 p. s.Δ6.
	6:56 a. vf.		4:58 p. vf.		4:46 p. vf.
	7:36 a. s.		6:20 p. vf.		7:14 p. f.
	8:08 a. vf.		6:30 p. vf.		7:17 p. s.Δ6.
	8:57 a. f.		7:42 p. vf.		11:47 p. vf.
	11:45 a. vf.		10:46 p. vf.		11:50 p. vf.
	11:47 a. vf.	5	1:31 a. vf.	20	6:13 p. vf.
	2:48 p. vf.		2:42 a. f.	21	6:44 a. f.
	3:48 p. f.		3:18 p. vf.		3:28 p. vf.
	6:56 p. f.		4:41 p. vf.		4:41 p. vf.
	8:07 p. f.		11:30 p. vf.	22	8:43 a. vf.
	8:19 p. vf.	6	12:40 a. vf.		8:44 a. vf.
	8:52 p. sΔ3.		1:55 a. vf.		9:06 a. vf.
	8:55 p. vf.		5:00 a. vf.	23	7:34 p. vf.
2	12:40 a. f.		5:18 a. vf.	24	8:32 a. f.
	4:23 a. vf.		8:31 a. vf.		12:25 p. vf.
	5:04 p. f.		10:17 a. vf.		1:11 p. vf.
	6:21 p. d.m.Δ6.		11:16 a. vf.	25	8:45 a. vf.
	11:52 a. f.Δ4.		12:33 p. s.		8:56 a. vf.
	6:14 p. vf.	7	9:00 p. vf.		9:01 a. vf.
3	12:08 a. vf.	9	2:22 p. vf.	26	11:52 p. vf.
	2:00 a. vf.		3:07 p. vf.	28	1:08 a. vf.
	4:17 a. vf.		9:18 p. vf.		4:33 p. vf.
	5:37 a. s.Δ9.	12	4:10 a. vf.		4:35 p. vf.
	7:59 a. s.		4:11 a. vf.		5:14 p. f.
	8:17 a. vf.	13	12:30 a. vf.	29	6:36 a. vf.
	2:47 p. vf.		6:11 a. s.		7:18 a. vf.
4	5:50 a. vf.	14	2:45 a. vf.	20	4:24 p. f.Δ4½.
	6:10 a. vf.		3:10 p. vf.		
	8:23 a. vf.				

Most of the slight earthquakes and the moderate ones were felt locally.

Teleseisms.

June 12,	6:35 p. m.	Slight.
13,	12:32 a. m.	Slight.
16,	10:40 a. m.	Slight.

Spasmodic Microtremor.

This type of tremor, by weeks, beginning June 3, was registered as follows:

- June 3-9. Moderate.
10-16. Slight, increasing to moderate on 14th.
17-23. Slight.
24-30. Slight, increasing to moderate on 28th.

Harmonic Microtremor.

This type of tremor was moderately strong on June 1 and slight thereafter.

Microseismic Motion.

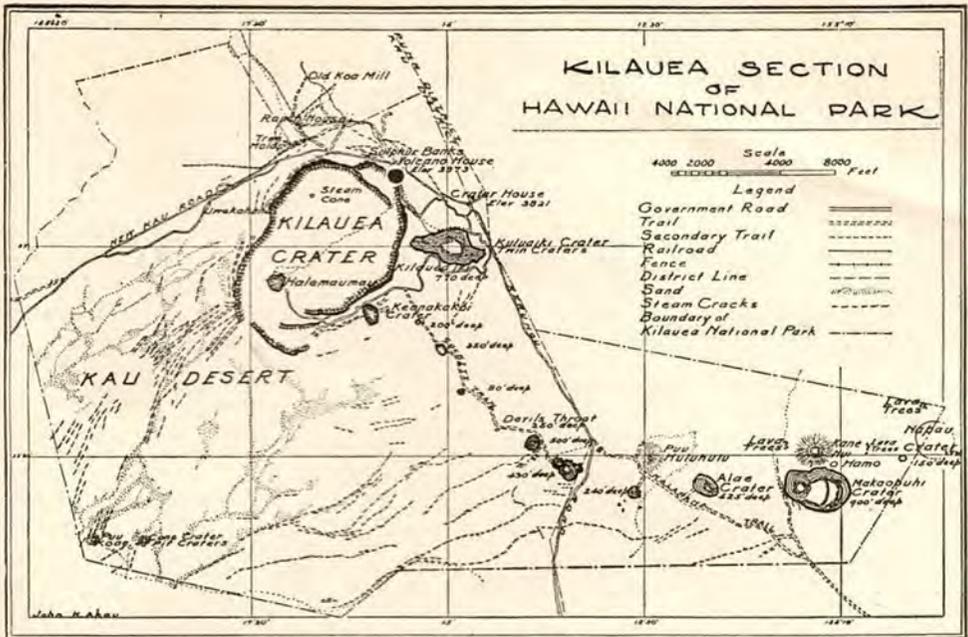
The amplitude of microseisms was moderate on June 11 and slight on other days.

Tilting of the Ground.

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

- June 3-9. 2.6 seconds SSE.
10-16. 0.4 second S.
17-23. 4.5 seconds SSW.
24-30. 2.1 " SSW.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges should be addressed to

HAWAIIAN VOLCANO OBSERVATORY,

Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismometric instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of local earthquakes; one optically recording seismograph for distant earthquakes; one clinograph registering E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete piers in a closed basement room having practically constant temperature, beneath the chief Observatory building near the hotel. Time is referred to a rated chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. 19° 25' 54.2" N.; Long. 155° 15' 39.2" W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun," a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Sword (*Argyroxiphium*). Thirteen volcanic cones lie wholly within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvelously beautiful.

Wailuku is the point of departure, automobiles taking the traveler to Olinda, a summer residence settlement 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of 3½ hours. Here is a fine concrete rest house, built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa, a vast dome 13,675 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bril-

liantly colored lava slopes, has a summit crater 3 miles long by 1½ miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jetted 500 feet into the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaii National Park, if not in the world. The pit of fire, Halemauama, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overridden by the lava slopes of Mauna Loa on the west, so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solfataras and a strange desert where lava flows have poured out of cracks as recently as 1920.

The live pit of Halemauama is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvelous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory, which stands on the brink of the greater crater within the Kilauea Park.

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

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No. 7

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PROGRESS OF BORING EXPERIMENTS

Boring on Kilauea Floor.

Hole No. 3 on the Kilauea floor east of Halemaumau was bored down to depth 79.3 feet during July, 1922. Hole was begun with 10-inch bit, reduced to 8-inch 8 feet down, 6-inch 25 feet down, and 4-inch 70 feet down. Ten days out of twenty-four were without progress owing to repairs, wedging of tools and their recovery, reaming for casing, and altering casing. At the depth stated, 79.3 feet, boring was stopped and churn drilling suspended. The 4-inch bit was there sticking owing to wear on cutting end of tool reducing diameter, and so making hole smaller than shank of bit.

Bits gave much trouble throughout the month. They were sharpened at a forge 19 miles from the work. Bit in one case was too large for the casing when returned, then when casing was withdrawn broken rock fell in and jammed the tool. A day was lost recovering the string of tools by straining on tackles and jarring. To proceed safely it was necessary to replace casing and use a dull tool which fitted the casing. It was hoped to go down 100 feet and reaming was tried with this in view. This resulted in jamming and a broken treadle timber. This was replaced at a planing mill 36 miles away. On another occasion a break at a coupling made it necessary to transport a heavy sinker bar and bit 56 miles to Olaa machine shop and back.

Water consumption as before was very small. Following are the figures for May, June and July:

	Days of operation	Total gallons	Gallons per foot
Water consumption in May	13	530	12.6
" " " June	14	715	22.3
" " " July	24	855	10.8

The average use of water by the churn drill was therefore 41.2 gallons per operating day for the whole period, and 13.9 gallons per foot for 151.5 total feet drilled.

Drilling record for July is as follows:

Date 1922	Machine hours	Hours other work	Progress (feet)	Depth (feet)	Water hauled (gallons)	NOTES
July 1	0	4	0	2.2		Three men oiling other drill. Repairs.
5	5	3	5.8	8.0		8-inch bit. Water in hole.
6	6.5	1.5	9.0	17.0		Soft "sandy" rock. Water escapes.
7	5	3	5.0	22.0	100	Some repairs.
8	4	4	2.5	24.5		Hole caving.
10	2.5	5.5	3.5	28.0	90	Set casing. Bit 6-inch. Water escapes.
11	6.5	1.5	6.8	34.8	100	Lengthened casing.
12	6.5	1.5	4.2	39.0		Some repairs. Oversize bit.
13	2.5	5.5	5.0	44.0	100	Drilled without casing and bit became wedged.
14	2	6	0	44		Fishing for tools.
15	7	1	2.6	46.6		Lifted tools. Set casing. Water escapes.
17	7	1	0	46.6		Reaming to enlarge hole.
18	5.5	2.5	0	46.6		Reamer stuck and broke treadle.
19	0	8	0	46.6	100	Repairs and work on other drill.
20	5	3	3.4	50.0		Set casing. Bit 6-inch. Water in hole.
21	7	1	14.0	64.0	90	Soft rock.
22	5.5	2.5	6.0	70.0		Soft rock. Water escapes. Repair car.
24	1.5	6.5	0	70.0	50	Tool wedges and recovered. Caving.
25	6.5	1.5	0	70.0	175	Caving hole. No progress.
26	0	8	0	70.0		Hauling and setting casing.
27	5.5	2.5	7	77.0		Start removal of spare tools. 4-inch bit, followed with casing.
28	6	2	2.3	79.3		Bit sticking. Water escapes. Hauling
29	5	3	0	79.3	50	Bit worn, shank wedges. Hauling.
31	0	8	0	79.3		Dismantling. Repair car.

Summary of July Drilling.

Average drilling in rock for this period was 0.75 foot per machine hour, and drill operation was 4.25 machine hours per drilling day. Footage averaged 3.21 per drilling day. The maximum day's progress was 14 feet and the minimum for a day of actual drilling was 0 feet when the hole caved in continuously for 6.5 hours. When this was cased it was found that 5.8 feet of loose material had caused the caving. Down to 50 feet an iron ladle was found useful when the sand-bucket failed in material of this kind, but the ladle could not be handled deeper than this.

Temperature of Hole No. 3.

Temperature measurement of Hole No. 3, Kilauea floor, with maximum Centigrade thermometer, was as follows; air temperature was read in the field:

1922 Date and Time	Depth (feet)	Air		Bottom		Notes
		Temperature Cent.	Fahr.	Temperature Cent.	Fahr.	
June 27, 4:00 p.m.	0.0	20.0	68.0	25.0	77.0	Surface
July 5, 5:00 p.m.	8.0	20.0	68.0	35.0	95.0	In water.
6, 4:30 p.m.	17.0	19.5	67.0	37.5	99.5	1 foot water. No odor.
7, 5:00 p.m.	22.0	17.0	62.6	47.0	116.5	
8, 1:00 p.m.	24.5	24.0	75.2	46.0	114.9	
11, 4:30 p.m.	34.8	19.5	67.0	60.0	140.0	
12, 4:30 p.m.	39.2	17.0	62.6	57.5	135.6	Two readings.
17, 3:15 p.m.	46.6	23.5	74.2	65.5	150.0	Debris in sump.
20, 4:30 p.m.	50.0	20.5	69.0	65.5	150.0	In water.
21, 3:40 p.m.	62.5	18.0	64.5	66.0	150.8	Two readings.
24, noon	70.0	24.5	76.0	64.0	147.2	Mud remains after 40 hours without new water.
25, 4:00 p.m.	70+	20.5	69.0	65.0	149.0	Caving formation; mud.
28, 2:50 p.m.	79.3	22.5	72.5	69.0	156.2	Cased to 76 feet depth.

It was supposed that under the Kilauea floor very high temperatures might be found. Therefore this gradient was a surprise. No sulphurous smells came up the well and at the end of the work only odorless warm moist air rose from the opening. As will be seen from the table the gradient resolves itself into five stepwise rises of temperature with distinct flattenings of the curve, and even downward bends, in between. These are

Rise 0 to 8 feet depth	Rise 25 to 35 feet depth
Flat 8 " 17 " "	Fall 35 " 39 " "
Rise 17 " 22 " "	Rise 39 " 46 " "
Fall 22 " 25 " "	Fall 46 " 70 " "
	Rise 70 " 79 " "

Neglecting the steps, the curve is steepest for the first ten feet and then flattens progressively from a temperature of 35° C. to a fairly constant temperature of 65°+ from 46 to 80 feet of depth.

Summary of churn drilling May-July, 1922.

The following table sets forth the statistics of drilling with four men and a superintendent at Kilauea to date. The working day was eight hours and "machine days" were those when machine was not dismantled.

The record is for the separate months May, June and July, and also shows averages deduced from summation of the monthly records:

Month 1922	Average drilling per machine hour (feet)	Average number machine hours per day (hours)	Average rock footage per day (feet)	Maximum days rock progress (feet)	Total footage per month (feet)	Number of machine days	Number of non-machine days
May	0.79	3.15	2.49	5.8	42.1	13	0
June	0.69	3.32	2.29	8.9	32.1	14	12
July	0.75	4.43	3.35	14.0	77.1	23	1
Whole period	0.74	3.63	2.71	14.0	50.4	17	4.3

The men who labored on this contract did heroic hard work uncomplainingly. The reason for examining these statistics so particularly with reference to engineering methods is that the writer has in mind carrying forward boring experiments for years to come for geophysical purposes, and he hopes others will do likewise and profit from these figures. It is difficult to find out what drilling methods were used at the steam power plant of Larderello in Italy, for example, and what was the cost in labor and time. It is hoped to use our figures as basis for incessant experimental improvement until apparatus is perfected for scientific borings deep and shallow at maximum efficiency and minimum expense.

The churn boring here described is neither efficient nor inexpensive; when drilling was in progress there were men waiting; when road-making was in progress there were too few men and those too highly paid for such coarse work; machine was too weak for this method on such hard rock; bits were too few, too dull, and not of most effective shape; rock specimens were poor and ineffective; the method of slow up-and-down churning like mortar-and-pestle makes a ragged hole unnecessarily big that tends to go crooked, to cave in and wedge the tools, and to require casing that shuts off side vents of gas or steam if such exist. Rock was too dry for sand bucket. The rope method gives no grip on the tool nor precision to its motion. What in the air-percussion or rotary drills is achieved by high speed is here attempted by extra weight of tools. Where rotation for a rod drill will extricate a bit, there is here only jarring and pulling. Extra weight means difficulty of transportation.

The contractor, Mr. Hobart, did everything possible and this is not criticism of him or his crew. It is a criticism of churn drilling in general as applied to lava-flow topography. These flows behave like tough trap sheets, not like the brittle porous lava that seems so friable on the surface. Confidence that high-speed drilling would make better progress is based on a demonstration of air percussion drill, at a basalt quarry, given the writer by the Hawaiian Contracting Company in Hilo. This drill with star bit and solid steels delivering 500 blows per minute bored holes 3 inches in diameter and 20 feet deep in a little over an hour. The limit of such drilling is usually set at 30 feet of depth, but as the average depth of the three holes at Kilauea is only 50 feet, it would seem that valuable work ought to be possible with an equipment using compressed air.

Discussion of special features.

THERMAL GRADIENT OF BORE HOLES. In every possible way Hole No. 3 is thermally different from the holes at Sulphur Bank. Both are cut through hard lava flows but there the resemblance ends. The Sulphur Bank wells are steaming under some slight pressure, they hold a nearly constant temperature at the boiling point of water for the elevation, and if there is a gradient in 50 feet of depth it is hardly more than the rise of boiling point for 50 feet of depression. Moreover the steam smells strongly of sulphurous acid gas and weakly of sulphur, and contains mostly water vapor and little air. Here on the Kilauea floor there is much air and little water, and nothing else perceptible, at a temperature 80 feet down 26° below the boiling point; and the gradient flattens out remarkably, with positive inversion at certain depths.

Comparing temperature survey of cracks published in June 1922 Bulletin, the area in which Hole No. 3 is placed corresponds to "south central floor Kilauea," a low temperature region. The hotter cracks are near the edges of the floor, but also in the marginal cliffs, as at Sulphur Bank and near Keanakakoi. The places of highest temperature, as in Halemaumau, are along the "wall-crack," that is, where gas from below percolates through buried talus slopes and border cracks concentric to the heavy fill that has choked center of funnel. The hot Postal Rift is an old wall-crack of the 1894 pit. Possibly along the wall-crack also there is the best supply of oxygen for union with combustible gases below.

If Sulphur Bank is an ancient wall-crack, the high temperature may be attributable to such gas reactions below, and the constant temperature to the kettle effect of boiling rain-water at no great depth. As there are no geyser explosions or puffings, the presumption is that such water, in this region of 100 inches rainfall per annum, has an established underground circulation. It is possible that the depth is no greater than the surface of the present subterranean lava column; in 1921 the live lava was at elevation 3730 feet, and now it is about 2900. Sulphur Bank is at elevation 3940. If this argument had any value a boring in 1921 of 190 feet depth at Sulphur Bank would have reached the critical level, and a boring now would reach it at 1040 feet depth.

However, the bottom of Kilauea Iki in 1921 was 600 feet below the live lava of Halemaumau, and the southeast wall margin of the greater crater, yielding hot sulphurous steam, was 200 feet below it, without any outpouring of geyser waters. Live basaltic lava is little controlled by hydrostatic laws, and the underground magma is a different substance from the surface froth. That froth rises hundreds of feet above the open basins by percolation through small cracks, and gas heating is in evidence at the top of Mauna Loa when the observed lava column is flowing vigorously on the flanks of Kilauea 10,000 feet below.

This discussion merely leads to the conclusion that a hole 1000 feet deep at Sulphur Bank should yield an instructive thermal gradient and some changes in gas composition with increased depth.

VOLCANIC CONDITIONS IN JULY

Activity of Halemaumau.

During the week ending July 2, Halemaumau pit showed no essential change and there was no volcanic activity of any kind on Mauna Loa or Kilauea, other than the usual quiet fuming.

In Halemaumau the principal fuming place was at the great southwest chasm, an extension of the pit itself, where the top of the talus was becoming yellow with sulphur and the blue smoke smelt of sulphurous acid. During the recent subsidence an enormous block of old rim rock on the north side of this chasm sank down about 20 feet, leaving crevasses on the outer

side, and making a crescent-shaped bench of a portion of the rim. This block is hundreds of feet high so that the crevasses are breaks hundreds of feet deep. The lava on the surface dates from 1894. Heat at the cracks is so great that red hot rock must be only a short distance down. Either an oxidation process is heating up the cracks, or the underpinning of the Kilauea floor is locally excessively hot even in its older portions.

This heat at the line of breakdown is of interest in connection with the borings on the outer floor of the big crater. Hole No. 3 80 feet down reveals no such high temperature, though of course it might do so if it were 500 feet deep, and the crevasses are at least that deep.

During the first week of July the pit resembled an immense quarry where every rock lying on the convergent slopes inside might be plainly seen. The sulphurous fuming patch at the chasm showed glow at night along the top of the debris slope about 100 feet below southwest rim of Halemaumau.

This patch was the main source of what little smoke now rose at the pit. It lay in the chasm between outlying pinnacles, where formerly the outermost rift well lay, and this was the vent that gave rise to the largest flows of March, 1921. The glow appeared to be evidence that live lava still occupied the great Kau Desert rift and might be rising through the rift cavern that is buried under the boulder slope. There were no flames nor gas hissings. The glow lay along a zone three feet wide by 25 feet long, the hottest cavities among the fragments being bright cherry red, the others dull red. In the crevasses farther north no glow was discernible, and the air rising there was odorless and scorching hot, so that paper thrown in browned immediately.

The second week showed increase of glow in the southwest talus heap so that by July 12 the glowing area covered a large part of the upper slope of boulders in the chasm. One bright glowing patch was nearly two feet square, of incandescence brighter than cherry red and probably maintained by invisible flames of burning gas. The surface looked like a bed of coals for a length of 75 feet. At the 1921-flow tunnel on the surface back from rim of pit transverse cracks had widened and brought up hot air from below. This place is just above the smoking chasm, but there was no sulphur fume in the tunnel cracks. The same is true of the northwest crevasses, and here sparks were seen to rise at this time.

Small avalanches occurred in Halemaumau, a notable one making a big dust cloud at 10:30 a. m. July 13. Avalanches were numerous July 16 and this was followed by an outbreak of lava at 2 a. m. July 17 at the top of the southeastern talus. This liquid lava was evidently from the wall-crack, gushed up in a fountain, and cascaded down the debris slope making a crusted pool in the bottom of the funnel.

The pit during the early morning hours of this day glowed brightly, whereas it had been dark before. Visited at 8 a. m., the new floor was found to be a glowing pool 350 feet long, and this increased to 490 feet during the day. The pool was fed by a trickling cascade 150 feet long sweeping down the debris slope. At top of cascade there was a pot next wall of pit 670 feet down where fountains rumbled and splashed and molten spray was hurled 30 to 50 feet in the air. The edges of the torrent had quickly formed a trough of black lava, mostly pahoehoe, but showing some aa on the edges. Everything was plainly visible and the display at night was brilliant. The outbreak resembled the Makaopuhi eruption of May 28.

It was a matter of great interest to note that this lava broke out 194 feet above the bottom of the pit, where the convergent talus slopes met at a depression 861 feet below rim. By noon July 17 the bottom was filled to a depth of 60 feet, the fill being fed wholly from above. This high source vent was destined to be the main lava conduit for the remainder of the year.

The new lava activity made little progress and its main flowing and filling action lasted four days, July 17 to 20. On the second day there

was a crusted pool that exhibited spells of breaking up, and the ribbons of black lava down the debris slope had become tunnels where the trickling streams flowed under crust to add substance to the lake below. The source cone smoked and falls of rock from the cliff above broke it open occasionally with spectacular effect.

On the third day there were avalanches and the pool was swollen and making trickling streams around its edge. The source pot was open and flinging up incandescent spray and splashes. Sometimes the whole lake surface broke up and made brilliant patterns like fiery ferns until it solidified and blackened.

By July 20 the lake surface had sagged, and the source cone, now 10 feet high, made three trickle flows on the slope below.

The next three days showed dwindling activity and increasing rock slides that overwhelmed and jumbled the cone, covered north side of floor, and whitened half of the black lava surface with dust. The cone continued to puff sluggishly and to give up smoke.

During last week of month the crusted pool developed enough gas to break up its shell so that the fragments foundered in the melt below and the surface was left lower than before with a shoreline bench around it. At the top of the frozen cascade that had supplied the pool, there was still a glowing and smoking pot that coughed occasionally. There had been a spell of much avalanching just before this that filled the air with dust and whitened the lava surfaces. Finally the glow waned, small avalanches continued, smoke increased, and the puffing became very slight. The first return of lava activity was succeeded by a quiet spell.

Discussion of special features.

THE VOLCANIC CYCLE. The parallelism of 1922 to 1913 as a quiet year following general collapse has now developed two striking similarities. The first was the disappearance of the lava in May, the second its temporary reappearance in July. The July eruption of 1913 was a welling up of lava at very low levels in a smoky pit and this was followed by extreme quiet in August. The main difference in the two years is in the present absence of smoke and in the much greater size of pit and depth of collapsing in 1922.

It should be borne in mind that the distinctive feature of the end of an eruptive cycle is not merely a collapse of the floor of a crateral pit, for such collapses often occur right in the middle of a term of productive outpouring. An example was the profound subsidence of November 28, 1919, at Halemaumau, followed at once by a startling recovery and great floods of lava in the Kau Desert for seven months. This indicated that the pit is mobilized so to speak, for a subsidence to depths of 600 feet and more and recovery therefrom at any time if a lava column with a high gas pressure is available.

The characters distinctive of the major subsidences of 1913 and 1922 were (1) risings about a year before the subsidence, accompanied by excessive tumultuous fountain action; (2) the subsidence itself giving evidence of utter burial of the lava column under debris; (3) a year of comparative dormancy, with lava at very low levels, following the collapse.

The meaning of these three features in bringing to a close an eruptive epoch at any volcano is probably (1) a release of pressure due to loss of substance and consequently a geyser-like gushing of gas; (2) an unusually great collapse occasioned by the voids left below; and (3) such depletion of gases in solution, throughout the magma chamber, as to require a definite interval before a new supply of the slow moving deeper substance rises to effect a new stress. This stress is destined to demand of the volcanic edifice a new rupture or series of ruptures during the next cycle. Each rupture relieves pressure and so permits effervescence.

Such analysis leaves open the following questions to be answered as ingenuity may direct experiment in the future. What is the volume evacuated during a single cycle? Is this a constant each cycle? How does this bulk, reduced to some common standard for porosity, compare with the measured uplift or subsidence of the resulting landscape? How do tilt and geodetic measurements check with the times of such vertical movement? What astronomic or geonomic forces control the rise of deeper magma? What is the best way of measuring total energy output during a single cycle? And lastly, what theoretical conditions, mechanical and chemical, in the deeper magma, check quantitatively with the heat and energy so measured? It will be seen that questions of this kind require definite measurements, instruments, workers, laboratories and surveys. And as partial answers are attained by investigation, each research adds new methods of greater precision to the routine recording done by an observatory.

It is entirely within the bounds of probability that volcanic districts equipped with recording stations will in a few years yield useful solutions of their problems by means of measurement. The station may be expected to report:

- (1) The major cycle of this volcanic system is q years.
- (2) The constant (or average) output extravasated per cycle is r cubic meters.
- (3) The area of the system is s square kilometers, containing t active vents.
- (4) The depression per cycle is distributed over an average area of u square kilometers and amounts to v cubic meters.
- (5) The lava veneer each cycle is supplemented by w cubic meters net elevation distributed over x square kilometers.
- (6) The ratio of depression to gross elevation is y/z showing cumulative (elevation or depression) for the present century.
- (7) Heat radiation amounts to p kilogram calories per cycle at the vents, and n kilogram calories from the surface of the system outside the vents as shown by abnormal rock temperatures.

It is obvious that such data will gradually throw light on what is happening underground and will produce formulae delimiting volcanic systems and comparing them on a quantitative basis.

The bottom of Halemaumau.

The return of the lava July 17 by way of the top of a talus heap 194 feet above the bottom illustrates just what happened at Kilauea Iki in 1868 and at Makaopuhi 1922. The liquid lava foams up the "wall-crack" as the pathway of least resistance. Least resistance means least pressure. The rock walls of these pits are funnel shaped and the real bottom is masked by talus. If the real bottom is the lava plug left by the last subsidence, then the release of pressure that leads to the new activity is probably a lift of this tapering cork so that the taper parts from the funnel and releases incandescent matter below. The smoke and glow seen along the talus zone before the lava appears mean that the melt is cementing the talus to the taper plug so that when the lift comes plug and talus are thrust up together as a cake moulding the bottom of funnel. All volcanic craters show tendency to smoke around borders of the floor.

The lava pool that formed July 17 was identical in its mechanism with a slag heap or lava fill fed from a flow vent. The filling of this pool 58 feet in nine hours from one small side vent leads to the query "Does Halemaumau always owe its risings to one small vent at one side of the bottom plug?" That the rising comes from one side has been the experience of the past decade. It has hitherto generally been the west and northwest ponds that were considered the source pools. Now it is the southeast corner that is building a source cone.

The convergence of the rock wall makes it seem probable that the bottom plug is very small. The hypothetical deeper magma, a compressed



Figure 10. Southwest wall of Halemaumau May 25, 1922, showing remarkable tunnel at base of wall revealed by subsidence. This is the rift channel leading to the flow vents of 1920 in the Kau Desert. Note the talus at entrance to tunnel and lava pool inside.



Figure 11. May 28, 1922. Chasm formed by wall of Halemaumau breaking inward during the great subsidence, southwest side of pit. Block on left afterwards became the inner pinnacles.

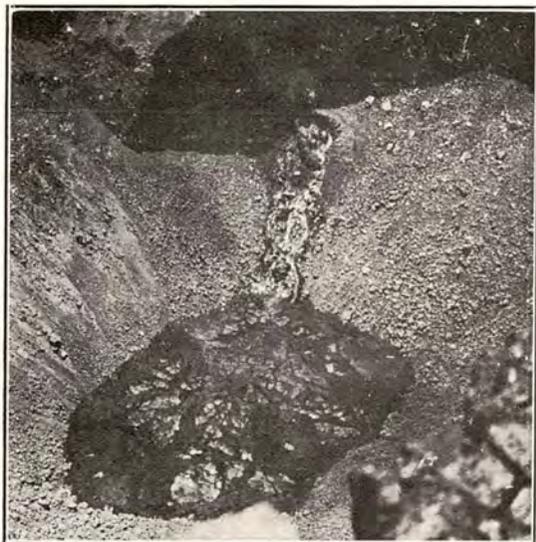


Figure 12. July 17, 1922, 11 a. m. New lava cup and fountain at top of debris slope, making cascade and pool in bottom of Halemaumau. Source 194 feet above bottom of funnel.



Figure 13. July 21, 1922. Churn drill at work on eastern lava field of Kilauea floor. Waldron's Ledge and Volcano House in distance. Road made across pahoehoe lava in foreground. Photos—Jaggard.

substance as discussed above, must be lower than this plug. It probably occupies a crack and its rise and fall under the plug is dependent on the squeezing together or pulling apart of the walls of this crack. There is then a transition not far down from the concentric funnel to the bilateral crack. This will permit the under magma to have length-wise extension in one azimuth, and the probable azimuth at Kilauea is that of the Uwekahuna fault zone (1920 rift line).

If all the mechanism of lake lava and crag lava, pahoehoe and aa, shallow foam pool and gas-free bottom paste can be kept up by a small vent like, the talus cone of July 17, after the latter becomes wholly submerged, then it would appear that all the Halemaumau changes are merely the transformation of a jet of pahoehoe lava pumped up the side of the bottom of the funnel by the internal gas expansion of the lava itself. The deeper magma with its gases compressed and in solution, is therefore considerably more than 1000 feet down.

One other feature of the lower walls of Halemaumau 600 to 900 feet down deserves some comment. That is the earthy decomposed appearance of most of the wall matter at these low levels. There is much red oxidation and whitish solfataric staining. There was a time about 1888 when Halemaumau was a triangular depression a mile across, and this earthy matter may be the talus of that period buried by later lavas.

Another possibility is that the acids and acid salt solutions such as formed in the Postal Rift cavern of 1919, are washed down by rain water through the porous lava sheets, reaching maximum concentration at 600 or 800 feet of depth. A layer of sulphuric acid concentration would bring about notable disintegration of these ferruginous and porous rocks. The condensation following each lava flow period produces large quantities of acid, and to judge from the salts in hot caverns the process continues for years. At the hot solfataras rock shells are completely decomposed in a few weeks. It seems likely therefore that such decomposition is at a maximum some distance underground.

In connection with the borings in progress this suggestion is interesting. Borings into the Kilauea floor may possibly yield cores of highly altered and mineralized rock from depths of 600 to 800 feet.

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July 2. From 10 a. m. to 12 noon Halemaumau was very quiet with some small falls of rock from the walls. The pit was clear. The west talus near the bottom appeared to round downward from a flatter slope above. Fume at southwest chasm puffed up at times as though very hot and smelled strongly of sulphurous acid. Scorching hot air rose along the fault cracks back of the west bench. Some glow at night was reported in stained bowlders in southwest chasm.

July 6. In forenoon stations had been located and a survey was made. Datum station northeast rim of pit was now 3716 feet above sea level. The former station had been 11 feet higher. Mean elevation of five rim stations before was 3732 feet, now it is 3714, a loss of 18 feet. The new stations are 100 feet back from the old rim of pit, and as the slope outward from the pit is downward, the caving away of the old edge left the new stations lower. Indeed on the southwest side a band of old rim 500 feet wide had collapsed. Bottom of pit was 861 feet below northeast rim station and 2855 feet above sea level. Width of pit at upper rim was 1485 feet north-west-southeast, and 2000 feet northeast-southwest. The ground plan was a pointed oval with the point at southwest chasm.

The lava column under the pit appeared to be stationary. One fall of rock fell from the lower south wall where the cliff is very straight and upright. Such avalanches as occurred were from the walls above the talus, the latter remaining quiet and in adjustment. The south-southeast wall under the remnant of pressure ridge at upper rim, had broken away as an

upright cylinder of smaller radius than the pit as a whole, as though a well existed there under the talus at the smoking place where the lava of southeast arm was last seen.

The focus of the talus slopes, however, was out in the center where four or five distinct heaps were arranged in a rosette around a north-south valley bottom about 40 feet long. The thin blue veil of smoke rising from the pit came from a very few slight smoke holes at upper edges of talus. Walls of pit were pink with avalanche dust and so was all the leeward country. Following the rim from road terminus on east side around to the south, the observer met first a small remnant of the eastern end of south pressure ridge at southeast margin of pit. The edge next west is a high slag heap remnant from 1919. Then comes the southwestern embayment with the pinnacle ledge standing out as a huge castle-like mass and then the fault bench extending the whole length of west side of pit. This is where the backslope of the west niche rampart of 1894 had been and here now are crevasses omitting scorching hot air. North of the pit may be recognized the 1921 fill of the north niche with a slight shelf in the wall below corresponding to the second shelf of 1920. The northeast region is the flat that was an overflow pool in March 1921. Next come the hillocks and driblet heapings that were a slag-heap center in 1919, and this brings us back to the road terminus.

No caverns are revealed in wall of pit except at the extreme top southwest. Solfataric staining is seen far down the south wall and many of the layers are massive and heavy like intrusive sills. Cross dykes and oblique intrusions were visible in places, but always concentric with the pit and dipping at high angles. Radial vertical dykes are wholly absent. The oblique dykes seen appeared to be the filling of oblique upward breaks along old funnel ways like the former Postal Rift or the present western crevasses. It was up such a circumferential crack that the Postal Rift flows emerged in 1919. The 1920 rift flows came up a radial break of altogether different origin.

July 6. At 6:30 p. m. a light avalanche cloud hung over Halemaumau, and marked fume in two jets was unusually conspicuous over Mauna Loa summit, making a diffuse mushroom above.

July 7. At 10:30 a. m. no change of conditions was observed in Halemaumau. A careful study of the pit showed that the wall tended to form four embayments parallel and at right angles to the southwest rift line. There was a smoking place and a vertical crack at the top of northeast talus corresponding to the rift. There was smoke in all four lobes at top of talus. Three blocks which had slipped down formed inner pinnacles in western part of pit and solid ledge protruded through the talus two-thirds of the way down to the bottom on both north and south sides of the interior and again still higher up in the southern talus. Everything indicated that the rock wall was funnel-shaped. The most continuous vertical wall was at the southeast.

July 8. At 11 p. m. the glowing area in southwest chasm was seen to affect sulphur stained boulders in a zone 4 feet wide and 25 feet long. The glow was between the boulders, varying from dull red to bright cherry red. The hot cracks back of west fault bench were examined for glow at night but no glow could be seen.

July 11. At 9 p. m. the glowing area in southwest chasm was larger than before. Avalanches fell from north wall of pit. The hottest cracks at the west were again examined and glowing sparks were seen to rise from two of the cracks.

July 12. At 11 p. m. glow had extended itself over most of the broken rock at the end of the southwest chasm. Next the wall there was a bright glowing patch nearly two feet square and the 1921 tunnel above had become very hot. The glow in the chasm was easily seen in bright moonlight.

July 13. At 10:30 a. m. an avalanche at the pit made a rumbling noise and sent up a dust cloud. At 7 p. m. no change was perceptible in the bottom area. After dark the glow in southwest chasm was seen to be an elongate zone following the yellow-stained smoking spots in the talus and the contact of talus and wall. The glow was entirely invisible by daylight, but became a bright cherry red at night making the talus look like a bed of coals. The area glowing was about 70 feet long.

July 14. At 7 p. m. the glow in southwest chasm appeared less then before.

July 15. A few light avalanche clouds were seen over south end of Halemaumau.

July 16. Avalanche clouds increased in number and became bigger towards evening.

July 17. At 1 a. m. the seismographs showed a sudden slight development of harmonic tremor and at 2 a. m. a night watchman reported glow over Halemaumau.

At 7:30 a. m. lava was found flowing from top of talus in the south-east niche of the cliff and cascading down to a flat black pool that already occupied considerable area in bottom of pit as in the case of Makaopuhi May 28. The vent was a lava pot with built-up edges enclosing a vigorous fountain that threw spray 30 feet into the air. There were growling, splashing and rumbling noises. Streams of the trickling type made a narrow zone of black lava down the slope, having tendency to fork out and distribute. The red ribbons of melt were running moderately fast and forming festoons at the bottom. The pool below showed a few zigzag bright-lines and live toes around the edges invading the talus. One or two fountains developed at northeast side of pool. Some places around the edges appeared like aa lava and the spatter material of the source cone was scoraceous. Just as at Makaopuhi the activity and volume diminished during the day and at 5 p. m. there was little fountaining visible in the pot and the trickle flows had narrowed and crusted over. The pool still exhibited live toes at its edges. Fume remained thin and the only odor was of sulphurous acid. There were slight rock falls, mostly from above the source cone and some of these in the evening broke the cone open revealing sluggish lava below the orifice.

The measurements at 11 a. m. made the source cone 667 feet down, the new bottom 800 feet down, and the cone vent accordingly 194 feet above the previous bottom which it had filled. Dimensions of new pool were 490 feet north-south by 380 feet east-west, and the cascade belt was about 100 feet wide.

July 18. At 2:30 p. m. the new lava appeared dead. The crusted pool consisted of flat black pahoehoe. The zone of cascade ribbons was wider than at first and smoke rose from the source cone but no lava was seen in motion. There was evidently lava in the cone at night for it made a pale pinkish-yellow light over south side of pit.

July 19. At 9 p. m. there were several small avalanches. Glowing cracks traversed the pool, especially around the edges, and the surface appeared swollen and one or two trickling toes were visible at the edge. There were glowing cracks in the cascade slope and from the source pot lava spray and splashes spurted out. An avalanche sent up a dust cloud and broke crust of lake so as to cause a foundering and produce a pattern of big cracks and many fern-like glow lines. There was some fountaining and numerous border flows penetrated the talus. Shortly afterwards the crust thickened and the pit became very dark.

July 20. At 4 p. m. lake appeared larger than before and its crust was sagging. The source pot had built up a cone 10 feet high and was now flinging spray 15 feet into the air. Small rock falls from the south wall continued. Three trickle flows had broken out from the base of the cone

and were moving down the slope along the western side of the frozen cascades.

July 21. At 3 p. m. the cone was throwing up light blebs of lava. The pool was inactive. At night there was glow.

July 22. Cone was partly covered with avalanche debris. Pit was dark at night.

July 23. Avalanches fell from north wall between 9 and 10 a. m. North side of floor was left covered with avalanche dust and a large new slope of talus overlapped the floor lava on that side. The source pot southeast was jumbled and half buried under debris, its remnant smoking and making an occasional weak puffing noise. No glow could be seen in daylight. There was much dust in the air.

July 24. At 3 p. m. the pit was clear and the pool was found to have broken up and swallowed its crust since the previous day. This left the edge of the previous surface a dusty bench 10 feet wide and 4 feet high around the pool and the latter was covered with black blistered crust. The cascade slope southeast was dusty but the pot on top had changed to a small orifice two feet in diameter showing orange glow in daylight. It was not spitting nor puffing. Some fresh caving in was noticed at the 1921 cavern southwest on top of the cliff.

July 26. At 4 p. m. there were small avalanches and the source cone was coughing at long intervals.

July 28. At 3:30 p. m. the smoke at source cone was whitish yellow and denser than before and in sunlight the glow was not discernible; one puff was heard here. A little fume rose at the lowest sag at the north talus. More fallen stones lay on the cascade slope. A small fall of rocks occurred at the north cliff. There was dust over the newest surface of the lake, and the fume from pit as a whole had increased. There was no glow over pit at night.

July 30. At 4 p. m. there were small rock falls from the south wall and much smoke from source cone and southwest solfatara. Night view showed glowing places inside of pit.

At the end of July Halemaumau was quiet and dark except for a few small avalanches. Fume as a whole was thin and the lava column appeared to be stationary or slightly sinking.

LAVA MEASUREMENTS

New surveying stations on edge of Halemaumau were completed and occupied July 6 and the dimensions measured have been cited in the Journal under the dates July 6 and July 17.

Progressive changes expressed as depression below new northeast datum station (3716 feet above sea-level) were as follows:

	Bottom of pit
May 26, 2:30 p. m.....	-648 feet (lake)
July 6, 11:00 a. m.....	-861 " (debris)
July 17, 11:00 a. m.....	-803 " (pool)

The filling of the bottom cup July 17 amounted to 58 feet vertically in nine hours between 2 a. m. and 11 a. m., averaging 6.5 feet per hour. This all came from the side cascade. Cascade lay on a talus slope and its source at top of talus was 136 feet above surface of pool, and 274 feet horizontally southeast from junction of cascade and pool.

The filling of this pool was illuminating in showing what a large volume of liquid lava can be produced by a single small vent in a short time.

SEISMOMETRIC RECORD

During the month ending midnight July 31, 1922, twenty-nine local earthquakes and one teleseism were recorded at the observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is

Hawaiian Standard of meridian 157° 30' W, 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

July 1.....	4:09 a. m.	Very feeble.	
2.....	9:27 p. m.	" "	
	10:19 p. m.	" "	
	11:31 p. m.	" "	
3.....	8:06 p. m.	" "	
	8:13 p. m.	" "	, distance 5 miles.
4.....	10:45 p. m.	" "	
5.....	4:55 a. m.	" "	
	4:56 a. m.	" "	
	9:15 a. m.	" "	
	5:44 p. m.	" "	
6.....	8:58 p. m.	" "	
9.....	5:22 p. m.	" "	
	5:40 p. m.	" "	
11.....	3:12 a. m.	" "	
12.....	1:17 a. m.	" "	
	4:54 p. m.	" "	
13.....	10:30 a. m.	" "	
14.....	10:31 a. m.	Feeble, distance 2½ miles.	
15.....	3:52 p. m.	Very feeble.	
18.....	4:36 a. m.	" "	
	4:44 a. m.	" "	
20.....	7:58 p. m.	Slight, distance 25 miles.	
22.....	8:47 a. m.	Very feeble.	
23.....	9:43 a. m.	" "	
24.....	4:59 p. m.	Slight, distance 24 miles	Felt locally.
27.....	10:26 p. m.	Very feeble.	
29.....	11:38 a. m.	Feeble.	
31.....	4:22 a. m.	Very feeble.	

Teleseism.

July 2..... 3:13 a. m. Moderate, distance 2300 miles.

Spasmodic Microtremor.

This type of tremor by weeks, beginning July 1, was registered as follows:

July 1-7.....	Slight.
8-14.....	Moderate.
15-21.....	Slight.
22-28.....	Moderate.

Harmonic Microtremor.

This type of tremor was extremely slight throughout the month, being scarcely detectable except on the 2nd and 17th.

Microseismic Motion.

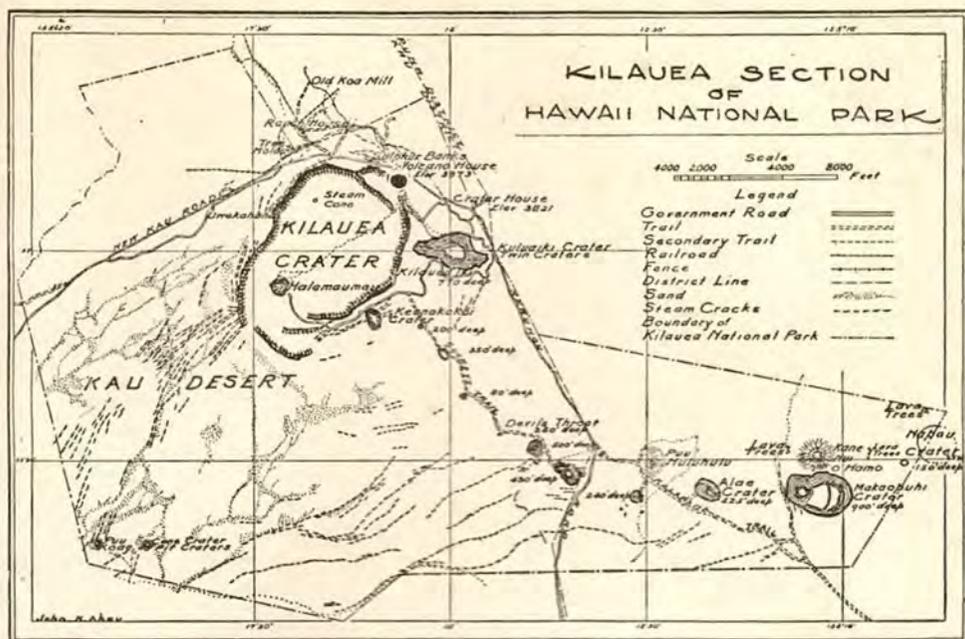
The amplitude of microseisms was slight throughout the month with the exception of moderate on the 9th.

Tilting of the Ground.

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

July 1-7.....	3.1 seconds	ESE.
8-14.....	3.2	SW.
15-21.....	3.2	NNE.
22-28.....	2.0	SW.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges should be addressed to
HAWAIIAN VOLCANO OBSERVATORY,
 Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismometric instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of local earthquakes; one optically recording seismograph for distant earthquakes; one clinograph registering E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete piers in a closed basement room having practically constant temperature, beneath the chief Observatory building near the hotel. Time is referred to a rated chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. $19^{\circ} 25' 54.2''$ N.; Long. $155^{\circ} 15' 39.2''$ W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun" a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Sword (*Argyroxiphium*). Thirteen volcanic cones lie wholly within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvellously beautiful.

Wailuku is the point of departure, automobiles taking the traveler to Olinda, a summer residence settlement 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of $2\frac{1}{2}$ hours. Here is a fine concrete rest house, built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa, a vast dome 13,676 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bril-

liantly colored lava slopes, has a summit crater 3 miles long by $1\frac{1}{2}$ miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jetted 500 feet into the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaii National Park, if not in the world. The pit of fire, Halemaumau, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overridden by the lava slopes of Mauna Loa on the west, so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solfatras and a strange desert where lava flows have poured out of cracks as recently as 1920.

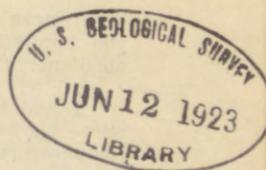
The live pit of Halemaumau is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvelous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory, which stands on the brink of the greater crater within the Kilauea Park.

U. S. DEPARTMENT OF AGRICULTURE
Weather Bureau

CHARLES F. MARVIN, Chief

MONTHLY BULLETIN
OF THE



HAWAIIAN VOLCANO OBSERVATORY

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PRELIMINARY TESTS OF THE GASES AT SULPHUR BANKS
HAWAII

By EUGENE T. ALLEN

August 1922, I was privileged, as a representative of the Geophysical Laboratory in Washington, to carry out some tests from the chemical viewpoint in connection with the interesting boring operations which have recently been undertaken in and near the crater of the volcano Kilauea by Professor Jaggar.

At that time three holes had been sunk; two at the Sulphur Banks on the crater rim, 22 feet and 50 feet in depth, and one on the floor of the crater, 80 feet in depth. Temperature measurements were made in these bore-holes with a maximum thermometer and experiments were also carried out with an alumel-chromel thermocouple in expectation of temperatures later on which might be beyond the range of a maximum thermometer.

It was a surprise to me, as no doubt it will be to others, to find that the temperatures in these bore-holes at Sulphur Bank showed no marked gradient; they were virtually the same from top to bottom.

I had not anticipated that the drill holes like natural fumaroles would serve as vents for escaping gases, constant currents of which keep the temperature equalized. At the Sulphur Banks where steam pours from the bore-holes at some velocity, the temperature is about 95.5° C, corresponding very nearly to the boiling-point of water for that elevation.

The rainfall on the northeast rim of Kilauea is high (103 inches per annum) and the ground remarkably porous. The rain-water penetrating into hot ground would naturally be evaporated by volcanic heat and returned to the surface as steam, the temperature of which would depend on the relation of the heat supply to the water supply. The fact that the temperature in the drill-holes is kept down to that of boiling water indicates that the water supply is great enough to keep some liquid water in constant contact with the steam as the conditions are in the boiling process.

Along with the steam other gases are escaping, as we infer from the odor of sulphur dioxide and from the deposition of sulphur at the surface of the ground. These two gases (SO_2 and S) are in all probability volcanic since they are also found in the liquid lava of Halemaumau.

Gases characteristic of fumarole regions like the Sulphur Banks are of interest for a number of reasons. A knowledge of their relationship to the gases which escape directly from the lava would be highly desirable. It would enable us to say whether the composition of the gases is an index of volcanic activity and might conceivably prove of practical value.

Fumarole gases also serve as the active agency in the often extensive alteration of rocks to the clay and other products which occur in all fumarole regions. Professor Jaggar has recently found in the borings at the Sulphur Banks pyrite (or possibly marcasite), a mineral which rarely occurs in this region. The pyrite is in all probability a product of action of the fumarole gases on the lava, and it was with this problem in view that I attempted an analysis of the gases.

The Gases of the Sulphur Banks

In 1910 A. Brun of Geneva made a number of partial analyses of these gases, but a consideration of the methods he used and some tests of my own convinced me that further investigation was desirable. Next to the condensation of steam the most conspicuous characteristic of the gases is the odor of sulphur dioxide either at the drill-holes or at the natural fumaroles. The odor in 1922 was obvious to anyone, yet Brun says * (1910) no sulphur dioxide occurs here. Sulphur crystallizes where the gases emerge from the ground and the water condensed from the gases is always milky with sulphur. Lead paper (paper soaked in acetate of lead and dried) is decidedly blackened when brought into contact with the gases. This test is generally assumed to indicate hydrogen sulphide, which, at the temperatures prevailing at the Sulphur Banks, is incompatible with sulphur dioxide. Tests made at the Hawaiian Observatory on the condensate from the fumaroles with cadmium chloride gave no indication of hydrogen sulphide. Later the fact was established that a mixture of steam, sulphur dioxide, and sulphur vapor **does not blacken lead paper**. It is therefore certain that the gases of the Sulphur Banks contain some unusual constituent, probably a compound of sulphur, possibly carbon oxysulphide.

* Recherches sur l'exhalaison volcanique. Paris and Geneva, 1911, p. 251.

As soon as it had been ascertained that the gases from the drill-holes responded to the same tests as those from the natural fumaroles, attention was focused entirely on the former because the ground around them was better adapted to experiments and the greater velocity of the gases from the drill-holes lessened the chances of contaminating the gases by air. The drill-holes were encased with iron pipe for several feet from the surface, but any possible change in the composition of the gases which might result from their contact with iron was avoided by the use of a glass intake tube which was thrust down to a point several feet below the end of the casing.

Determinations were made of the steam, sulphur dioxide, and sulphur vapor, which together made over 96 per cent of the gases, while samples of the residue were sealed up and taken to Washington for further study.

Determination of Sulphur Vapor. In the determination of sulphur vapor the gases were aspirated through a couple of small glass cylinders in series. The capacity of each cylinder was about 125 cc. The first, in which most of the water condensed, was kept cold by standing it in a dish of ice water. A small measured quantity of water was poured into each cylinder at the start to aid condensation. At the end of the experiment (30-40 minutes) the volume increase was determined. This is due almost entirely to water which is calculated into steam at 95.5°C and the pressure corresponding, about 646 mm.

The water, milky with precipitated sulphur, is now washed into a glass-stoppered bottle and left to stand for some days, with shaking at intervals, until the sulphur is filterable. It is then filtered on a Gooch filter, washed and dried to constant weight in a desiccator over sulphuric acid. This is quite accurate enough for present purposes, but on some accounts it would be interesting to control this result by oxidizing the sulphur to sulphuric acid, precipitating the latter as barium sulphate, and weighing.

The volume of the sulphur vapor at 95.5° and 646 mm is easily computed when we remember that the molecule of sulphur at low temperatures is S₈. The numerical data and results follow:

1. Water condensed at ordinary temperature = 191 cc.
Volume of steam at 95.5° and 646 mm = 371900 cc.
Weight of sulphur collected = 0.110 g.
Volume of sulphur vapor at 95.5° and 646 mm = 15 cc.
Volume of sulphur vapor to 100 volumes steam = 0.004.
2. Water condensed at ordinary temperature = 142 cc.
Volume of steam at 95.5° and 646 mm = 276500 cc.
Weight of sulphur collected = 0.85 g. ^{0.855}
Volume of sulphur vapor 95.5° and 646 mm = 11.7 cc.
Volume of sulphur vapor to 100 volumes steam = 0.004.

Average = 0.004 volume sulphur vapor to 100 volumes steam.

Determination of Sulphur Dioxide. The determination of sulphur dioxide requires an apparatus similar to that used for free sulphur. Here a glass flask of 750 cc capacity is added to the train. The latter contains 100 cc caustic soda solution of 20 per cent strength and the cylinders 22 cc each of the same solution. In experiment [2] only one cylinder was used. The sulphur dioxide was dissolved with the formation of sodium sulphite, the free sulphur forming at the same time thiosulphate and polysulphide. At the end of the experiment the increase in volume, which is due almost entirely to the condensation of steam, is measured and from this figure the original volume of steam computed. At the observatory later the whole solution was diluted to a measured volume and aliquot parts taken for analysis. The sulphur in the alkaline solution was first oxidized to sulphate by boiling with hydrogen peroxide ("dioxogen"), then acidified and precipitated as barium sulphate. Thus the whole amount of sulphur was found, the amount of it originally existing as free sulphur was subtracted and the remainder computed to sulphur dioxide at 95.5° and 646 mm. From these data the ratio of the sulphur dioxide to water was found.

1. Water condensed = 218 cc at ordinary temperature.
 Volume of steam at 95.5° and 646 mm = 424.5 liter.
 BaSO₄ found (1/5 of the solution).....0.831 g.
 BaSO₄ from free sulphur..... .186 g.

 BaSO₄ from SO₂645 g.
 Total BaSO₄ from SO₂3.225 g.
 SO₂ equiv. to BaSO₄885 g.
 Volume of SO₂ at 95.5° and 646 mm..... 480 cc.
 Volume of SO₂ to 100 volumes steam.....0.11

2. Water condensed = 215 cc at ordinary temperature.
 Volume of steam at 95.5° and 646 mm = 418 liter.
 BaSO₄ found (1/5 of the solution)..... .679 g.
 BaSO₄ from free sulphur184 g.

 BaSO₄ from SO₂495 g.
 Total BaSO₄ from SO₂2.475 g.
 SO₂ equiv. to BaSO₄679 g.
 Volume of SO₂ at 95.5° and 646 mm..... 367 cc.
 Volume of SO₂ to 100 volumes steam.....0.09

Average = 0.10 volume sulphur dioxide to 100 volumes to steam.

Ratio of Steam to the Remaining Gases. The ratio of steam to fixed gases was determined by measuring the volume of non-condensable gas which accompanies a measured amount of condensed water. The intake and the two cylinders for the condensation of steam were used as before, but to the second cylinder was tightly connected a gas collecting tube (capacity 250 cc) with a glass stopcock at each end. The collecting tube was supported in a vertical position with both stopcocks open. The upper end of the latter was connected by a good rubber tube directly to a tight metal aspirator of measured capacity (about 10 liters). The aspirator was filled with water at the start and a pinch cock on the rubber tube connecting it to the remainder of the train enabled the operator to control the flow of the water. When the water flowed out the fumarole gases of course flowed in, gradually displacing the air in the train and following it into the aspirator. At the same time the steam condensed in the cylinders. The first cylinder was cooled at the start, but it was allowed later to become hot enough to drive out practically all the carbon dioxide. The second cylinder, in which little condensation occurred, remained cool and the gas collecting tube cold so that the water was condensed with negligible loss. The volume of steam is calculated from this as before and the volume of the fixed gases CO₂, N₂, etc., is equal to the water displaced in the aspirator less the relatively small volume of condensed water. By taking account of the temperature of the gas, its volume at 95.5°, that is, its volume in the fumarole gas, may be computed, and thus the ratio of the steam to the fixed or "insoluble" gases may be obtained. *

In the same experiment it will be observed that a sample of the fixed gases is collected in the vertical tube by displacement of air. At the end of the experiment, this is confined by closing the stopcocks, the sample is taken to the Observatory, transferred to a vacuum tube by displacement with hot water to avoid solution of carbon dioxide, sealed up and shipped home for analysis.

* No correction is necessitated by the fact that the air in the intake is displaced by a volume of fumarole gas not comparable to it on account of temperature difference, because the air is mostly displaced by the heat before the intake is connected into the train.

The results follow:

Determination of Fixed Gases

- Water condensed = 154 cc at ordinary temperature.
 Volume of steam at 95.5° and 646 mm = $154 \times 1.947 = 299.8$ liters.
 Volume of fixed gas at 25.5° and 646—25 mm = $9.585 - 0.154 = 9.431$ liters.
 Volume of fixed gas at 95.5° and 646 mm = $9.431 \times \frac{368.5}{298.5} \cdot \frac{621}{646} = 11.2$ liters.
 Volume of fixed gas to 100 volumes steam = 3.73.
- Water condensed = 153 cc at ordinary temperature.
 Volume of steam at 95.5° and 646 mm = 298.0 liters.
 Volume of fixed gas at 17.8° and 646—15 mm = $8.935 - 0.153 = 8.782$ liters.
 Volume of fixed gas at 95.5° and 646 mm = 10.9 liters.
 Volume of fixed gas to 100 volumes of steam = 3.66.
- Water condensed = 148 cc at ordinary temperature.
 Volume of steam at 95.5° and 646 mm = 288.2 liters.
 Volume of fixed gas at 20° and 646—18 mm = $9.885 - 0.148 = 9.737$ liters.
 Volume of fixed gas at 95.5° and 646 mm = 11.9 liters.
 Volume of fixed gas to 100 volumes of steam = 4.13.
- Water condensed = 152 cc at ordinary temperature.
 Volume of steam at 95.5° and 646 mm = 295.9 liters.
 Volume of fixed gas at 21° and 646—19 mm = $9.385 - 0.152 = 9.233$ liters.
 Volume of fixed gas at 95.5° and 646 mm = 11.2 liters.
 Volume of fixed gas to 100 volumes steam = 3.79.
 Average = 3.8 volumes of fixed gas to 100 volumes steam.

Assembling the results:

Sulphur vapor = 0.004 volume to 100 volumes steam.
 Sulphur dioxide = 0.10 volume to 100 volumes steam.
 Fixed gases = 3.8 volumes to 100 volumes steam.

The following composition of the fumarole gases is obtained:

Steam	=	96.2
Fixed gases	=	3.7
Sulphur dioxide	=	.096
Sulphur vapor	=	.004
Hydrochloric acid	=	trace

100.00.

I wish to express my thanks to Professor Jaggard and Mr. Finch for friendly cooperation and assistance in this work, and to the University of Hawaii, the Planters' Experiment Station at Honolulu, and especially to Mr. Guido Giacometti of the Oloa Sugar Company for the loan of apparatus which was used in this work.

Geophysical Laboratory,
 Carnegie Institution of Washington,
 Washington, D. C.,
 December, 1922.

VOLCANO CONDITIONS IN AUGUST

Activity of Halemaumau.

The end of July had left the pit quiet with the lava pool crusted and dusty and a few small smoking vents at top of talus heaps. The first week of August showed only such slight change as would accompany a

moderate withdrawal or shrinkage of the lava column lying below the debris in the bottom. The July pool had lost all signs of activity. Avalanches of small size tumbled from walls of pit, and one fairly heavy fall of rocks in evening August 4 buried under its accumulations the sloping frozen cascade which in the July outbreak had fed the pool below. The vent at top of cascade was covered with rubbish, but smoke still rose there. The most notable smoke hole elsewhere was at the glowing patch, stained with sulphur, about 100 feet below southwest rim of pit. This was the only marked glow seen anywhere and the light from it was insufficient to illumine the fume above.

By the middle of the month floor of pit was overlapped with new avalanche debris and dust. Avalanches continued to fall occasionally. Pit was a vast smoking cauldron, much bigger than the pit of the previous year with a flat lava floor 791 feet down surrounded by talus slopes on all sides. The slaggy cascade left in July on the southeast slope was now obliterated by avalanches, and even the smoking hole at the top was no longer to be seen. The wall higher up, however, showed some fuming 300 feet above floor of pit.

On the southwest side a very long slope of debris led up to the notch, pinnacles and benches where the 1920 rift tunnel lay buried under slopes of slide rock. Here there was ample evidence of live volcanic fire if the visitor looked down from the edge at night. At top of talus the cracks between boulders glowed vividly like a bed of coals, and the same place in daylight was yellow with sulphurous stains and emitting brownish fume smelling of sulphurous acid gas. The glowing patch was at least 50 feet long and followed contact of debris with wall of pit. Still farther north along the great crevasse west of pit scorching hot air was rising.

The third week showed some increase of fuming at the southeastern wall with smell suggesting acetic acid. These smoking cracks were right over the region that was fountaining and flowing with liquid lava in July. The field glass showed them to be making pale yellow stain on the walls high above the top of the debris slopes. The upper rim caved away making avalanches from a cracked area near the road terminus. Small falls of rock from eastern and southern walls were usually seen by visitors.

The western crevasses were hotter than ever and the fault bench between them and pit showed some signs of having subsided farther. Everything in the pit was plainly seen as the fume was thin at all times. Indications were that the lava column under the pit bottom was sinking slowly, and so giving rise to the avalanches, the yawning cracks, and the great piles of debris that covered much of the lava floor of July.

At the end of the month a yellow patch wet with sulphurous vapor appeared at the top of the southeastern debris slope, just about where the July lava spouted out. A jet of dense white vapor was now rising steadily from the cracked wall above. The eastern rim of pit had so fallen away that the verge was only a few feet from road terminus. Two avalanches near noontime August 23 fell from the pinnacles southwest, and sent up conspicuous clouds of dust.

It should be noted that at several places along the outlying circle of 1894 cracks formerly called the Postal Rift there were now hot vapors and solfataric stains which had asserted themselves through the veneer of 1921 lava. Near the old "Pele's Kitchen" north of Halemaumau acid salts were being deposited along cracks having a temperature over 200° C, the rock was intensely altered and blue sulphurous fume at this place was in marked contrast to the white vapor of the ordinary cracks. Another place of intensely altered lava and colored or white fibrous sublimates along this zone lay east-southeast from Halemaumau.

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August 4. At 11 a.m. Halemaumau was found quite unchanged in interior appearance. Fume was slightly denser, probably owing to heavy recent rain. Rock debris had increased at the cascade slope southeast. There was possibly slight decrease of heat at the western crevasses. A big avalanche occurred in the evening.

August 5. In the forenoon the only notable change was the burial under debris of the July lava cascade slope southeast of bottom area.

August 7. In the afternoon the cascade slope locality showed no remnants of the lava bank and smoke no longer rose there at top of talus. The wall above, however, formed an arcuate niche with cracks where a little smoke emerged. There was smoke also from top of talus north and northeast and from southwest chasm. Debris had rolled out on lava floor where base of cascade lay buried.

A test at the western crevasse back from Halemaumau rim with white paper dropped in the cracks, discovered that the paper yellowed slowly in the scorching heat one foot down. A slip of paper dropped 12 feet down a crevasse one foot wide blackened quickly. No odor whatever could be detected in the hot air rising from the cracks.

August 9. An avalanche at Halemaumau about noon made first a cloud of reddish dust, and thereafter much white vapor hung over the pit as though the finer dust were nucleating and making visible water vapor which is usually quite invisible.

August 10. There were avalanches during the day. At 9 p. m. no glow whatever could be detected inside the pit proper. At southwest fuming patch at top of talus in chasm the glow appeared like a large bed of coals. Fume over pit was somewhat variable but at all times slight.

August 12. Pit at this time was usually very free from fume in the morning, whereas more fume was apparent in the evening. This was partly due to the position of the sun, which from the Observatory lay back of the pit in afternoon, but there was probably increased condensation also. The fume from south wall was whitish, and that from southwest chasm brown in transmitted light and blue when seen against a dark background.

August 17. At 4 p. m. rock debris was found to have increased on southeast floor of Halemaumau covering one quarter of July lava surface. There was some increase of smoke from numerous cracks in the lower southeast wall of pit, one vent being specially conspicuous. At the glow locality of southwest chasm the yellow stain along top of talus extended over a long area. The western fault bench appeared slightly lower.

August 19. Measurements at 2 p. m. made bottom of pit 791 feet down. A boulder on the bench surrounding the floor was 4 feet higher and the smoke hole at top of northern talus was 40 feet higher still. Top of northeast talus was 522 feet below rim and the southeastern smoke cracks 490 feet below rim.

There had been some falling away of the upper southeastern rim of pit and a few rock falls from the southern and eastern walls were observed. An odor was perceived somewhat like acetic acid in the vapor rising from the inner cracks. The southwest chasm talus appeared increasingly stained yellow and hot air rose from a crevasse just north of this fuming patch. The fuming patch smells strongly of sulphurous acid.

An examination with field glass of the southeast wall vent revealed a small crack stained pale yellow, and the whole wall for 50 feet or more above top of talus was fuming from other smaller stained cracks. The talus itself was not fuming, and no trace of the July fountain vent was discernible. At the smoke holes in wall at top of north and northeast taluses there was more yellow stain. At the northeast and southeast vents the wall itself appeared to be smoking, whereas at the north talus and in the southwest chasm the smoke and stain were distinctly among the boulders and along the line between them and wall of pit.

August 23. At 11 a. m. a yellow patch, probably iron sulphate, was observed at top of southeast talus about where the July lava had come out. There was a marked jet of vapor from crack in wall above. Avalanches fell from the southwest pinnacles at 11 a. m. and 1 p. m. Southeast rim of pit was now only about 50 feet from the road terminus.

SEISMOMETRIC RECORD

During the month ending midnight August 31, 1922, seventeen local earthquakes and four teleseisms were registered at the Observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W, 10h 30m slower than Greenwich.

Local earthquakes.

August 4.....	12:02 a. m.	Very feeble.
	1:48 a. m.	" "
	7:40 p. m.	" "
9.....	11:31 a. m.	Feeble.
	11:33 a. m.	" "
11.....	7:42 a. m.	Very feeble.
	7:44 p. m.	" "
	11:12 p. m.	Feeble, distance 5 miles.
	11:13 p. m.	Very feeble.
14.....	8:02 a. m.	" "
	11:42 a. m.	" "
	12:05 p. m.	" "
15.....	6:12 a. m.	Feeble
16.....	3:43 a. m.	Very feeble.
17.....	7:22 p. m.	Feeble.
26.....	3:57 a. m.	" "
31.....	7:35 p. m.	Very feeble.

Teleseisms.

August 7.....	2:19 a. m.	Very slight.
16.....	5:43 a. m.	Slight.
25.....	1:38 a. m.	Very slight.
	8:15 p. m.	" "

Spasmodic Microtremor.

This type of tremor was moderate on the 1st, 15th, 23rd, 25th, and slight on other days.

Harmonic Microtremor.

This type of tremor was practically absent throughout the month except for a short period on the 31st.

Microseismic Motion.

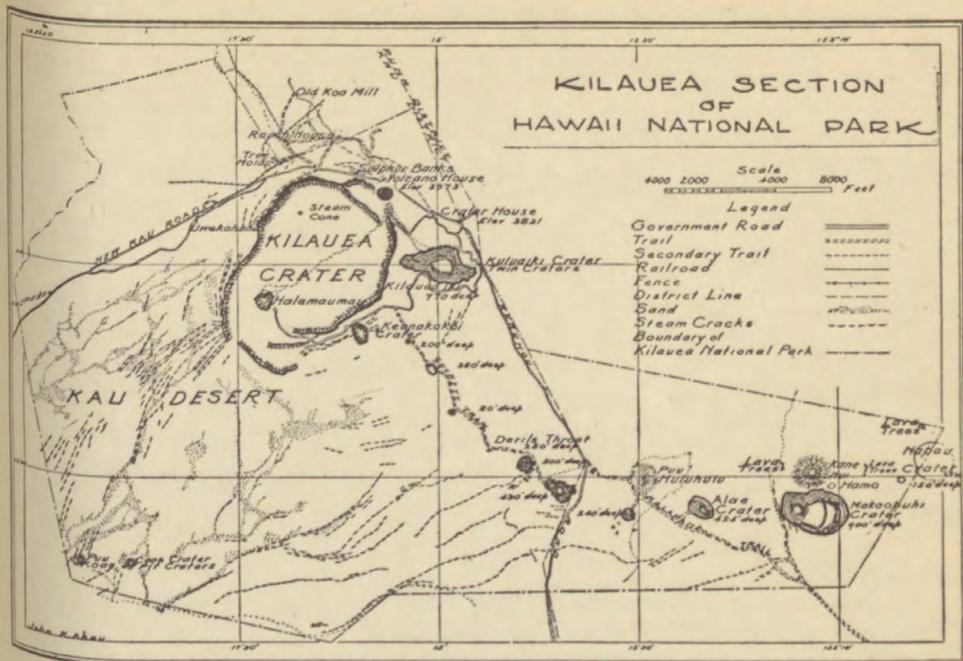
The amplitude of microseisms was slight throughout the month.

Tilting of the Ground.

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

July 29-Aug. 4.....	0.9 seconds	NW.
5-11.....	0.1	" N.
12-18.....	2.0	" NNW.
19-25.....	0.5	" S.
Aug. 25-Sept. 1.....	2.0	" ENE.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges should be addressed to

HAWAIIAN VOLCANO OBSERVATORY,

Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismometric instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of graph for distant earthquakes; one optically recording seismograph E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete pillars in a closed basement room having practically constant temperature, beneath the chief Observatory chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. 19° 25' 54.2" N.; Long. 155° 15' 39.2" W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun," a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Cholla (*Argyroxiphium*). Thirteen volcanic cones lie within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvellously beautiful.

Waipuku is the point of departure, automobiles taking the traveler to Olinda, a summer residence set at an altitude of 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of 3½ hours. Here is a fine concrete rest house, built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa, a vast dome 13,675 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bril-

liantly colored lava slopes, has a summit crater 3 miles long by 1½ miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jetted 500 feet into the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaii National Park, if not in the world. The pit of fire, Halemaumau, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overriden by the lava slopes of Mauna Loa on the west so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solfataras and a strange desert where lava flows have poured out of cracks as recently as 1920.

The live pit of Halemaumau is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvellous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory, which stands on the brink of the greater crater within the Kilauea Park.

U. S. DEPARTMENT OF AGRICULTURE

Weather Bureau

CHARLES F. MARVIN, Chief

MONTHLY BULLETIN

OF THE

HAWAIIAN VOLCANO OBSERVATORY

VOL. X

HONOLULU, HAWAII, SEPTEMBER, 1922

No. 9

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PROGRESS OF BORING EXPERIMENTS

Assembling the Shot Drill: August Work.

During the first week of August the work of hauling the churn drill out of Kilauea crater was finished and it was shipped to Honolulu. Two men were sent back and two were kept for work on the Calyx Shot Drill. The casing in Hole No. 3 on Kilauea floor, 75 feet long and four inches inside diameter, was cemented in place and capped.

The reduced crew of two men, Waikoloa and Kaili, worked August 7 to 23 on setting up the tractor engine as a power plant, and assembling the Calyx drill with its tower, pump, hoist and water-barrels. The place selected for Hole No. 4 is in the Observatory grounds 120 feet southeast of main building. Assembling the rig was slow because the machinery was rusty, some repairs were necessary, and the water piping required complete renovation. The machine was placed at one side of a shed which had been built for the purpose and the tower was erected above this shed; an opening in the galvanized iron roof permitted passage of cables, ropes and drill rods.

The overburden of volcanic ash and lapilli is here eight feet thick and the upper hole bored in this material was cased with 5-inch pipe surmounted by a T-joint that led to three settling barrels in a trench connected

by piping. The third barrel was used as a water supply for the pump foot-valve, and pipes with faucets were led over this barrel from several sources of water-supply. Three of these sources were from twenty-five new barrels in series set up to catch the roof drip of the outbuildings, and another was from the main tanks that constitute the Observatory water-supply. Of these there are now three 5000-gallon tanks receiving the roof drainage of the larger buildings, and one 2000-gallon tank adjunct to the janitor's cottage. Capacity of the roof-barrels is 1250 gallons.

Record of the work in starting Hole No. 4 in August, 1922, with shot core drill was as follows:

Date 1922	Machine Hours	Other Work (Hours)	Progress (Feet)	Depth (Feet)	Water Used (Gallons)	NOTES
Aug. 7	0	8				Assembling shot drill and work at Sulphur Bank.
8	0	8				Assembling drill.
9	0	8				Broken gear sent for welding. Assembling.
10	0	8				Began assembling water pipes.
11	0	8				Placed machine and laid tower timbers.
12	0	4				Boring bolt holes in sills and readjust hoist clutch.
14	0	8				Erecting lower half of tower.
15	0	8				Erecting upper half of tower.
16	0	8				Work on tower, water pipes and tractor frame.
17	0	8				Work on water connections, oiling drill rods, etc.
18	0	8				Making pipe rack, adjusting tractor engine and belt.
19	0	4				Connecting machinery, adjusting welded gear.
21	0	8				Test operation and arrange adjustable belt shift.
22	0	8				Set up water barrels and pipes. Trial of drill.
23	0	8				Make pipe connections and readjustments.
24	2	6	8.0	8.0	no rec'd	Bore in overburden with toothed cutter and drive weight.
25	1	7	0.7	8.7	" "	Connect casing with settling tanks. Bore with shot.
26	1	3	0.9	9.6	" "	Take lava core. Broke welded gear. Water pressure 40 lb.
28	0	8				Repairs. Drove casing to bedrock. Re-laid pipes.
29	0	8				Apply weight and pulleys for pressure; new gear.
30	0.3	7.7	0		" "	Drill through debris. Broke collar tractor engine.
31	0	8				Work on water barrels (increasing catchment).

Ground was broken for new hole at the end of month. In this respect the month of August for Hole No. 4 was much like June for Hole No. 3; that is, the first week was used up in finishing the previous hole, the main body of the month was occupied with assembling, and only the last week was given to drilling. This drilling accomplished only 9.6 feet of depth as breakage and water leakage occasioned set-backs. The statistics do not include water consumption as water was not measured until September in use of Calyx drill.

The figures for the few days of August drilling show that four days out of six and a half were without progress after ground was broken. Average drilling in rock was tested for two machine hours, averaging 0.8 foot per machine hour. Drill operation for 2.5 drilling days (days when some drilling was done) amounted to 1.6 machine hours per eight-hour day. Total footage (including overburden) averaged 3.8 feet per drilling day.

September Work With Shot Drill.

The crew of two men continued throughout September to operate the Calyx drill at Hole No. 4, under Mr. Jaggar's direction. Progress in footage of drilling was small, the hole reaching a depth of 24.5 feet. The delays were occasioned by experiments with the water system and by waitings incidental to cementing bottom of hole, and boring out cement; also set-backs due to broken cores remaining in the hole, followed by loss of the abrasive shot among the crevices in redrilling over the fragments.

Following table exhibits the record for September:

Date 1922	Machine Hours	Other Work (Hours)	Progress (Feet)	Depth (Feet)	Water Used (Gallons)	NOTES
Sept. 1	2	6	1.2	10.8	400 (about)	Took core 1.5 foot long. Water returned to settling tanks from well. Leakage around casing. Repairs.
2	1	3	0.7	11.5	100 (about)	Alternated drilling dry and drilling with water. Core clogged and stuck.
5	2.2	5.8	3.2	14.7	335	Measured water used. Drilled rock 36 minutes to the foot. Failed to recover core. Underground leakage.
6	8	0	0.3	15.0	954	Recovered cores but wasted water. Crack in bottom hole. Wasting shot. Cemented hole.
7	0	8	0	12.7		Set up more water barrels. Cement setting.
8	0	8	0	12.7		Work on water supply and repairs.
9	0	4	0	12.7		Experimental attempts to seal well with cement and clay.
11	1	7	0	12.7	200	Drill tools plugged with clay. Leak around casing.
12	2	6	4.1	16.8	491	Cleared hole, cemented it again. Repairs.
13	1	7	0	16.8	124	Drilled without progress. Leakage. Cemented seat of casing.
15-16			0	16.8		Crew laid off waiting for cement to harden.
18	5	3	0	16.8	177	Drilling through concrete and broken core. Use of clay unsuccessful, washed away.
19	5	3	2.1	18.9	267	Crevice in bottom. Used clay.
20	2.5	5.5	1.1	20.0	242	Fishing up core, spudding, sealing hole by pouring cement around plugged tools.
21	0	8	0	20.0		Experiments with pumping system. Hauling sand and clay.
22	0	8	0	20.0		Experimented with small inner pipe for water circulation in core barrel.
23	1	3			32	Drilled out plug of clay. Experiments.
25	2.5	5.5	0	20.0	31	Drilled with toothed cutter to clear hole. Water circulation inside string of tools.
26	1	7	0	20.0	10	Drilled with toothed cutter. Overhauled pump.
27	2	6	1	21.0	128	Used shot bit and inside circulation. Distinct saving of water and clean core.
28	6	2	1	22.0	218	Used neat cement. Drilling without progress. Lost core.
29	6	2	2.5	24.5	325	Plugging of pipes. Rearranged hose. Took core.
30	0	4	0	24.5		"Frozen" thread on core barrel. Disconnected for repairs.

The statistics here set forth exhibit facts both favorable and unfavorable for shot-drilling in a land of waterless basalt sheets. These layers of lava are mostly thin, one to two feet thick, separated by brittle porous shells and broken matter. The best cutting of the rock with shot-bit was done September 5 in a thick massive layer of fine-grained basalt yielding pieces of core twelve to thirteen inches long and making 3.2 feet progress in two hours, averaging 1.6 foot per hour. Most of the core fragments are only two to six inches long and these break-up. Pieces fall out when the tool is lifted and jarred by striking rock shoulders alongside the well. These pieces clog the bottom of the well, and drilling over them merely churns them around and crushes them or rounds them, most of the abrasive falling down the crevices and doing no work.

The process of "grouting," that is, catching and jamming the lowermost core fragment by washing small rounded pebbles down the rods until they reach the space between core and tubular bit where they wedge, is successful in lifting the cores if the lifting is done smoothly. Stratified lavas make walls unfavorable for smooth lifting. Shoulders necessarily occur where the well opens into cavernous spaces under massive layers. The core-barrel is bigger than the rod above, and even though its upper end is bevelled, the clearance is insufficient to keep it from jamming, bumping and sticking in its progress upward from the bottom. This loosens the cores and they drop out. If the well could be cased all the way down this might be avoided, but the expense of under-reaming and casing would wholly prohibit boring for scientific purposes.

It early appeared that "broken ground" was destined to be our most formidable enemy in this work. Broken or cracked country rock at bottom of well meant an instantaneous loss of water pressure at the pump and cessation of all backflow of water from well to settling tanks. A pressure of 45 to 50 pounds at the gauge would decrease to 5 or 10 pounds. This water brings up the mud or drillings and so washes the well clean. It is customary to use an open cylinder with closed bottom surrounding the rods at top of core-barrel, called the "calyx" or sludge bucket, for catching the heavier sediment brought up the well by the pumped water that has gone down the rods, past the bit in its annular groove, and up the well outside. The water pressure is sufficient to lift the dirt but not the shot. At Kilauea the calyx proved superfluous and useless, for all the dirt went off into the rock cavities, after the well was 15 feet deep. And with it went the water. The country is a natural sieve of cracks, porous layers and vesicles, hence the absence of all springs and watercourses above sea-level anywhere south of Hilo.

Hydraulic Experiments.

The hydraulic problem presented was how to keep a water pressure sufficient to feed the shot down, wash the core clean, keep the abrasive wet and the bit cool, and yet not waste water. It took two months to solve this problem, and September was largely given to experimenting with it. The mechanical problem of drilling rapidly in broken ground was left to the October program.

As the muddy water at first returned up the well very satisfactorily, and flowed back to the pump through the settling barrels, during the ten days of early work at this hole, it was hoped to save water by this method. On September 6, however, a crack was encountered, and nearly a thousand gallons was wasted, with boring progress of only a few inches in eight hours' work. Cement was poured down hole, then followed a long wait for the cement to set. As soon as drilling was resumed the cracks were again revealed. Various experiments were made with clay and cement, leaving these substances overnight around a closed pipe in bottom of well, and

whirling the pipe to fill the rock pores centrifugally, etc., etc. The fillers would seal the leaks temporarily, but as soon as new ground was broken big cracks would appear, water and abrasive would disappear, boring progress was too slow, and the cavities were much too big for this treatment. As the well was crossing cracks diagonally, it became evident that these cracks athwart upper part of well were increasing in number as the hole progressed, so that return of water to settling tanks would totally cease.

A successful experiment in saving water was made as follows and this method was retained for two months. There are two hose connections from pump to T-shaped swivel head at top of rods. A smaller hose is for feeding in shot, a larger for wash water. By way of economizing water and keeping a good pressure at the pump, the smaller hose was adopted for all injected water and the larger hose, attached to other side of swivel-head, was disconnected from pump and led into settling tanks as a drain pipe. A very small iron pipe (quarter inch) was connected inside the rods to the inner opening of this drain hose where it entered the swivel. This little pipe hung down inside of string of rods as far as top of core-barrel, open below, and rigidly attached to swivel above, so that the tools rotated around it. Water pumped through the shot hose passed down the rods to and around the core, washing past the latter more or less as the rock bottom was tight or creviced. The closed system full of water above core reflected the tightness of core by either filling through the rods up to the swivel-head and then sending a muddy overflow through the little pipe and the drain hose, or else if core was leaky a certain head of water was maintained in the rods sufficient to compensate pressure at pump and leakage at core openings. The little inside pipe thus replaced the leaky outer well as return passage for the water pumped, and if the bottom held water at all, by muddiness or otherwise, some water occasionally came back and trickled into the barrels. The small feed-hose and the core partially plugging the bottom made sufficient resistance to permit maintenance of about 25 pounds pressure at the pump, so that the shot were carried down to the bit as required. It was found eventually, as the well deepened, that no water returned to the surface, but the bit was cooled and kept free from sludge without consuming any excessive quantity of water. Pumping was not kept up continuously, but was repeated at short intervals, and shot were fed through the valve leading to hose whenever pump was started.

Summary of September Drilling.

There were fifteen drilling days (fourteen whole days and two half days) out of twenty eight-hour working days in September (eighteen whole days and four half days). For the fifteen drilling days, machine operation averaged 3.21 hours per day. Progress for the month was 14.9 feet. Average drilling per machine hour 0.31 foot. Average footage per drilling day was only 0.99 foot. These low averages are due to the time spent in experimenting and drilling out cement and broken cores. Of the fifteen drilling days six were without progress. The maximum day's progress was 4.1 feet, partly in cement, achieved in two hours of drilling.

Of water there were consumed in September 4033 gallons, averaging 269 gallons per drilling day, and 271 gallons per foot of progress. The maximum drilling day's consumption was 954 gallons, the minimum 10 gallons. For this month's record, therefore, the use of water per day was six times as great as with the churn drill, and per foot was twenty times as great. (See July Bulletin.)

Temperature of Hole No. 4.

Temperature measurement of Hole No. 4, Observatory yard, northeast rim of greater crater Kilauea, 60 feet back from rim, near eastern limits of steam crack belt, was as follows: Readings made with maximum centigrade thermometer, air temperature being read in the field. The erratic

temperatures are doubtless due to "steam" or hot air cracks obliquely crossed by the boring.

Date and Time 1922	Depth (feet)	Air Temperature		Bottom Temperature		NOTES
		Cent. Fahr.	Cent. Fahr.	Cent. Fahr.	Cent. Fahr.	
Aug. 26, 4:30 p.m.	9.6	21°	70°	36°	97°	Water in hole 3.2 feet deep. Tool hot.
28, 9:30 a.m.	8.0	23°	73°	26°	79°	Mud in bottom and 1.2 feet of water.
Sept. 2, 8:30 a.m.	10.8	21.5°	70°	28.5°	83°	Water in hole 1.7 feet.
4, 8:15 a.m.	11.7	19°	66°	32.5°	89.5°	Water in hole 1.3 feet.
6, 8:30 a.m.	14.7	18°	64°	33°	91°	Core fragments and no water in hole.
24 noon	18.9	21°	70°	39°	102°	Eight inches muddy water in hole.

VOLCANIC CONDITIONS IN SEPTEMBER

Activity of Halemaumau.

At the beginning of the month Halemaumau, the inner pit of Kilauea Volcano, awakened from its slumber for the second time since the great subsidence of May, 1922. On September 2 in the forenoon a lava fountain appeared at the top of the southeast talus, inside the pit, the glowing melt forcing its way up the cracks between the debris slope and the cliff wall. A cone about 15 feet high was quickly formed surmounted by an open pot six feet across, shaped like a tulip with five rampart scallops. Trickle flows escaped between the petals. This source cone stood approximately 150 feet above bottom of pit.

The flows progressed about 100 feet down the slope in the course of the afternoon, each trickling stream taking a tree-like form with narrow stem and branches spreading out below. The fountain at the source belched noisily at time, and flung up scoriaceous lava from ten to fifteen feet into the air, this material falling in a shower that resounded on the surrounding rocks. There was some fume adjacent to the active pot, but the jets of smoke that had been emerging from the wall at that place were no longer visible.

On September 3 the flows lengthened until their fronts rested on the July floor of hard lava 800 feet below rim of pit. The area covered by flows was about 300 feet long by 130 feet wide. The source cone increased in size to a large bell-shaped structure 30 feet high. This was vomiting out a stream of lava that followed the east side of the flow belt. The flows exhibited piles of aa fragments on each side of their lower courses, the upper parts of the heap being pahoehoe.

The inflow of lava continued throughout the month. During the second week the outpouring for each day had become inconspicuous owing to the formation of a large crusted pool fed by a torrent from the source cone flowing in tunnels. The pool was five sided and about 600 feet long, entirely covering the July lava. Every few hours the crust broke up so that the slabs sank in the melt below, and there were flows around the edges invading the rock slopes so as to increase continually the diameter of the lake.

The source cone at the top of the southeast debris slope become large and smoky with a hole in the top showing cherry red glow. Occasionally

the top of the cone fell in so as to reveal a bright well where the splashing lava sent up rocketing spurts of spray 50 feet into the air. At night the tunnel leading from the cone down to the lake was seen to be marked by glowing cracks, but in daytime there was merely a broad band of black lava flows made up of individual snaky ribbons. Some of these had edges of black clinker. Usually the cone was puffing, either rhythmically or irregularly.

On the evening of September 15 the crusted lake broke up leaving an open pool with one large fountain and several small ones in action. The lake thereafter remained open, and whereas the pit before had shown little glow, there was now flaring light on the fume cloud so that Halemaumau resumed its old time appearance, glowing now brightly, now dimly, as the fountains waxed and waned. At first there were two open patches but later the southern opening crusted over. The fountaining was in dome-shaped bursts with occasional upward flings of viscous lava, the crusted area round about being broken and the slabs drawn inward at each major explosion. The lake was extraordinarily flat like Keanakakoi. The lake was about 650 feet long and 735 feet below rim of pit, so that it had risen 126 feet since early July.

It had gained on the frozen lava cascade of the source cone, the latter maintaining an incandescent flagree on top where much smoke rose. Elsewhere, however, the pit was very clear. The lake shore in one place touched the wall of the pit above the debris slope and about the 17th some avalanches fell. On the 20th there were heavy avalanches from the north wall making a new debris slope and covering all the recent lava with dust. A gray scar was left where the wall rock had peeled off.

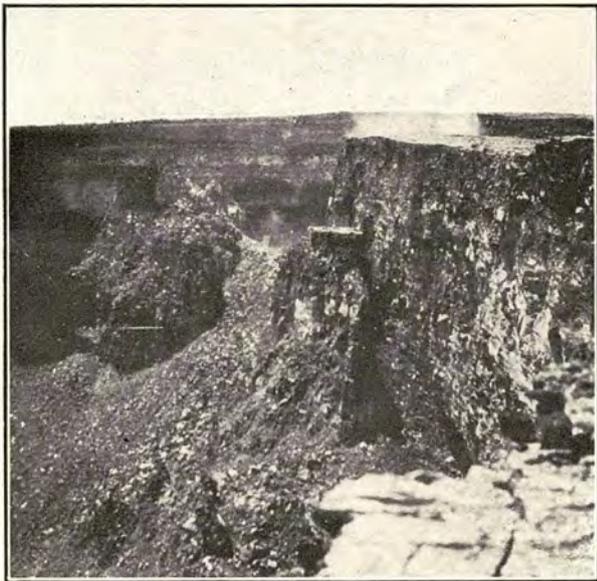
Immediately after this a flat-topped lava slag-heap was built up against the new slope and over the previous pool, the structure covering three-quarters of the crusted area and standing 20 feet above the earlier surface. The edges of the plateau so formed fell off steeply, with streams dribbling over, some black and some actively flowing. Near one edge of the flat black surface there was a partially open pool with a small fountain playing.

The early dusty pool showed as a crescent border under the cascade slope and glowing cone that still stood high above the lake areas against the southern wall of the pit. This cone of September 2 appeared still to be the main source of all the lava, which was presumably coursing downhill in tunnels of its own crust and filling up the pit with the aid of the new fountain as outlet.

By the last week in the month the plateau heap had spread out and covered up the older lake. Bright trickling streams ran down its border slope. The fountain built up a noisy grotto oven and the liquid lava rose 45 feet in eight days. The plateau pool stood 36 feet above the floor margin.

At the end of the month the source cone was high, glowing, flaming and hissing. The liquid lava was rising five feet a day. It occupied a brimming saucer overflowing its edge so that slopes led down all around it to a lower floor. This border fill had become an elliptical ring of lava in the space between the plateau created by the lake and the debris slopes that lay against the pit wall. The oval plateau stood 40 feet above the annular floor. There were generally seven trickling flows running down the flank of the heap, but sometimes bigger flows broke out and made delicate leaf-like patterns of fiery melt. The fountain on top coughed and spurted more or less noisily.

The source cone of September 2 was now only about 50 feet above the floor, lying against the southeastern wall of pit surmounting a dusty pile of frozen lava cascades. The opening darkened after September 28 and the smoke there increased in volume.



September 3, 1922. Southwest rim of Halemauau, showing rift chasm, debris slope, and inner benches. Photos—Jaggar



September 3, 1922. New lava cone and driblet flows on talus inside Halemauau. Bottom area is the July pool. Looking southeast.

JOURNAL, SEPTEMBER, 1922

September 2. At 1:30 p. m. it was found that a new lava vent had broken out at top of southeast talus inside of Halemaumau just where the July vent had been. An open pot had formed by engulfment of talus fragments in the lava beneath, and this hole was overflowing and gradually building up a small cone, the trickling stream being pahoehoe in the middle and aa at the edges. The outbreak had begun during the morning. At 3:30 p. m. the cone source appeared to stand about 150 feet above floor of pit, the width of flow belt was about 25 feet and the flows extended about 50 feet down the slope. The cone itself was built up about 15 feet above the ground on which it rested.

In the evening the flows had slowly extended themselves but there was no increase of action and the glow was insufficient to make an illumination seen at a distance.

September 3. At 10 a. m. the action of the new vent was somewhat stronger than before and the flows had developed delicate arborescent form with leaf-like widening below. They resembled the streams at Makaopuhi pit during the May eruption. There were black velvety aa heaps on both sides of glistening pahoehoe festoons, and each line of flow maintained a channel down the middle as in the Mauna Loa flows. Each trickle formed a separate narrow ribbon down the talus slope. Around the cone all the lava was pahoehoe. The cone had grown to a high bell-shaped dome standing 40 feet above the talus material on either side. The flow belt now extended out on to the July lava floor and was 300 feet long and 75 feet wide.

One side of the cone was seen to fall in and become slowly engulfed in the splashing melt. At the cone pot there was strong belching action and incandescent spatter fell round about. During the forenoon the flowing was from a gap in the east side of cone and the stream was adding an eastern ribbon in rapid motion to the side of the flow area. This ribbon was seen to reach the foot of the talus slope.

This talus had been created by avalanches that covered the southeastern half of the July floor with debris. The flow belt exactly corresponded with the debris cone, and the flows reached the floor and there came to rest.

In the evening by moonlight hardly any glow was visible over the pit, but the visitor on the rim could see glow in the quieter ribbons of the flow area indicating streams crusted over and moving in tunnels of their own crust.

September 4. At 3 p. m. the flows were found to have become mostly pahoehoe lava, and they covered one half the July floor. On the sides of the belt there were remnants of flows partly aa. The cone had become a large smoking structure with no lava visible, where gas was puffing faintly and irregularly. One ribbon of live lava was seen flowing partly under crust, and spreading into festoons below with its front pushing forward in large toes. From the beginning the rate of advance had been constant by means of one narrow live stream, now here, now there. There were occasional but rare falls of rock from walls of pit. The new cone was 606 feet below rim, the narrows of flow belt at upper lava bench level 766 feet down, and the front of flow belt about 800 feet below rim.

September 5. At 8 p. m. the flowing continued in about same volume as before. The July lava was now concealed and bright toes of live melt pushed out from edge of new fill on all sides. The source cone was puffing regularly about every two seconds. In southwest chasm at top of talus the glowing spots remained as before.

September 6. At 9 p. m. the new fill showed glowing cracks in the central region and a belt of bright toes around the edges that were invading the talus. The central pool occasionally broke up by cracking and foundering of crust.

Down western half of cascade slope a line of glow cracks was visible, where lava was flowing down to the pool by way of tunnels. During the evening the source cone collapsed and through the opening spray was flung up 50 feet or more into the air. There was fume and flame at the opening, and fountaining lava inside. Some avalanches occurred where the talus was disturbed around border of new pool. Puffs were heard from the cone early in the evening and these were weaker after the top fell in. Surface of pool was said to break up every four or five hours.

September 7. At 11:30 a. m. the activity was found to have decreased. No glow had been seen at night. Smoke had somewhat increased and no puffing was audible at rim of pit. The pool sent out a few live toes at its edges and one glow spot was visible along the cascade tunnels. No opening was seen in the source cone.

September 9. From 3 to 4 p. m. some renewal of activity was seen to be in progress. Live toes were making out from edge of pool in three places on west and north sides, and one live puddle was moving on the crusted surface of pool at foot of cascade slope. A cherry red hole had reappeared in top of cone, and here puffing occurred every thirty seconds or less. The pool was pentagonal in shape, covered with smooth black crust, and higher than before. No glow showed in cascade slope. Some of the lower streams on this slope still showed edges of aa lava. There was but little fume.

The cavern of March, 1921, back of southwest rim of Halemaumau showed signs of having fallen in lately, and hot cracks had developed athwart it parallel to the Halemaumau rim. These made the cavern hot. In southwest chasm the belt of glowing talus had increased in length and width.

September 11. At 4 p. m. there was weak and irregular hissing at the source cone and glowing toes were detected at four places around edge of lava fill.

September 13. At 10 a. m. no molten lava was visible anywhere, the fill seemed to be stationary and the source cone was hissing at irregular intervals.

September 15. At 11 a. m. measurement made surface of pool 737 feet below rim and there had been some bright flaring breakings up of the pool on the previous evening. The pool appeared large and as smooth as Keana-kakoi crater floor. Around the edges live black pudding lava was in motion. The source cone was high and cindery with smoke on top. In plan the pool had now assumed a diamond shape with the long points north and south. The northern point was now only a few feet below the smoke vent which had been in action at base of north wall of pit throughout August. Puffing was not audible but there was some sliding of rocks.

The southwest pinnacles had changed shape from day to day. A seam of white stain nearly vertical and trending east and west had developed in lower part of south wall of pit following a fissure there. At top of talus west of source cone a yellow patch was conspicuous.

At 4 p. m. all was quiet in the pit and the cone was glowing.

At 6 p. m. there was a strong breaking up of crust in the lake making bright flare on the fume above. Glow continued all night from a fountain-

ing patch on northwest side of pool which kept up a persistent bubbling. At first there were two patches, the second being near base of cascade slope, but this afterwards went out of action.

At 8 p. m. a line of fountains was seen on northwest side of lake. One of these was large, flinging up the melt 30 or 40 feet. This was continuous and the smaller ones on each side were intermittent. Crust of pool was cracked and glowing in many places and source cone showed bright glow.

September 16. At 4:30 p. m. a small fountaining patch was observed on northwest side of lake and the crater was now bright at night. Source cone had become a glowing filagree structure emitting smoke. No noise was heard from the cone but the lake fountains puffed and splashed. Fume from the pit had increased.

The return of a fountaining lake to Halemaumau and two small earthquakes at this period gave evidence of an equinox effect.

September 17. At 12:50 p. m. an avalanche cloud rose from northeast side of pit and some other avalanches occurred during the day. Pit at night was glowing.

September 18. At 9:30 p. m. the pool showed many bright lines and one fountain throwing up viscous lava. Source cone glowed brightly. The lake fountain had built up a spatter grotto. Three glowing toes were observed at edge of fill.

September 19. At 9 p. m. there was an open lake in the pit with a fountain on the side remote from the source cone and cascade slope. This fountain was feeding flows that trickled sluggishly over a crust as though the fountain were at the top of a heap. The flows moved mostly northwest to southeast across the lake area, and front of flow continually infringed on the crusted area by producing with its weight an irregular cracking and foundering of the crust beneath. There was some noise from the fountain. Summit of source cone remained a glowing and smoking filagree. The cascade slope was dark at night. Edge of lake area on the north had now surmounted the smoking talus and lay against rock wall of pit. On northwest side trickling lava still invaded the talus.

September 21. At 11 a. m. there was marked increase of activity and other changes simultaneous with the equinox and the pit had become brighter as seen at night.

Heavy avalanches had fallen from the north wall burying the smoke hole there and covering the floor and cascade slope with dust. This left a new high northern talus above which a gray scar in the wall extended up to the northern shelf remnant. A flat topped slag heap had formed around the lake fountain and this overlapped the new talus slope. The heap had a margin of dribble flows on the south, east and northeast sides and a big flow from it was pouring northeast over part of the new talus, the remainder being black and fresh in marked contrast to the dusty floor on southeast side of pit forming a crescent around the slag heap. The latter appeared to stand 15 feet above this floor. The source cone at top of cascade slope was glowing and smoking. On top of the new slag heap there was a flat plateau where the fountain puffed, but the fountain was nearly lost in the flat black pool and could barely be detected, tending to lift a small lid. In plan the slag heap showed a scalloped edge.

September 23. Measurement at 3:30 p. m. made the lower borders of the floor 728 feet, and the fountain on the slag-heap 688 feet below rim of pit. The slag-heap was thus 36 feet high. The source-cone at top of cascade slope southeast was now a high structure fuming and hissing, with

some black granular spatter below it. The fountain on the slag-heap had become a grotto puffing and spattering, open toward west. The older floor was entirely covered by new lava. Seven trickle flows coursed vigorously down the south, southeast and southwest slopes of the heap. The main floor or fill below the heap was also trickling at the northern and southern edges in five places. In front of the grotto lay an open pool 30 feet in diameter. The fuminess had increased, and at southwest chasm the glow and smoke remained as before.

September 25. At 11:30 a. m. there were seven moving flows of snaky shapes with festooned skin on their surfaces trickling down the outer slopes of the slag-heap. The grotto on top was puffing and splashing, at the edge of a flat pool smaller than before, this forming the top of the slag heap and occupying about one-fifth of the area of bottom of pit. The source cone southeast and fresh debris near it were smoking.

September 26. At 9 p. m. the source cone glowed brightly, and one fountain of the slag-heap pool was playing and making hissing noise. Trickling flows poured away from the slag-heap, and one flow at the base of cascade slope under the source cone was directed toward center of pit.

September 28. At 3 p. m. the southeast source cone exhibited no glow by daylight, but sent up smoke. The fountains in slag-heap pool exploded every three seconds and eight trickling flows were counted around margin of heap.

September 29. At 6 p. m. the eight flows were still in evidence, and the fountain of the slag-heap pool was spurting and snorting. The flows poured from the overbrimming edges of the summit lake. There was a pattern of glow lines seen after dark between the crust blocks of the lake surface, and also at the border fill outside of the slag-heap, but not on the outer slope of the heap. The source-cone southeast was dark at night.

About 6:30 p. m. the lake developed a notable increase of lava pressure and a large flow broke over its southwest edge and poured downhill on slope distributing its branches westward. The distributaries made a thick foliate pattern like a lettuce leaf. The liquid bubbling out at source of this flow made a rushing noise. The flow became 200 feet long and glowed brilliantly, and other small flows increased. The top area, or summit pool, remained crusted.

The pit was smokier and the fume more acrid. The "glowing coals" of the talus at southwest chasm were less luminous than before, though the incandescent area was the same. At night the pit as a whole glowed variably, with some flaring caused by the fountain.

September 30. At 10 p.m. two trickling flows were in motion and one large fountain was nearly continuous in its action at the grotto. Some small fountains broke out occasionally at other parts of the lake. The source cone glowed dully.

LAVA MEASUREMENTS

The only measurements of the pit in August were described in the Journal for August 19 when the July floor was found to be 791 feet below northeast datum station (datum 3716 feet above sea-level). There was probably some little subsidence of the floor just before September 1.

Progressive measurements of the September inflow of lava to the pit, expressed as depression in feet below northeast station, were as follows:

	July Floor	Sept. Cone	Bottom Cascade Slope	Pool	Floor Border
Aug. 19, 2:00 p. m.....	791	.....	.....	.....	.....
Sept. 4, 3:00 p. m.....	800	606	800	.....	.....
“ 15, 11:30 a. m.....	.....	584	736	740	740
“ 23, 3:30 p. m.....	.....	.....	.....	688	720

On September 4 the narrows of the flow belt on the cascade slope were 766 feet below rim. Base of cascade down talus from the source cone was 29 feet lower than the floor of August 19 on the eastern front, and 11 feet higher on the west side of the front; this made the mean depression of front 800 feet. The source cone at top of talus stood 194 feet above bottom of pit.

The September 15 measurements indicated pit at border of new pool had filled 60 feet since September 4, averaging in eleven days 5.5 feet per day. The source cone had built itself up 22 feet, averaging .2 feet per day.

September 23 the pool had risen by building up a slag-heap around itself, the edges of the new fill, against the talus, being much lower than the pool. In eight days the lake had thus risen 52 feet, averaging 6.5 feet per day, whereas the border had filled only 20 feet, averaging 2.5 feet per day.

The following figures show monthly changes of level of bottommost part of pit, approximately, beginning with July 1922. The starting point was the debris cup of June, left by the May collapse, 861 feet below rim station.

July, lava inflow.....	+ 70 feet
August, slight slumping.....	- 29 “
September, lava inflow.....	+100 “

No attempt is here made to evaluate data as of last day of month, but figures exhibit results of measurement nearest to that day. This is mentioned because the comparative monthly change tables (see May 1922, Bulletin) are ordinarily computed for last day of month on basis of rate of lava fluctuation.

SEISMOMETRIC RECORD

During the month ending midnight Sept. 30, 1922, fifteen local earthquakes and one distant shock were registered at the observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W, 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

Sept. 3.....	11:44 a. m.	Very feeble.
3.....	7:41 a. m.	“ “
10.....	5:06 p. m.	“ “
13.....	7:35 a. m.	“ “
14.....	8:54 a. m.	“ “
	3:51 p. m.	Feeble, distance 9 miles.
	10:07 p. m.	Very feeble.
16.....	1:57 a. m.	“ “

17.....	11:30 a. m.	“	“
21.....	10:25 p.m.	“	“
22.....	2:46 a. m.	“	“
23.....	2:09 a. m.	“	“
	5:44 a. m.	“	“
25.....	11:55 a. m.	Feeble.	
30.....	12:50 p. m.	Very feeble.	

Teleseism.

Sept. 9.....10:30 p.m. Slight.

Spasmodic Microtremor.

This type of tremor was slight throughout the month.

Harmonic Microtremor.

This type of tremor was extremely slight throughout the month.

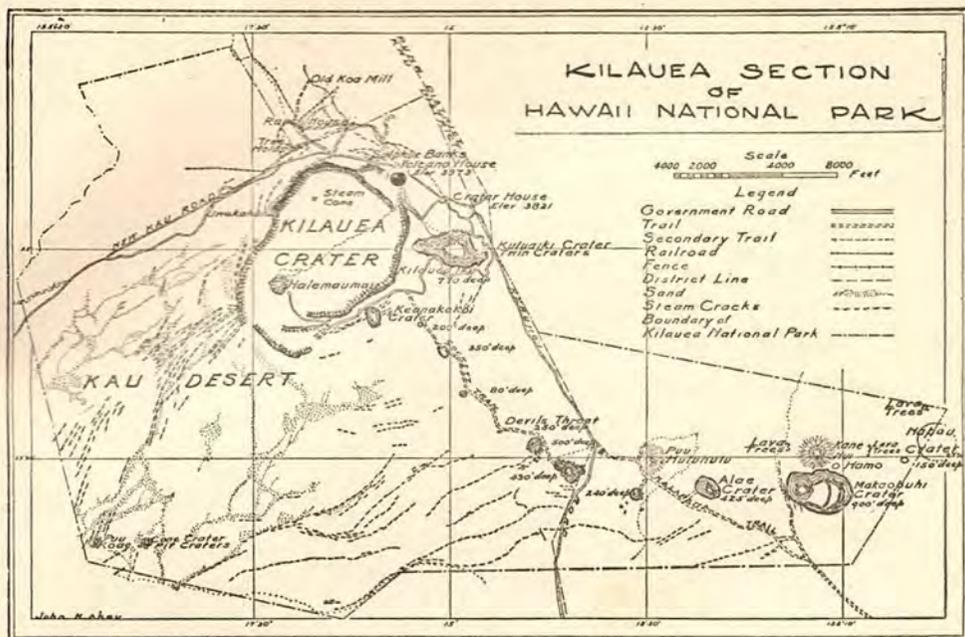
Miscroseismic Motion.

The amplitude of miscroseisms was slight throughout the month.

Tilting of the Ground.

Sept. 2 - 8.....	1.2 seconds	NNW.
9 - 15.....	2.9	SE.
16 - 22.....	6.3	NNW.
23 - 29.....	4.5	NE.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges should be addressed to

HAWAIIAN VOLCANO OBSERVATORY,

Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismic instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of local earthquakes; one optically recording seismograph for distant earthquakes; one clinograph registering E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete piers in a closed basement room having practically constant temperature, beneath the chief Observatory building near the hotel. Time is referred to a rated chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. $19^{\circ} 25' 54.2''$ N.; Long. $155^{\circ} 15' 39.2''$ W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun," a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Sword (*Argyroxiphium*). Thirteen volcanic cones lie wholly within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvelously beautiful.

Wailuku is the point of departure, automobiles taking the traveler to Olinda, a summer residence settlement 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of 3½ hours. Here is a fine concrete rest house built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa, a vast dome 13,675 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bri-

liantly colored lava slopes, has a summit crater 3 miles long by 1½ miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jetted 500 feet into the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaii National Park, if not in the world. The pit of fire, Halemauau, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overridden by the lava slopes of Mauna Loa on the west, so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solfataras and a strange desert where lava flows have poured out of cracks as recently as 1920.

The live pit of Halemauau is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvelous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory, which stands on the brink of the greater crater within the Kilauea Park.

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

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No. 10

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PROGRESS OF BORING EXPERIMENTS

October-November Work With Shot Drill.

Owing to illness of assistant-driller, work was delayed early in October. The shot drilling at Hole No. 4, Observatory grounds, was continued until a depth of 65 feet was reached November 4.

Owing to the loss of abrasive in vesicles and cracks, a series of tests was made with six different models of magazine bits designed by Mr. Jaggar. The final test November 4 bored out 6 feet of hard vesicular basalt in 2.3 hours, recovered the core, and used only 267 gallons of water. This was at 65 feet of depth where the temperature was 36° C. (97° F.)

The good progress was not wholly due to the special bit. During the last three days of drilling an average of 3.6 feet per hour was attained in 4.3 hours drilling with this bit and ordinary bits, using an average of 100 gallons of water per hour. The maximum speed was on November 3, 5.7 feet in an hour with an ordinary bit. The cores from this rapid drilling were both coarse and fine rocks, partly broken and with large vesicles and in no way unusual.

Two new methods contributed to success: one was the use of two vertical slots on opposite sides of the bit for the passage of shot, instead of one inclined slot: the other novelty consisted in feeding shot and water

down the well outside the tools as well as inside, so as to keep the bit grinding the wall of the well and leaving the core barrel loose. It had been learned by experience that too much water in this porous rock was undesirable as it washed the shot away; it was better to keep the shot in a muddy paste, washing away the excess drillings at intervals, and not using the pump continuously.

Following table exhibits the record for October-November. The work was suspended after November 4 in order that preparations might be made for further work at Sulphur Bank in January 1923, and to give time for repairs, alterations and purchases incidental to moving the drill and its tower.

Date 1922	Machine Hrs.	Other Work Hrs.	Progress Ft.	Depth Ft.	Water Used Gals.	NOTES
Oct. 2	0	4	0	24.5		Repairs. One man sick Oct. 2 to 13.
" 3	3	5	1.5	26.0	330	Test with first magazine bit. Broken rock. Progress with ordinary bit.
" 4	3	5	3	29.0	313	Progress followed by magneto trouble.
" 5	1	7	0	29.0	181	Repair magneto. Recover core.
" 6	1.5	3.5	1	30.0	207	Engine trouble. Recover core.
" 9	2.5	5.5	1.5	31.5	210	Engine trouble. Broken rock. No core.
" 10	6.5	1.5	1.3	32.8	628	Broken rock. No core.
" 11	3	5	0	32.8	380	Recovered core with toothed cutter.
" 12	5	3	2.2	35.0	418	Test with second magazine bit.
" 13	3.5	4.5	1.7	36.7	501	Broken rock. No core.
" 14	0	4	0	36.7		Repair car.
" 16	4.5	3.5	4.0	40.7	400	Broken rock. Shoulder of rock jars tools. No core.
" 17	4.5	3.5	0	40.7	378	Drilling out core. Test with third magazine bit. Pump Trouble.
" 18	2	2	0	40.7		Engine fan broke. Repairs.
" 19	3.5	4.5	0	40.7	651	Drilling out core.
" 20	3.5	4.5	0	40.7	348	Remove core. Spudding.
" 21	0	4	0	40.7		Test with fourth magazine bit. Drop tools in hole.
" 23	0	8	0	40.7		Fishing for tools.
" 24	1.5	6.5	0	40.7	197	Recover tools. Continue test.
" 25	4	2	1	41.7	1118	Ordinary bit. Wasting water. Recover core.
" 26	5.5	2.5	2.7	44.4	775	Spark plug trouble. Recover core.
" 27	3.5	4.5	1.8	46.2	291	Short core barrel used; discard calyx. Recover core.
" 28	2	6	3.1	49.3	147	Tools stick at shoulder. No core.
" 30	5	3	0	49.3	369	Core obstructs well. Spudding. Fan broke.
" 31	0	8	0	49.3		Repairs.
Nov. 1	6	2	0	49.3	794	Rapid drilling over core of Oct. 28. Feeding shot outside.
" 2	3.5	4.5	4	53.3	466	Test with fifth magazine bit. Remove core. Progress with ordinary bit.
" 3	5	3	5.7	59.0	388	Another test. Progress with ordinary bit, shot fed inside and out.
" 4	3	5	6	65.0	267	Successful test with sixth magazine bit.

Summary of October-November Drilling.

There were twenty-three drilling days out of twenty-six-and-one-half working days in October-November. For the drilling days, machine operation averaged 3.74 hours per day. Progress for the month was 40.5 feet. Average drilling per machine hour was 0.47 foot and average footage per drilling day was 1.76 feet. Of the twenty-three drilling days, eight and one-half were without progress owing to cores blocking hole, broken machinery, experimental tests, and fishing for tools. The average footage for the 14.5 drilling days of progress was 2.79 feet. On this basis the drill operation and daily footage compare favorably with the record of churn drill in June. The maximum day's progress was six feet, achieved in 2.3 hours of drilling.

Water consumption was 9757 gallons, averaging 424 gallons per drilling day and 241 gallons per foot of progress. The maximum drilling day's consumption was 1118 gallons, the minimum 147 gallons. Consumption per foot of progress was an improvement on the September record, but the use of water here in shot drilling is enormously greater than in churn drilling.

Temperature of Hole No. 4.

It was shown in the September Bulletin that this hole in the Observatory yard, 60 feet back from the northeast rim of Kilauea Crater, reached a bottom temperature of 39° C. (102° F.) at 18.9 feet of depth, and that the temperature higher up was erratic owing to hot vapor in crevices. These are the so-called "steam cracks" near the hotel. Following table exhibits readings of thermometer farther down the hole, made as the boring proceeded, with maximum Centigrade thermometer, air temperature being read each time.

Day and Time 1922	Feet Depth	Temperature Air		Temperature Bottom		Notes
		Cent.	Fahr.	Cent.	Fahr.	
Oct. 6, 8:00 a. m.	30.0	18	64	37	98.5	Core in hole. Mouth of well steamy.
" 13, 9:00 a. m.	35.0	21	70	38	100	
" 26, 4:00 p. m.	44.4	18	64	37	98.5	
Nov. 4, 3:30 p. m.	65.0	18	64	36	97.0	Mean of three read- ings.

The gradient of the whole 65 feet showed highest temperature 19 feet down of 39° C and a slight decrease from there to the bottom. The aberrant temperature was just below the overburden of soil at 9.6 feet of depth, where the temperature was 36° C; after two days accumulation of mud reducing depth to eight feet the temperature dropped to 26° although the air temperature was higher. From this time on to the opening of the hole at depth 19 feet the rise of temperature was gradual, but below that the temperature was lower and nearly constant. It is probable that this gradient is affected by air circulation through the broken and vesicular layers of basalt, and by the proximity of the face of the bluff, which exposes openings.

VOLCANIC CONDITIONS IN OCTOBER

Activity of Halemaumau.

During the first week of the month the lava of the Kilauea firepit rose slowly, much of the flowing from the lake being expended in filling around the edges of the floor area. This wall-valley was lower than the middle region, where the crusted pool stood high like a plateau, hemmed in by

border ramparts. Over these ramparts the lake continually overflowed, its surface being about 650 feet below the Halemaumau rim.

Off at one side the smoking cone which was the source that gave rise to all the new activity, had collapsed on top leaving exposed a black hole, where at night some faint glow was visible. The smoke around this cone was decreasing and the pit as a whole was quite free from fume.

The rampart overflows were in continuous motion, some of them being visible whenever the pit was visited. Their locations were ever changing, the lava moving down the outer slopes of the plateau in from five to seven streams. The lake itself was not in the center of the floor area but off towards the northwest side. Small live tricklings of lava were generally to be seen at some portion of the outer edge of the floor, where the surface was extending itself and burying the debris slopes.

By the middle of the month there was some augmented activity accompanied by avalanches from the walls. Whereas on October 8 three flows were seen running over the rampart that hemmed in the lake, five days later eighteen flows were counted and a new spurting cone had made its appearance. Moreover the older source cone off to one side at the top of the talus, resumed its spouting activity, overflowing its lip and exhibiting a splashing fountain in its crater. It snorted and hissed at intervals and the fuming near it entirely disappeared.

Four avalanches at the pit on October 13 were audible even at the Observatory, and were seen to send up clouds of red dust. These left raw scars in wall of pit over the region where the old southeast cone had broken out. New debris slopes were formed here. There had been very few earthquakes during the summer, but an earthquake occurred each night October 13 and October 14.

With the source cone less than 640 feet down and the floor covered with brilliant flows, spurting cones and splashing grottoes, Halemaumau was again becoming spectacular.

The measurements indicated that rising had been slow early in October, but during the last half of the month the floor built up more rapidly. October 21 the marginal source cone was 624 feet below rim, the active lake 648 feet and the edge of floor 670 feet. The lake thus occupied a raised basin 22 feet above the lava flows surrounding it and 24 feet below the spouting cone at top of debris slope. The lake in six days had risen 16 feet.

During the third week activity was variable, a fountain playing all the time at one grotto on the lake shore, and other fountains breaking out when a spell of overflowing cracked up the marginal crust of the lake and let loose confined gas. The overflows were now usually of short duration. A new pond formed on the east side of the floor area and outside of the lake basin, with a spurting cone at its side and overflows at its edges. The southeast source cone overflowed its lip in several places and built up its summit, creating a pile of glowing filagree. The main lake was about 350 feet long. Trickling flows were usually visible all over the floor area outside of the lake basin proper, and this fill was slowly building up the bottom of the pit and infringing on the slide-rock slopes. Spatter cones had appeared at several small active spots.

The change of habit during the month from continuous visible overflows of the lake basin to continuous trickling border flows coincided with a change in the rising at the end of the month. There was now only a slight rise of the surface, but the new lava coming in was spreading out and evening up to the levels of the outer fill and the lake basin. Much of the liquid was doubtless flowing in tunnels. The lake dome swelled and cracked so that a large crevasse developed athwart it. This tumescence left the lake depressed in its cup with a wall 15 feet high on one side.

All around the dome there was a fill that was much of it an annular pool with smooth flat crust and liquid trickling out about the edges. Through this crust at one place a spurting cone had formed.

The southeast source cone now glowed continually and surmounted a cascade slope of fresh lava so that the summit stood above the top of the talus and about 30 feet above the floor.

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October 1. At 11 a. m. the floor was found to have increased in size with its outline convex east and west, concave northeast and southeast, and straight on the south. There were clustered flows on the east slope of the heap containing the lake and at the southeast margin of the border fill. There were other small trickling flows making about seven in all. The fountaining grotto was coughing and the lake crusted over. Six or seven frozen festooned flows extended northeast and northwest from the grotto fountain. The big cone on top of the cascade slope southeast and the adjacent ground were smoking. The cascade slope which it surmounted appeared lower than before, about 50 feet high.

October 4. At 4:30 p. m. floor area showed same general outline. Lake activity was sluggish, the grotto fountain heavy, and one flow poured from the edge of pool near grotto towards the northwest. Five other sluggish flowing places were detected on the slag-heap slopes and in the border area. This border floor appeared very black and granular and its south end was inactive. There was an open black hole in the top of southeast source cone.

October 5. At 9 p. m. faint glow was visible in southeast cone and the grotto fountain at the lake was bursting only three or four times a minute. One small flow poured northwest from bank of lake near grotto.

October 8. At 8 p. m. three adjoining flows were seen pouring over south bank of lake. There was loud hissing of gas through a small hole in roof of grotto and the lake level was flush with the grotto oven and so confining the gas inside. Occasional fountaining occurred there.

October 10. At 8 p. m. there was one vigorous fountain, which with the hissing grotto was noisy for a half-hour. Then there was quiet. Flows poured east and west over the lake rampart and crust would crack up and founder at south end of lake.

October 12. At 6:30 p. m. both floor and lake showed glowing cracks and some recent flows lay on flanks of slag-heap. The grotto fountain was active and the southeast source cone was spraying, snorting, flaming and glowing. The cascade slope beneath the cone was now short, and smoke there was lessening.

October 13. Four avalanches sent up red clouds of dust during the day and were heard at the Observatory. Some of these fell from the semi-circular cliff overhanging the southeast source cone. At 6 p. m. small slides were seen to fall from the southwest pinnacles just inside the Halemaumau rim. At this time the slag-heap was overflowing and in the course of an hour the number of streams increased from twelve to eighteen. These were chiefly towards the southeast, each flow making a pattern like a tree with the cascade for its trunk. The grotto fountain sent its spurts high in the air and a new cone was spurting on the eastern floor. The southeast source cone hissed and snorted loudly inside a large broken crater opening, and new flows from it had poured down the cascade slope. There was no smoke there and the pit was remarkably free from fume. Fume had lessened even at the southwest chasm and the glow there was less bright than formerly.

October 15. Measurements at 11 a. m. made the lake 666 feet below rim of pit. The lake surface was cracking and foundering and large overflows poured eastward. The eastern floor cone appeared to be at the eastern border of a new pool. The southeast source cone exhibited splashing lava in its crater, making a rushing noise as though a cascade poured from it in a tunnel. There was the scar of a recent avalanche on southeast cliff and fresh debris lay below. The recent border floor showed a sagged edge coated with dust and over this trough new black flows from the slag-heap were crawling. A pronounced spatter rampart had been built at the lake grotto, and all the western edge of lake showed definition, but the eastern margin was obliterated by overflow.

The southwest pinnacles had been changing shape by collapse during the last few weeks. At the old southwest cavern on top of the cliff margin of the pit new hot cracks had opened parallel to the Halemaumau edge. Scorching hot air rose here.

October 17. At 6:30 p. m. the main lake and east pond were outlined by glow cracks. Recent flows were similarly depicted. The grotto was fountaining, there was glow in the source cone and the pit was very quiet.

October 20. At 5 p. m. the lake exhibited three short overflows, and there was a flow inward on the floor from its northeast edge. There were many glowing spots in the southwest floor, the source cone glowed brightly and there were hissings at the east cone and at the grotto, where the usual fountain was playing.

October 21. At 3 p. m. the lake was 650 feet below rim and the border fill had been gaining on the slag-heap. The eastern pond showed a definite spatter border. The main lake was about 350 feet long and its single fountaining grotto lay at the north end. From the southeast source cone a new flow had poured down the west side of the cascade slope under the cone. The edges of the floor were trickling, seven live places were seen, and the slag-heap slope around the main lake exhibited radial flow markings. A strong overflow at the lake edge was followed by general breaking up along the shoreline and a subsequent lowering of the lake surface. It was evident that the small east pond tended to form its own heap as flows extended radially away from it. There were four or five places on the floor that appeared to be dormant spatter cones. Inside the southeast source cone crater there was a hissing and flaming filagree.

October 24. At 7 p. m. there was one small overflow from the lake, the surface of which was cracking and foundering and several trickling flows were in motion on the outer floor.

October 26. At 6 p. m. the border fill was broad and glowing in contrast to the slag-heap slope which was dark. The lake grotto was fountaining and spurting, and the source cone flaming and spitting. The east cone was capped with a bright flame and hissed loudly. The wall bounding the main lake on the north was three feet high. Small live toes were trickling here and there on the floor.

October 27. At 5 p. m. the east pond vent was seen to be a cone spurting and flaming, the southeast source cone was flaming through filagree orifices and the grotto fountain ejected high spurts, making a ring of spatter around its orifice. Fresh avalanche dust covered the northeast floor and some small slides were seen. Near the eastern cone and at the base of the cascade slope the crust on large puddles was cracking and foundering.

October 29. At 4 p. m. it was evident that north bank of main lake was lifting and the whole slag-heap was swelling, as a large crevasse had formed in the latter trending northeast from the lake, and the bank on north side of lake was now 15 feet high. Shoreline all around lake was



Figure 16. July 21, 1922. Automobile with special gears, drawbar and double wheels, hauling water for drilling on Kilauea floor.—Photo Jaggar.

higher than before. Moreover the wall-valley northwest of the slag-heap was sagging. The east cone had become a tall spire which was spitting out lava and there were live toes on the southwest floor.

LAVA MEASUREMENTS

Measurements of depression of the mobile lava column, made with transit, referred to northeast station on rim of Halemaumau pit (3716 feet above sea-level), for the month ending October 31, 1922, including floors of bench magma and liquid level of lake magma, were as follows:

Date	Time	Northwest Pool	Border Floor	Southeast Cone
September 23,	3:30 p. m.	688 feet	720 feet	.....
October 1,	11:00 a. m.	676 "	699 "	.....
October 15,	11:00 a. m.	666 "	678 "	634 feet
October 21,	3:00 p. m.	650 "	672 "	626 "

Progressive changes for the liquid lava were as follows:

Sept. 23-Oct. 1, 8 days,	floor rose 21 feet,	averaging per day	+2.6 ft.
October 1-15, 14 "	" " 4 "	" "	+0.3 "
October 15-21, 6 "	" " 16 "	" "	+2.7 "

Progressive construction of the border floor was as follows:

Sept. 23-Oct. 1, 8 days,	lake rose 18 feet,	averaging per day	+2.2 ft.
October 1-15, 14 "	" " 21 "	" "	+1.5 "
October 15-21, 6 "	" " 6 "	" "	+1.0 "

The floor continued to build itself up until the end of the month as shown by November measurements, increasing its rate of rising 1.7 feet per day, whereas the lake rose only half as fast as before, namely 1.3 feet per day.

The September source cone southeast was recorded as being 584 feet below rim September 15, and it was a collapsed funnel fifty feet lower than that a month later. October 15-21, in six days, its inner fountain rose 8 feet, averaging 1.3 feet per day.

The monthly changes of the bottommost part of pit measured from July to October were as follows, starting with the June low level 861 feet below rim station:

July	Lava inflow	+ 70 feet
August	Slight slumping	- 29 "
September	Lava inflow	+100 "
October	Lava inflow	+ 65 "

The October figure is evaluated for the approximate upbuilding of border floor at end of month.

SEISMOMETRIC RECORD

During the month ending midnight October 31, 1922, twenty-nine local earthquakes and three teleseisms were registered at the observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W. 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

October 2.....	12:03 a. m.	Feeble.
3.....	9:10 p. m.	"
5.....	4:55 a. m.	Very feeble.
	11:29 a. m.	" "

	3:23 p. m.	Feeble, distance 11 miles.	
6.....	1:33 a. m.	Very feeble	
7.....	5:05 p. m.	" "	
11.....	12:38 p. m.	" "	
12.....	2:54 a. m.	" "	
13.....	12:23 p. m.	" "	
	12:25 p. m.	" "	
	12:26 p. m.	Feeble	
	11:08 p. m.	Slight, distance 40 miles. Felt in Hilo and strongly in Kohala.	
15.....	12:55 a. m.	Very feeble.	
18.....	11:13 a. m.	Slight, distance 20 miles.	
20.....	6:04 p. m.	Very feeble.	
21.....	1:40 a. m.	" "	
	10:35 a. m.	" "	
23.....	7:34 a. m.	" "	
25.....	2:55 p. m.	" "	
27.....	12:51 a. m.	Slight. Felt locally.	
	6:47 a. m.	Very feeble.	
	1:36 p. m.	" "	
	2:00 p. m.	Slight.	
29.....	9:51 p. m.	Very feeble.	
	10:13 p. m.	Slight, distance 16 miles. Felt in Hilo.	
30.....	8:55 a. m.	Very feeble.	
	2:25 p. m.	" "	
31.....	2:40 a. m.	Feeble.	

Teleseisms.

October 24.....	11:00 a. m.	Slight, distance 3680 miles.
29.....	3:36 p. m.	Slight.
	4:28 p. m.	Slight.

Spasmodic Microtremor.

This type of tremor was slight throughout the month.

Harmonic Microtremor.

This type of tremor was extremely slight throughout the month.

Microseismic Motion.

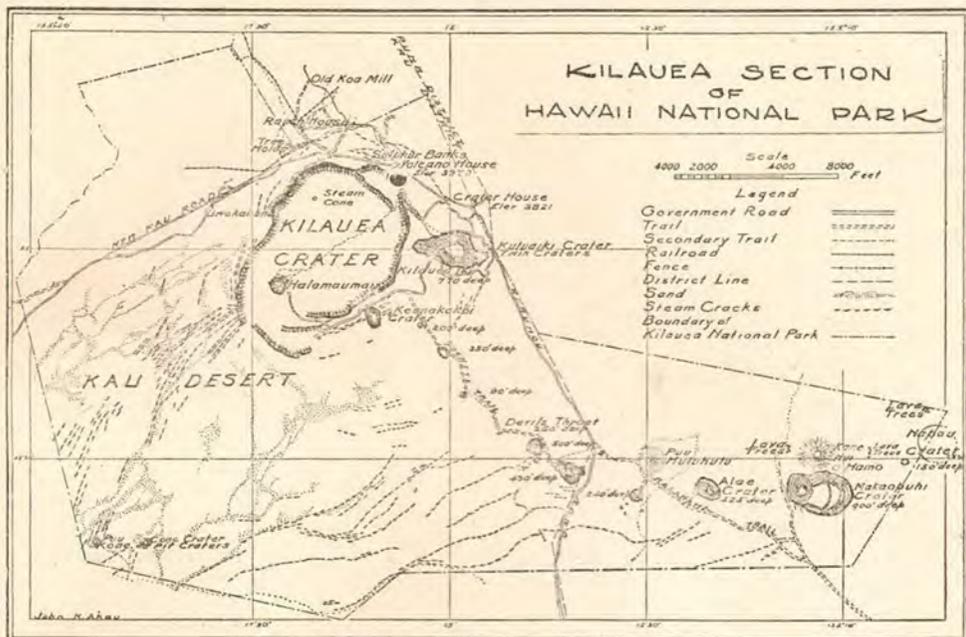
The amplitude of microseisms was slight throughout the month.

Tilting of the Ground.

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

Sept. 30-Oct. 6.....	0.6 second	NNE.
Oct. 7-13.....	5.3 seconds	SSW.
14-20.....	2.1	NE.
21-28.....	3.3	S.

T. A. JAGGAR,
Volcanologist.



All exchanges should be addressed to
HAWAIIAN VOLCANO OBSERVATORY,
Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismometric instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of local earthquakes; one optically recording seismograph for distant earthquakes; one clinograph registering E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete piers in a closed basement room having practically constant temperature, beneath the chief Observatory building near the hotel. Time is referred to a rated chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. 19° 25' 54.2" N.; Long. 155° 15' 39.2" W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun," a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Sword (*Argyroxiphium*). Thirteen volcanic cones lie wholly within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvellously beautiful.

Wailuku is the point of departure, automobiles taking the traveler to Ohihina, a summer residence settlement 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of 3½ hours. Here is a fine concrete rest house, built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa, a vast dome 13,675 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bril-

liantly colored lava slopes, has a summit crater 3 miles long by 1½ miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jetted 500 feet to the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaii National Park, if not in the world. The pit of fire, Halemaumau, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overridden by the lava slopes of Mauna Loa on the west, so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solfatara and a strange desert where lava flows have poured out of cracks as recently as 1920.

The live pit of Halemaumau is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvellous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory, which stands on the brink of the greater crater within the Kilauea Park.

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

Activity of Halemaumau.

At the beginning of November the lava in Halemaumau was more or less stationary. The floor of the pit appeared flat from above but measurements indicated that it was not flat. The lake of viscous heavy melt had become a crusted pool occupying the depressor at the top of an inverted saucer with cracked slopes leading down and away from the lake. The lake was no longer visibly overflowing. It had acquired high enclosing banks with a fiery grotto under the overhang on the northern side. Here a fountain of gas bubbles would burst at intervals through the sluggish fluid, breaking the crust in concentric rings, and sending up spray with an explosive cough that made a pattern of red flecks on the dark surface and shore of the pool.

At night outlying areas of glowing lava were visible on the floor that lay at the foot of the sloping dome surmounted by the lake. Here also there was a flaming cone, and another glowed dull and smouldering a few feet higher amid the debris slopes.

For the rest the pit had become a gigantic cauldron with but little smoke by day and little glow by night. The first week of the month was notably dull, and the rate of rising decreased markedly.

During the first half of the month the action of the lava was uniform with some rising in progress, but the effect of the inflowing resulted chiefly in increase of bottom area and diminution of bottom relief. The lowest portions of the floor stood about 650 feet below rim of pit.

The upheaval of bench lava northeast of the lake was becoming conspicuous. Several raised shorelines came into view, new cracks formed athwart the lifted dome of craggy matter adjacent to the pool, and the opposite shore was overflowed occasionally as though the lake basin were tilted. The annular border fill was always trickling with glowing streams around the edges of the big floor area. This fill was widest at the south, on the side away from the upraised half-dome.

This arrangement appeared to mean that the great weight of the southern filling, constantly added to from the source cone and its subterranean passages on the southeast side of the pit, was depressing the underlying cake or dish of hard lava and either tipping it up or causing an under flow to the opposite side.

The third week of November exhibited fresh rising whereby the lava made extensive pools all around margin of the floor area, in addition to the lake proper with its raised craggy rim and fixed fountaining area.

The floor area was now 1100 feet long by 900 feet wide, and the highest crag stood 600 feet below rim of pit. The lowest part of edge of floor stood 53 feet below this crag. The lake had now built itself up level with the source cone of September 2. This cone on the talus had itself risen and developed an open splashing pit.

It was probably owing to the fact that the lake had reached the level of its source vent, that on the evening of November 16 there suddenly began a flooding of the annular floor from vents around the edge. The crust on these floods broke up with brilliant effect several times during the night. The lift of the lake basin had caused the underground tunnels to back up and seek outlets at lower level. The floods were so voluminous that the border region of the dome-shaped floor filled up until some of the outside lava was cascading into the lake basin on top of the dome. A new islet formed in the lake.

The sluggish stiff lava of the beginning of the month had now been replaced by much more liquid melt and the fountains were continuous and less explosive. Flows in one place were lapping against the north wall of the pit without any intervening debris slopes.

Avalanches the morning of November 24 gave evidence of renewed disturbance in Halemaumau pit, and this followed a general earthquake November 21 felt all over the island. The avalanches left a wide stretch of freshly broken wall along west side of pit and a new notch was left in the rim. By the afternoon of the same day, however, the debris slope from this fall was already almost drowned by floods of lava coming from the spurting source cone near edge of floor. This cone which in September had been at the top of a high debris slope, was now well out from the wall and surrounded by the floods of pouring melt.

Voluminous lava flows had so increased that this source cone had become a slag-heap with its summit 570 feet below rim of pit. The lake and general floor were about 600 feet below rim. The flows were sweeping over southern half of floor in all directions, encroaching on walls and slopes, and at times obliterating the southern half of the lake shore, and making cascades into the lake. The lake and its fountain became sluggish, whereas the slag-heap cone hissed and splashed with great vigor and the heat could be felt on the high rim above.

NOTE

ERRATUM.—In this Bulletin for August, 1922, on page 91, fifth paragraph, under "2", weight of sulphur collected should be 0.085 g.

At the end of November the voluminous flowing gradually lessened and the cone built up its summit opening until it was sealed except for a few flaming holes. By November 28 the southeast floor near this cone had been built up 52 feet within a fortnight, and the cone itself was 566 feet below rim of pit. The avalanches had carried away about half of the southwestern pinnacles and the glowing debris in the smoking southwest chasm had lost much of its brightness when seen at night.

There was now a horseshoe of glowing fresh lava around the dome-shaped uplift that contained the lake on its crest. This lava had all come from the southeast cone which was now 29 feet higher than the lake. The craggy edge of the lake stood 19 feet above the liquid, and the only sign of activity was a fountain bursting sluggishly. The craggy rim had been rising nearly two feet per day as though the pressure of the new fill were now taking effect in lifting it and the lake basin, and as though the source cone had reached a limit of upbuilding for the present.

Earthquakes.

The disastrous earthquake in Chile at midnight November 10 was well registered by the Observatory seismographs about 6 p. m. H. S. T. A succession of pronounced tidal waves on the beach at Hilo the next morning (November 11) may probably be attributed to submarine earth shocks off the South American coast, as the report from Chile indicates there were big water waves on the continental shoreline also.

Coincident with the rapid rise of lava at Kilauea there was a strongly felt earthquake on Hawaii at 3:27 a. m. November 21, causing some breakage of glass in Hilo and heavy shaking in Kona, Kau and Hamakua. There was a second shock the following night.

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November 1. The light from the pit was now dim and some fume had developed at the southeast source cone. At 6 p. m. the lake was very dull, with viscous lava at the grotto where the fountains were explosive and noisy, making rings of broken skin and a spotted glow pattern as the spray fell. The small east cone was hissing and occasionally spitting, and the eastern floor constituted a glowing area. The southeast source cone had a round glowing hole on top with incandescent filagree inside.

November 3. At 6:30 p. m. the lava was viscous and the grotto fountains very explosive. The pit elsewhere was very dull and the east cone inactive.

November 7. At 8 p. m. conditions were very dull as before, the source cone was flaming and lava glowing in cracks was visible on the eastern floor.

November 8. At 6 p. m. lava toes were trickling on the eastern floor. A new crack had formed in the slag-heap trending northeast-southwest tangent to the lake on its southern border. This made an angle of about 60 degrees with the two crevasses northeast of the lake. The northeast bank showed seven raised shore marks, in marked contrast to the west bank which had been overflowing.

The southeast source cone and cascade slope now stood 20 feet above the floor, and the bulk of the recent filling had been in the eastern part of the border zone of floor. Some slight falls of rock were heard. The southwestern pinnacles had lost their summit needles and the whole mass appeared to lean out from the Halemaumau wall. Crevasses south-southwest of the Halemaumau rim and parallel to the rim had opened slightly.

The lifting of the crevassed northeast side of the lake dome appeared to be the result of weighting down of the whole cake of floor on the southwest side by the overflows that had there made the deepest fill.

November 11. At 10:30 a. m. the bench lava was slightly higher north of the lake and trickling streams poured into cracks around the lake margin. There were the usual live tricklings in the border fill.

November 13. Measurements at 9 a. m. made the floor 1100 feet long north-south by 900 feet wide east-west. The highest crag was 602 feet below the rim of pit, the lake 621 feet, and the lowest place on the floor at its north edge 655 feet down. The crag thus stood 19 feet above the lake, and the lake 34 feet above the lowest floor margin.

Conditions on this day showed no change. There were trickle flows on the eastern and northeastern floor. The source cone was glowing about 20 feet above the floor. New yellowish avalanche talus lay to the west of the source cone, fallen from earthy layers in the cliff above. One slide was heard in that region. Caving had produced a shallow cavern in the north-east wall of the pit at the top of the talus slope there.

November 16. In the evening there was bright flaring at the pit due to new floods that increased the border fill and came from the region of the southeast source cone. Apparently the building up of the lake basin to the level of the source cone had caused the feeding tunnels to back up and make outbreaks in the wall-valley.

November 17. At 3 p. m. the increased flooding outside of the lake dome had so filled the border valley that the southeast source cone was half drowned under new lava and itself built up by spatter to a height of 10 feet above the matter surrounding it. This new fill was now cascading into the lake across the low south bank reversing the direction of flow that had so long persisted. At the top of the southeast cone there was an open pot showing surging lava inside about two feet down. The visible slag-heap was smaller by encroachment of the surrounding fill. Flows were sweeping north around the west side of the hill so as to fill the low northern corner of the wall-valley. There was a large flat pool at the south, and dribble lava heaps had formed toward the east. The grotto fountain, its lava less viscous, was in its usual position, building its rampart, but the lake showed crusted shoals at its south end. The northern crags were unchanged. The fill was against the cliff without intervening talus on the north, and the new south talus was half submerged. Fume was very thin.

November 18. At 11 a. m. the same vigorous flooding was in progress. Crusts cracked and foundered over very liquid lava in the north fill. The shoals had developed an elongate low island in the lake. One white-stained smoking cone was conspicuous on the east floor which elsewhere exhibited trickling snaky heaps of pahoehoe. A very large area to the south and west showed a flat surface like the floor of Keanakakoi crater.

November 21. A sharp earthquake was felt at 3:30 a. m. lasting ten or fifteen seconds and making a muffled rumble of avalanches around Kilauea crater.

At 9:15 a. m. Halemaumau showed the effect of the earthquake in slight accumulations of broken rock on the floor. The lake fountain had built a grotto half-dome, and the southeast source cone was covered with an open-work shell glowing. The craggy dome around the lake still retained its individuality. The only fume came from the edge of the floor. Spells of cracking and foundering made occasional bright flares at night.

November 24. At 7 a. m. and later some avalanche clouds rose from Halemaumau. At 4 p. m. it was found that a wide stretch of west wall of

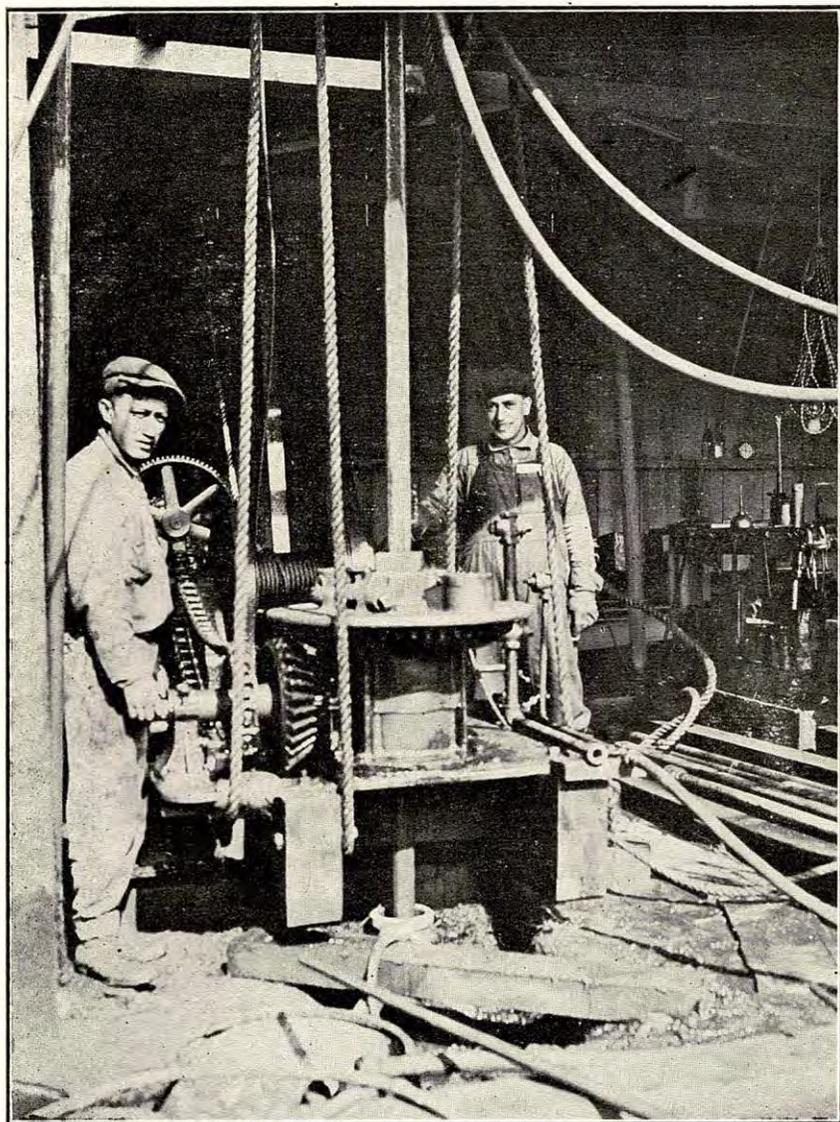


Figure 17.
November 4, 1922. Shot drill and borehole No. 4, Observatory grounds.
—Photo Jaggard.

pit had fallen away from the top downward and large boulders had been added to the west talus, some of which were partly engulfed in the floor lava.

The border fill had been rising so as to encroach upon the crag dome. There was a marginal rim around the lake and the grotto fountain was flinging spray fifteen or twenty feet. Southeast source cone was now completely surrounded by floor, stood about four feet high and was separated from the border talus by a width of ten feet of new fill. The cone was surmounted by an open spitting pot, incessantly flaming and changing shape. Occasionally it flung up umbrella splashes. From its base flows poured east and west, the former short, the latter long, satiny and festooned. At the front of the festoons toes were in motion and there was other trickling lava in the dribble region east and northeast. All the floor region had been rising rapidly since morning as the fresh avalanche material did not lie on the upper surface except at the northeast where a dust patch remained.

November 26. The source cone was now the highest part of the floor, 570 feet below rim, and the lake and west floor were 38 feet lower. The source cone was black and glassy, hissing and splashing and building itself up. The big flows from it were pooled around it. The largest of these was sweeping westward along the south side of floor where it reached the western talus and bent northward. This flow made a bright-line pattern and was covered with silky black skin. Other flows were trickling at the east side of pit. The lake in its crag rampart was oval and covered with crust, its grotto fountain feeble in action. Fresh trickle flows had poured from the outer floor into the lake all around the semicircle of shoreline on the south, this standing one foot above the lake level. The visible remainder of the crag dome was now a crescent around the north side of the lake basin. Some fresh debris lay on the floor north and southwest and small avalanches from the wall were observed. The southeast talus was dwindling as the source cone region built up against it.

Examination of the western bench forming the Halemaumau rim showed that the recent avalanches had made a new notch at the top. The glowing patch in the southwest chasm at the south end of this fault bench, when seen by daylight, was found to follow a curved line down the contact between talus and base of cliff marked by pale yellow stain.

At 9 p. m. the floor was glowing and the flows from the southeast source cone had changed direction to the north and east. The largest of these became sluggish and then the west flow developed again. It was evident that the source cone was building up a new slag-heap. The older lake and its fountain were sluggish. Small rock-falls were heard.

November 28. At 9:25 a. m. the source cone was 566 feet below rim and the lake 597 feet. The source cone was large and contained a splashing pot. The pool around it had become a smooth plateau. This was crusted over, but from the edge of the crust cascades poured down the outer slope of the new heap towards the old lake. Fresh festoon flows were pouring into the lake on its south side where the lake margin was obliterated. The lake surface was cracking and foundering. The inner bench that had surrounded the lake had mostly disappeared.

The crescent of northern crags, however, had been rising so as to lift the recent fill on its northern flank. Outside of this uplifted area there was a fresh live northwestern pool extending to the north corner of the floor. Similar live fills occupied the northwest wall-valley.

There appeared at this time to have been some more heavy avalanching from the west and southwest walls of Halemaumau but the exact date is not recorded. Inspected on this day the freshly peeled off portion of

the west rim of Halemaumau appeared wider than before. Another remarkable change discovered was in the south-southwest pinnacles opposite the southwest chasm. All the eastern half of the pinnacle mass had fallen, leaving only the two western pinnacles of what was formerly a much larger rocky buttress.

November 29. At 4 p. m. the source cone was capped and hissing harshly. The big floods were flatter on top and had increased in size. This floor lava had now joined in a ring around the lake dome and only a small crescent of crag matter remained on the northeast side of the lake. Bank of lake stood one foot high. Lava trickled in many places on the outer floor. The lake fountain was in action as usual, but it was evident that the southeast cone source was the dominant feeder of the floor area.

LAVA MEASUREMENTS

Measurements of depression of the mobile lava column, made with transit, referred to northeast station on rim of Halemaumau pit (3716 feet above sea-level), for the month ending November 30, 1922, including floors of bench magma and liquid level of lake magma, were as follows:

Date	Time	Northwest Pool	Southeast Floor	Southeast Cone	Northeast Crag
Oct. 21,	3:00 p. m.	650 feet	672 feet	626 feet	-----
Nov. 13,	9:00 a. m.	621 "	634 "	----- "	602 feet
Nov. 26,	noon	608 "	596 "	570 "	581 "
Nov. 28,	9:30 a. m.	597 "	582 "	566 "	576 "

Progressive changes for the lake were as follows:

Oct. 21-Nov. 13,	23 days,	lake rose 29 feet,	averaging per day 1.3 ft.
Nov. 13-28,	15 "	" 24 "	" " 1.6 "

On November 13 the lake was 5 feet and northeast crag 24 feet above the level of source cone southeast as recorded October 21. Hence the back flow and marginal flooding of November 16. After November 13 the lake was the lowest object measured.

Progressive building up of southeast floor was:

Oct. 21-Nov. 13,	23 days,	floor rose 38 feet,	averaging per day 1.7 ft.
Nov. 13-28,	15 "	" 52 "	" " 3.5 "

Progressive rise of northeast lake shore to make crag was:

Nov. 13-28.	15 days,	crag rose 26 feet,	averaging per day 1.7 feet.
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This crag lift was pure tumescence, whereas the rise of the southeast floor was accomplished mostly by overflow.

The rise and building up of southeast source-cone proceeded as follows:

Oct. 21-Nov. 26,	36 days,	cone gained 56 feet,	averaging per day 1.6 ft.
Nov. 26-28,	2 "	" 4 "	" " 2.0 "

The actual gains of cone and southeast floor were greatest after November 13.

Comparative monthly changes of level of the lowest solidified part of the pit bottom from June to November were:

July	Lava inflow	+ 70 feet
August	Slight slumping	- 29 "
September	Lava inflow	+100 "
October	Lava inflow	+ 65 "
November	Inflow and uplift	+ 73 "

SEISMOMETRIC RECORD

During the month ending midnight November 30, 1922, twenty-three local earthquakes and two teleseisms were registered at the observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W. 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

Nov. 1.....	2:23 p. m.	Very feeble.
2.....	5:37 a. m.	Feeble, distance 11 miles.
4.....	1:19 a. m.	Very feeble.
5.....	5:39 a. m.	" " distance 15 miles
6.....	6:03 p. m.	" "
	7:12 p. m.	" "
10.....	12:37 a. m.	Slight, distance 2 miles
14.....	2:10 a. m.	Very feeble.
16.....	5:47 a. m.	Three very feeble quakes together.
18.....	5:16 p. m.	Very feeble.
19.....	3:57 a. m.	" "
20.....	11:25 p. m.	" " Felt in Hilea.
21.....	3:27 a. m.	Strongly felt locally and at Hilea and Hilo. Dismantled instruments.
	9:21 a. m.	Very feeble.
	9:25 a. m.	" "
22.....	12:15 a. m.	Moderate, distance 9 miles. E-W component dismantled.
	12:56 a. m.	Very feeble.
	3:07 a. m.	" "
23.....	5:50 p. m.	" "
25.....	6:21 a. m.	Feeble, distance 4 miles.
	1:15 p. m.	Very feeble.
29.....	5:23 a. m.	" "
	7:28 p. m.	Feeble.

Teleseisms.

Nov. 7.....	1:03 p. m.	Slight.
10.....	6:16 p. m.	Moderate, distance 5875 miles.

Spasmodic Microtremor.

This type of tremor was slight throughout the month.

Harmonic Microtremor.

This type of tremor was extremely slight throughout the month.

Microseismic Motion.

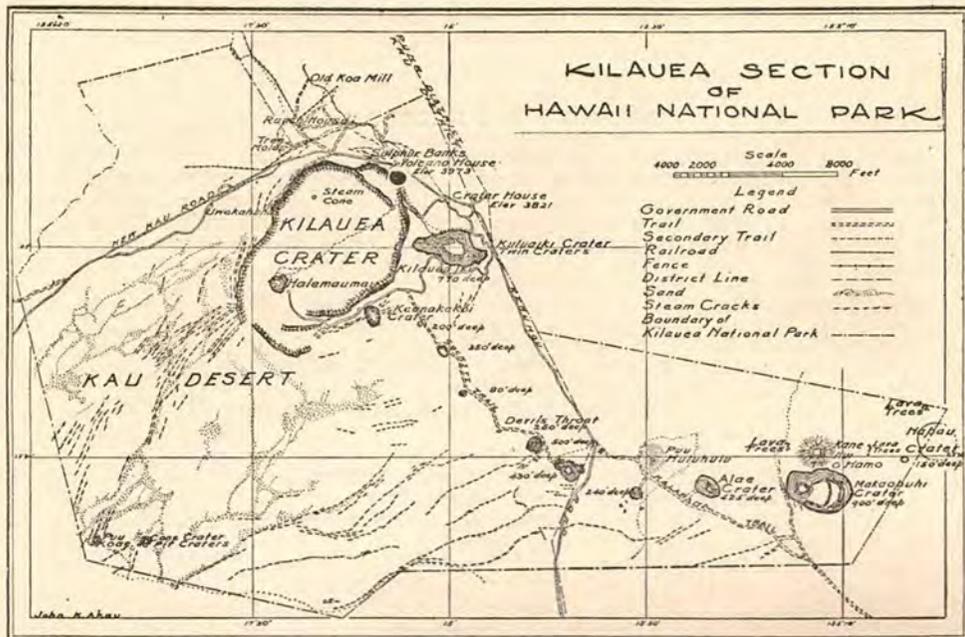
The amplitude of microseisms was slight except moderate on the 12th and from the 28th on.

Tilting of the Ground.

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

Oct. 29-Nov. 4.....	3.8 seconds	ESE.
Nov. 5-11.....	3.5	" SW.
12-18.....	1.7	" ENE.
19-25.....	1.1	" WSW.
26-Dec. 2.....	1.2	" E.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges should be addressed to
HAWAIIAN VOLCANO OBSERVATORY,
 Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismometric instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of local earthquakes; one optically recording seismograph for distant earthquakes; one clinograph registering E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete piers in a closed basement room having practically constant temperature, beneath the chief Observatory building near the hotel. Time is referred to a rated chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. 19° 25' 54.2" N.; Long. 155° 15' 39.2" W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun," a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Sword (*Argyroxiphium*). Thirteen volcanic cones lie wholly within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvelously beautiful.

Wailuku is the point of departure, automobiles taking the traveler to Olinda, a summer residence settlement 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of 3½ hours. Here is a fine concrete rest house, built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa, a vast dome 13,675 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bril-

liantly colored lava slopes, has a summit crater 3 miles long by 1½ miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jetted 500 feet into the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaiian National Park, if not in the world. The pit of fire, Halemaumau, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overridden by the lava slopes of Mauna Loa on the west so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solfatarae and a strange desert where lava flows have poured out of cracks as recently as 1920.

The live pit of Halemaumau is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvelous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory which stands on the brink of the greater crater within the Kilauea Park.

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

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No. 12

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VOLCANIC CONDITIONS IN DECEMBER

Activity of Halemaumau

The month of December at the Halemaumau fire-pit inaugurated renewed rising of liquid lava in big floods. These poured across the floor area from the southeast source cone, building up a lava plateau so high that the cascades of glowing melt were tumbling into the northern lake all through the first week. The crags around this lake had risen farther and the lifted ground was stained and cracked. The whole north half of the floor lifted away from the base of the cliff, making a new scarp there facing toward the cliff which continued as a long straight crevasse in the floor.

By December 9 the source cone was drowned under floods of its own slag, and its well had become a pond in the plateau. This place began some remarkable performances. For ten minutes at a time the lava source at the well stopped feeding and the liquid in the orifice subsided. Immediately a cascade torrent rushed back into the well from the plateau pool, and a funnel 80 feet in diameter was revealed, with walls of pasty aa lava red hot where incandescent crusts were flaking off and sliding down the slope. The grotto bank fell in. Then the upward pressure was restored,

the foaming liquid rose, the pasty banks disappeared, and there was an overflowing pond again.

The pit was now very bright at night and the heat was felt on the rim above. The floor was immense, about 1200 feet in diameter, and several of the marginal debris slopes were now drowned under the lava fill. The general level of the bottom was 550 feet below rim of pit.

The middle of December found vigorous lava activity increasing and the liquid spouting up through the source well was building up the bottom 20 feet or more per week. The average level of floor of pit was about 525 feet below rim, and the rise was partly accomplished by a swelling up of the northern half of the floor area, lifting the older lava pond on top of it.

This small lake was encroached upon by big floods of incandescent lava pouring into it from the other side of the pit. These cascades added to bank of lake on that side. The lake itself remained quiet except for one small grotto fountaining and spurting. Each cascade into the lake would break the crust and flow in for hours at a time without seeming to alter the lake level or cause it otherwise to fracture its shell around the margins. The other or northern side of the lake had become a cliff facing a crescent of crags 20 or 30 feet high, always lifting and cracking on top to compensate the fill of new lava that surrounded the craggy cup.

This annular fill was supplied by flows increasing in volume, heat output and liquidity. Their source had become another fountaining grotto on top of the big slag-heap occupying south half of floor. The floor alone was now as large as the whole pit of a year ago. On top of the slag-heap lay a pool usually more or less crusted, surrounded by a rampart level with its surface. This overflowed and built up continuously, keeping its edge level by the shift in the flows, first one side, then the other, and sometimes on all sides at once. Such displays were intensely hot and spectacular, the fiery liquid forking out into golden leaf patterns and flooding everything clear to the foot of the debris slopes.

The December solstice was marked by increasingly vigorous gushing of lava over floor of pit at a depression of 506 feet below rim. About December 17 a new spouting cone developed at the foot of the long south-west talus, and just where the 1920 rift emerges into the pit. This cone built up a new plateau pool so that by Christmas time there were three distinct lakes, two of them fed by spouting wells. The third was the crag-bordered cup of September and October, now at a lower level than the other two lakes. This cup remained a stagnant depression until December 22, when it was filled to overflowing by the inpouring floods from the other pools.

The result was a flat black floor with three lakes more or less definite in outline according as they sank or not within their cups. That there was really difference of relief in several places was shown by the cascading streams of molten lava from one lake to another. The crags that stood 15 feet above the north lake were now almost completely drowned under fresh flows. The whole floor was being lifted and built up so as to net a rising of from 20 to 25 feet per week. This represented a large bulk as the floor was more or less circular and 1200 feet across.

At the end of the year the lava was less than 500 feet below the rim, there was little smoke and on one day there was six feet of rising. The floor sloped from west to east, the highest source being now the southwestern vent whence lava cascades were pouring. During rapid overflow there were cascades over 100 feet wide. The height of liquid lava in the lakes was variable, sometimes obliterating the lake margins and sometimes leaving those margins 10 to 15 feet high. There was loud hissing from a

vent at the lake border and two or more fountains were always in action.

Discussion of Special Features.

UNIFORM RISING—Under the title "Lava Measurements" in this Bulletin appears a summary at the end of the section setting forth the total vertical gain or loss of the lowest part of the Halemaumau bottom each month from July to December, 1922.

The striking feature of these figures is that seventy feet, more or less, has been added to the funnel-shaped bottom of the pit every month excepting August, when the lava suffered a relapse. The measured figures for those months that are carefully evaluated, agree approximately with the monthly average for the whole period.

Uniform vertical growth each month in a pit that is funnel-shaped does not mean uniform volume each month, but rather increasing volume each month. That the volume increase should result in uniform rate of rising is remarkable. Uniform rate of rising independent of shape of containing vessel suggests a hydrostatic control, as though a much greater volume of lava were rising in the fissure under the island, and the Kilauea well were acting as a gauge to exhibit apportionate levels.

An apportionate level in foaming lava is not necessarily the same level, for the foam with its gas restrained from bubbling under Mauna Loa might hold a lower level for many months than the free froth in Halemaumau. Also after the big mountain yields and the explosive froth there pours forth, at the high summit, the first effect of gas expansion is a rising at Halemaumau, followed by sharp sinking when the Mauna Loa gas is released at the end of a flow period. The term hydrostatic is therefore not appropriate, as the result is rather "aphrostatic" or foam controlled, in accordance with the laws, as yet unstudied, that govern the movement of silicate melt charged with gas in solution.

Contemplation of this mechanism as exhibited in Hawaii reveals the remarkable probability that a common level in the hydrostatic sense is a condition of instability for two or more connected lava columns variously confined. They are variously viscous, variously saturated with gas, and variously vesiculating that gas, to make bubbles that chemically heat the melt and alter the viscosity. The vesiculating process alters internal pressure enormously, and is itself sensitive to external pressure. Underground lava is like the foam on beer confined within mobile and changeable bottles connected together. The earth crust is subject to tidal, atmospheric, oceanic and seismic pressures continually changing. Probably the lava occupies cracks in a mobile mosaic of rocky blocks or shells. Moreover the edifice constructed at the volcano is faulted and fissured and recemented so as to confine and release the expansive foams in accordance with some age-long habit.

It seems likely, then, that a uniform rate of rising independent of shape of pit gives evidence of a large low-level body of magma under the island which is also uniformly rising. The lava foam in the pit is maintaining a level apportionate to the bubbling of gases which the pit mechanism itself favors as a vent for reducing pressure locally. The larger underground body is denser and more viscous, less vesiculated, and possibly cooler than the pit lava.

Perhaps the entire recovery in 1922 was occasioned by the readjustments of pressure due to the breakage of the mountain along the Puna rift in May 1922. If so the greater lava body may also be rising under remnant gas pressure, but be losing its gas only at Halemaumau. This would make the rising movement a remnant feature of the cycle 1913-1922, rather than the initiation of a new cycle. The recovery in 1922 was more like

the events of 1911-12 than like those of 1913-14. It was more like one of the sharp risings at the end of a cycle, than like the dull years of a repose period followed by an awakening and gradual filling.

JOURNAL, DECEMBER, 1922

December 1. Halemaumau pit was now sluggish in its activity and dark at night. The crag wall over the lake was slightly higher, the lake crusted and the one fountain exploding in viscous fashion. The southeast source cone exhibited at its summit a small glowing filagree patch with flames and a slight hissing. Around the margins there were glowing, crusted flows that had their source towards the southeast and occupied a horseshoe around the raised dome containing the lake. The brightest glow cracks were on the northeast and southwest sides; there were hardly any moving toes of live lava. Some small falls of rock from the walls occurred. The southwest pinnacles at the entrance to the chasm on that side of the pit rim appeared smaller than before. The debris inside of that chasm had been glowing extensively two months before, but now showed only a little glow in its lower part.

December 4. At 4:30 p. m. the southeast source cone was bright and contained occasional fountains splashing well above the orifice. The flows from this source had increased, and there were bright toes all over the marginal floor except in the craggy region northwest of the lake. One small lava stream was cascading from the flow area into the lake.

December 5. At 4 p. m. the source cone was 554 feet, the lake fountain 594 feet and the lowest floor margin 598 feet below rim of pit. A big flow was pouring northwest from the cone into the lake and other fresh cascades were frozen all along south half of lake. A branch of the flow extended to the west talus, and a flat pool of live lava with black satiny skins occupied the whole southern half of the floor. Dribble flows from this pool filled the floor areas east and west of the lake. The north edge of the floor was freshly swollen and cracked and the northern crescent of crags around the lake had risen. The lake crust was swollen and cracked and the lava flung up at the fountain was viscous. Two or three small live cones had formed near the east border of the floor. From the source cone there were occasional strong breathings and spittings.

December 7. The pit was now bright at night and the fume was thin. At 6 p. m. the source cone was fountaining, and in addition to the big flow that cascaded into the lake there were three or four other streams pouring northeast over the edge of the source cone plateau. This plateau or slag-heap had been so built up and spread out that it covered the whole southeast half of floor of pit. There were bubble fountains at a small pool near west base of source cone. The flows were making a crunching, rumbling noise. The lake with its fountain and border crags remained as before.

December 9. At 10 a. m. the lake was 575 feet below rim and the southern plateau 25 feet higher. The southeast source cone was drowned under its own floods, but there remained a grotto rim facing west with a fountain beside it. A cascade continued to pour into the lake. The floods had encroached upon the northern crag area. The lake had become round and small in the northwestern part of the floor. The new craggy area created out of the floor near the north wall of pit had been lifted bodily so as to form a low wall facing north. Along the wall-crack below there was a swollen fill of fresh lava. Apparently the bench lava of the northern region had been squeezed up by the weight of the southern accumulations.

Just before 10:30 a. m. the southeastern source well suddenly became a cauldron of subsidence with glowing walls of aa lava shaped like a funnel. Into this a cascade rushed back from the plateau pool and the border

grotto fell in. Aa slabs and flakes slid down the slopes, red, pasty and powdery. The region south of the cauldron was seen to be a mass of cracked bench magma. The funnel was about 80 feet in diameter. This downrushing cascade lasted about ten minutes and after 10:40 a. m. the bottom of the funnel was seen to be filling up with bubbling lava. At 11 a. m. lava was flowing up the funnel strongly from the source well beneath so that the plateau pool was again filled. At noon the crust of old northwest lake cracked up with strong effervescence.

The southeast lake was now a definite oval puddle on top of the plateau from two to three times larger than the northwest lake. Near the splashing fountain at the well the bank was from one to two feet high. The aa bank had been gradually submerged, a pattern of bright-lines appeared on the surface of the pool, and toward the west the bank was overflowed.

This history revealed the mechanism whereby a blowing cone at the source of flows may be gradually converted into a lake by the building up of a slag-heap. When the sinking spell occurred, the liquid that flowed back into the source well was the shallow fresh pahoehoe of the pool and the material of the plateau on all sides appeared to be aa paste just beneath a thin pahoehoe crust. For except at the funnel of downflow, no depression was produced by the drainage, all the outer part of the plateau pool appearing like a mud flat vacated by the tide. The crust of the pool had been cracking and foundering just before the cascade and reversed flow began. Apparently everything just below the surface was potentially a stiff aa paste.

The southeast talus was now drowned under fresh lava. Great heat was felt on rim of pit. One small fall of rocks was observed at northeast wall.

At 5 p. m. the southeast lake was overflowing towards south and northwest, and one small northwest branch cascaded into the old lake. There was slight streaming into southeast lake towards southeast grotto where there was occasional fountaining.

A new cone had formed in the floor near the base of the southwest talus just where the cavern of the Kau Desert rift was buried up by the avalanches of May, 1922. This cone gave vent to a vigorous flow that divided into two branches, one going toward the east, and the larger stream cascading into the northwest lake. There was some fountaining at the source of these flows.

December 10. At 4 p. m. the lava plateau on the southern half of the floor was sending trickle flows down its flanks, the cooler crusted portions of the surface reflecting the light in moire or "watered silk" patterns. Flows were trickling into the northwestern lake which was sluggish and exhibited its usual fountain.

Then a series of great floods began, inaugurated by general cracking and foundering of crust at the southwestern part of the plateau pool and this was expanded into a general overflowing to the south and west. Big distributary flows reached the south wall and western talus, filling in the hollows. Large skins incessantly parted from the crust on the plateau pool and floated to the narrows of the several cascades where the pieces were rotated and torn and carried down the steeper slope. As the several rivers went over the edge of the plateau, they revealed a bed of red-hot paste, exhibited through the streams like incandescent mud banks. The liquid would advance in pulsations over these glowing banks, and this process was watched for a half hour. The only portion of the southeast lake that showed a bank was at the splashing source grotto. Everywhere for

an hour the lake was full to overflowing, and the overflows became concentrated towards the northwest.

There was almost no visible fume from the pit, but a bright blue gas rose at the southwest chasm and at the Postal Rift solfatara north-northeast of the pit.

December 12. The pit was very bright in spells on the previous night and very dull in the early morning. At 10 a. m. floor was quiet, southeast plateau was crusted, northwest lake was sluggish with its usual fountain, and live toes, were in motion amid driblet heaps northeast.

At 10:15 a. m. the crust of plateau pool suddenly broke up strongly and the bubbling hot melt welled up and flooded over the outer slopes of the plateau heap. Intense heat was felt on the rim. The flows were very rapid, cascading into the old lake and spreading westward to the talus. At the southeast grotto the streaming was toward the rampart with much bubble fountaining. The plateau lake showed banks more definite than before and a peninsula on its northern side. The cascade into the northwest lake broke a hole through the crust and thereafter produced no visible effect on the lake.

There followed a rapid cessation of overflow and the southeast pool became crusted without any lowering of level.

December 13. At 10:30 a. m. the plateau southeast was found higher than before and the northwest lake was becoming increasingly buried by encroachment from the south. Flows were pouring from four places in the edge of the southeast plateau, one of them reaching the northwest lake but the two largest had their source near the southeastern grotto and swept in a succession of rapids and pools around the wall valley to the west and north, there merging into one torrent. Across the southeast pool the crust was slowly cracking and foundering.

December 14. At 3 p. m. there were small fountains at the grottoes in the two lakes, a trickle flow poured into the northwest lake, some small rock falls were heard and there were flows on the outer flank of the southeast slag heaps. Sporadic fountains occurred in places of cracking and foundering or where a flow crossed the edge of the plateau. There was little fume even from the southwest chasm.

About 4:30 p. m. an avalanche from the northwest wall sent up a cloud of red dust. Then the plateau lake southeast was seen to be voluminously overflowing on all sides, each flow spreading out in intricate pattern like an immense leaf, the western flows reaching the talus in a few minutes. The pattern recalled the first outgushings of July and September. A big flood entered the northwest lake.

This pulsation of overflow was the biggest and most fluid in appearance that had occurred during the present rising period. In the evening, a big flow from the southeast followed the eastern and northern wall-valley in a half circle. At night the pit was variously bright and dull in spells.

December 15. From 9 to 10 p. m. the pit was rather quiet with a flow still in progress from the northeast side of the southeast pool. Small flows broke over the north side and entered the northwest lake, and others moved west. This older lake was quiet and small, its fountain active within a grotto nearly closed with stalactite curtains. The wall-fill was glowing on northeast, north and northwest sides of floor. The fill between southeast grotto and wall of pit southeast was seen to be cracking and foundering. A little glow and smoke were still in evidence in the high debris of southwest chasm.

December 17. At 3 p. m. southeast plateau pool was sending one main stream in a sickle-shaped channel from its northwest border around to the

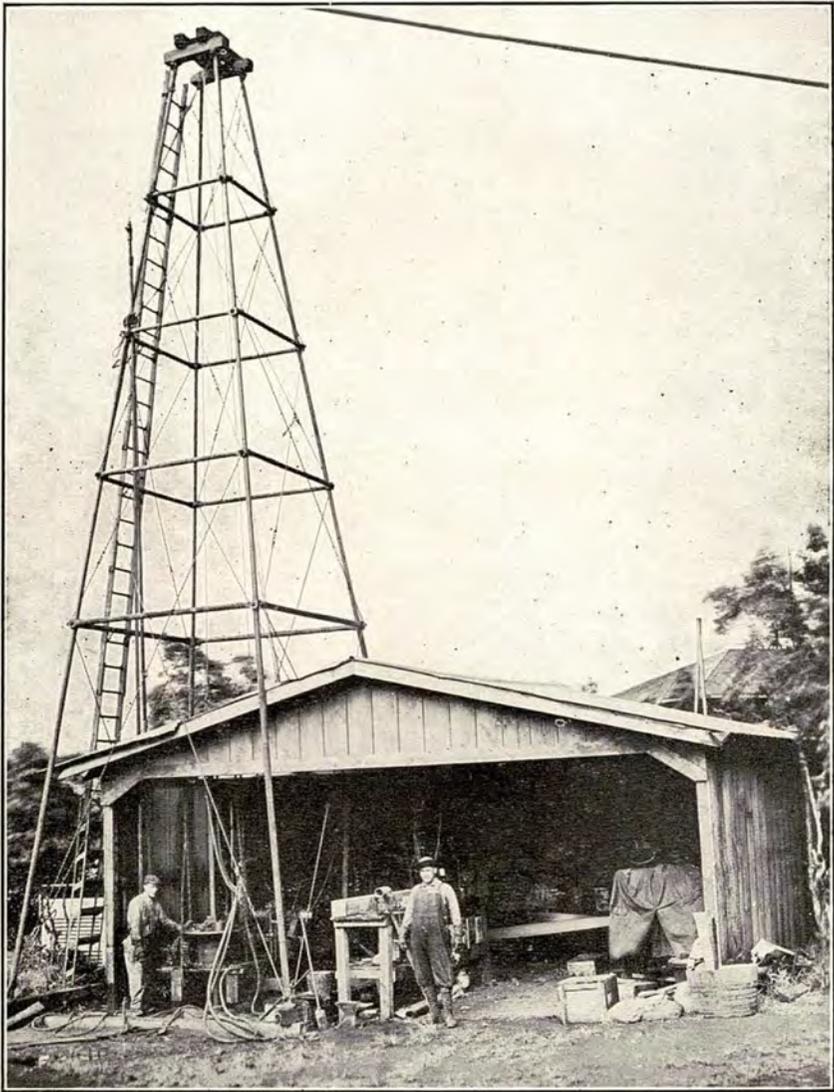


Figure 18.

Shot drill and its tower, as set up in Observatory grounds during August, 1922.—Photo Jaggar.

west side of the northwest lake. This torrent rushed downhill rapidly, with a slow moving portion in its middle course. Short flows moved on the northeast slope of the plateau.

The new southwest cone was smoking at the foot of the talus slope, standing about five feet high, with a fountaining pool splashing beside it. This appeared to be the source of large flows that moved along the west side of the floor northward. The north and northeast taluses were now nearly covered.

December 18. At 4 p. m. the northwest lake was low in its cup with collapsed crusts and neither fountain nor grotto was visible in its accustomed place. About four flow channels were visible extending to this lake from the plateau heap. Several flows into the west side of the old lake had built out a promontory, and these came from the new southwest cone now flooding west side of floor extensively. This cone was 10 feet high with bright spurting orifice, and a spring of viscous lava gushing out beside it. There were short flows and glowing lava fields supplied from the south, southwest and northwest sides of the plateau heap, but the northeast lava fields were quiet and dark. A rock-fall was heard towards the north.

December 20. At 4:30 p. m. southeast and southwest wells were both supplying flowing lava that poured towards the northwest lake. The southwest well showed a vigorous stream northward from a pool alongside the cone and this fed a creeping wall-valley pool northwest of the old lake and three trickling streams that poured into the west side of the lake. The southeast pool had been overflowing down the flanks of the heap northeast and a live stream running in a tortuous channel reached the crevasses of the craggy region on the northeast side of the old lake. The lowest part of the floor lay along the base of the northern and northeastern walls of pit.

December 21. At 9 p. m. the situation was much the same, one small stream cascading from southeast lake to northwest lake, and the southwest pool showing a bright outline and crusts cracking and foundering around the southwest cone.

December 22. At 10:30 a. m. the southeastern fountains were 505 feet below rim. The southeast pool was crusted and there were whitened cracks back of its east margin and driblet heaps northeast of it. The southwest cone source was now becoming dominant with smooth live streams sweeping northward from it to the northwest lake and beyond, for the latter lake was in turn overflowing its northern and eastern banks. There was even one crusted stream from the southwest that apparently entered the west side of the southeast lake. All of this western flood half circled the floor by way of the wall valley making a large flat pool at the base of the northern and northeastern walls. Only a small remnant was left unsubmerged of the northern group of crags.

December 25. At 11 a. m. the floor was quiet except for small flows making live toes along the northwest wall, some splashing and hissing at the southwest cone, cracking and foundering of crust in southeast lake and loud hissing towards the north, probably from the covered grotto of the northwest lake.

December 27. At 10 a. m. a vigorous flow was pouring from under the crust that surrounded the southwest cone. One branch of this flow went towards the northwest and three branches cascaded into the southeast lake showing that the southwest heap was now dominant. The southeast lake was in turn overflowing towards the northeast from a place near the base of east wall. There was loud hissing from the northwest lake vent and this

pool had a bright margin and stood about 10 feet below its banks. Great heat was felt on rim of pit.

December 28. At 4 p. m. a lava flow about 70 feet wide poured over the bank of the southeast lake towards the northeast into a valley along the wall that stood lower than the central region. This central floor appeared to be heaving, up, as large cracks had opened and cracking sounds were heard. There were small flows on the floor around the southwest cone.

December 29. The southeast lake was again vigorously overflowing into the northeast wall-valley, which continued to maintain its depression in spite of the rapid filling that had been going on there. Fountaining continued in the southwest cone and at the southeast end of the southeast lake. In the northwest lake an occasional fountain was observed and loud hissing was heard from the vent on north rim of this lake.

December 31. At 10 a. m. signs of subsidence had appeared. The southeast lake was falling and stood 10 to 15 feet below its banks. Aa paste had appeared on the banks. The southwest cone was still flowing and made two small cascades into the southeast lake. Small trickling flows were in motion on northwest floor of pit. The lava of northwest lake was streaming to the south from under the north bank where loud hissing occurred every few minutes.

LAVA MEASUREMENTS

Measurements of depression of the mobile lava column, made with transit, referred to northeast station on rim of Halmaumau pit (3716 feet above sea-level), for the month ending December 31, 1922, including floors of bench magma and liquid level of lake magma, were as follows:

Date	Time	North-west Lake	South-east Floor	South-east Cone	South-west Floor	North Floor	West Floor	South-west Cone
Nov. 28,	9:30 a. m.	597 ft.	582 ft.	566 ft.	.....	.....	.....	.....
			East Floor					
Dec. 5,	4:60 p m.	594 ft.	570 ft.	554 ft.	596 ft.	.....	.....	.....
				South-east Pool				
Dec. 9,	10:00 a. m.	575 ft.	.....	543 ft.	552 ft.	592 ft.	.....	.....
Dec. 22,	11:00 a. m.	524 ft.	.....	507 ft.	.....	534 ft.	506 ft.	494 ft.

Progressive changes for the northwest lake were as follows:

Nov. 28-Dec. 5,	7 days,	lake rose 3 feet, averaging per day 0.4 feet.
December 5-9,	4 "	" " 19 " " " 4.7 "
December 9-22,	13 "	" " 51 " " " 3.9 "

The eastern floor at the site of the southeast cone became converted into a plateau pool during the month. The growth here at the east and southeast was as follows:

Nov. 28-Dec. 5,	7 days,	cone and floor rose 12 feet, averaging per day 1.7 ft.
Dec. 5-9,	4 "	cone and pool " 11 " " " 2.7 "
Dec. 9-22,	13 "	pool " 64 " " " 4.9 "

The western floor was also built up and developed a spouting cone, as follows:

December 5-9,	4 days,	floor rose 44 feet,	averaging per day 11.0 feet
December 9-22	13 " " "	46 " " "	3.5 "

The cone on southwest floor was built 12 feet higher still, until it had become the highest point of the crater bottom. The northern floor had gained about 58 feet in the 13 days averaging 4.5 feet per day; here there was marked swelling as well as filling.

The monthly changes of the bottommost part of pit floor measured since the June low level that followed the May collapse, representing the vertical growth of the bottom, were as follows:

July	Lava inflow	+ 70 feet
August	Slight slumping	- 29 "
September	Lava inflow	+100 "
October	Lava inflow	+ 65 "
November	Inflow and uplift	+ 73 "
December	Inflow and uplift	+ 73 "

From July to September no attempt was made to evaluate figures as of last day of month. In October, November and December this was done. The average for the five months, omitting August when the pit was dead, is 76 feet per month.

SEISMOMETRIC RECORD

During the month ending midnight December 31, 1922, thirty-four local earthquakes and three teleseisms were registered at the observatory. These and other earth movements are exhibited below. Distance of origin when indicated by the instrumental record is stated in English miles. Time is Hawaiian Standard of meridian 157° 30' W, 10 h. 30 m. slower than Greenwich.

Local Earthquakes.

Dec. 1.....	5:01 p. m.	Very feeble.
	5:02 p. m.	" "
3.....	9:15 a. m.	Feeble.
4.....	11:17 p. m.	Very feeble.
5.....	8:50 p. m.	" "
6.....	12:22 a. m.	Feeble, distance 15 miles.
10.....	11:33 a. m.	Very feeble.
	11:40 p. m.	" "
16.....	2:51 a. m.	Feeble, distance 2 miles.
	5:00 a. m.	Slight, distance 22 miles.
17.....	12:18 p. m.	Very feeble.
18.....	2:14 a. m.	" "
	2:17 a. m.	" "
	2:40 a. m.	" "
	2:44 a. m.	" "
	1:30 p. m.	" "
	1:31 p. m.	" "
	1:45 p. m.	" "
	1:48 p. m.	" "
19.....	5:44 p. m.	" "
	6:05 p. m.	Feeble.
20.....	2:13 p. m.	" "
21.....	6:31 a. m.	Very feeble.
	10:35 p. m.	" "

29.....	5:01 a. m.	Slight, distance 3 miles.
30.....	2:32 a. m.	Very feeble.
31.....	3:57 a. m.	" "
	4:20 p. m.	" "
	6:40 p. m.	" "
	10:31 p. m.	Feeble.
	10:36 p. m.	Very feeble.
	11:50 p. m.	Slight, distance 4 miles.
	11:54 p. m.	Slight distance 4 miles.

Teleseisms.

Dec. 7.....	12:30 p. m.	Slight.
14.....	4:00 p. m.	Slight.
30.....	9:00 p. m.	Slight.

Spasmodic Microtremor.

This type of tremor by weeks beginning December 3, was registered as follows:

Dec. 3- 9	Moderate.
10-26.	Slight.
10-16.	Slight.
17-23.	Slight.
24-30.	Slight.

Harmonic Microtremor.

This type of tremor was extremely slight throughout the month.

Microseismic Motion.

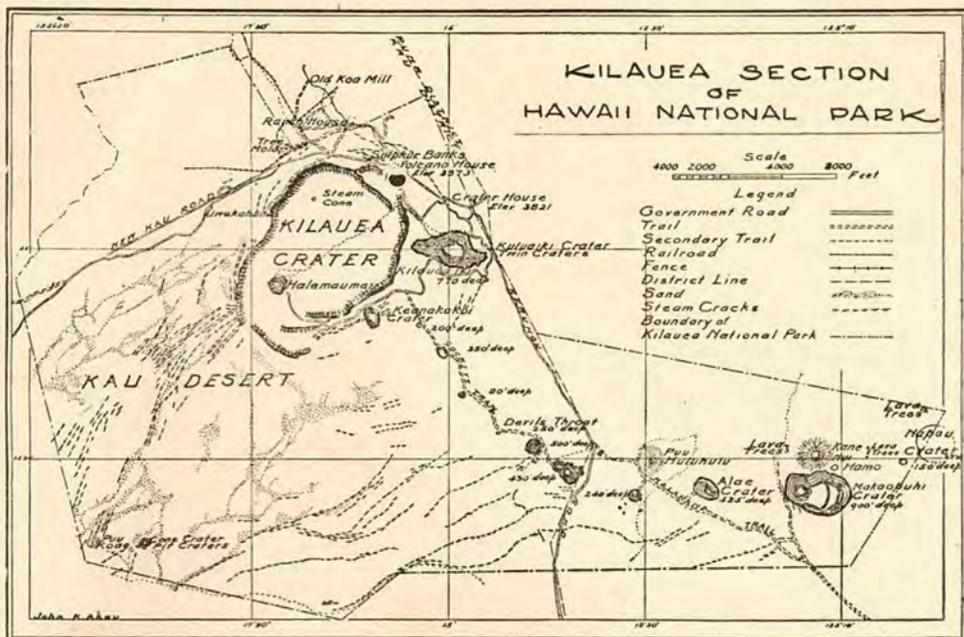
The amplitude of microseisms was slight except from 20th-23rd inclusive, being moderate during that period.

Tilting of the Ground.

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

Dec. 3- 9.....	1.3 seconds	NNW.
10-16.....	1.4	" NNW.
17-23.....	1.2	" NE.
23-30.....	1.1	" SW.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges should be addressed to

HAWAIIAN VOLCANO OBSERVATORY,

Volcano House P. O., Hawaii.

The Observatory is equipped with the following seismometric instruments rebuilt at the station in 1918 for the special needs of volcano research: two Bosch-Omori pendulums, high-speed registration of local earthquakes; one optically recording seismograph for distant earthquakes; one clinograph registering E-W tilting of the ground. A vertical component seismograph was in December, 1918, set up in experimental operation. These are seated on concrete piers in a closed basement room having practically constant temperature, beneath the chief Observatory building near the hotel. Time is referred to a rated chronometer, checked at intervals by wireless signal from the Pearl Harbor Naval Station. The chronometer is loaned by the University of Hawaii. Hawaiian standard time (H. S. T.) is 10 hrs. 30 min. slower than Greenwich time. Observatory Lat. 19° 25' 54.2" N.; Long. 155° 15' 39.2" W.; Elevation 1214.6 meters (3985 feet).

HAWAII NATIONAL PARK.

This park was created by act of Congress August 1, 1916, and includes three famous volcanoes—Kilauea and Mauna Loa on Hawaii and Haleakala on Maui. Frequent passenger steamers ply between these islands and Honolulu.

Haleakala Section—Haleakala, "house built by the sun," a peak more than 10,000 feet high, carries an immense fissure-like crater 8 miles long and 3 miles wide, with walls 2000 feet high. Here, as well as on Mauna Loa and Mauna Kea, grows the Silver Sword (*Argyroxiphium*). Thirteen volcanic cones lie wholly within the crater, some rising nearly to the height of the summit. The scene at sunrise is marvelously beautiful.

Waikuku is the point of departure, automobiles taking the traveler to Olinda, a summer residence settlement 4043 feet high. After 2 hours drive to this point, saddle horses are taken to the summit, a ride of 3½ hours. Here is a fine concrete rest house, built by the citizens of Maui, and fully equipped with iron beds, blankets, stoves and cooking utensils.

Mauna Loa Section—Mauna Loa a vast dome 13,675 feet high, reached through forests of Hawaiian mahogany (koa) and tree fern, then up bril-

liantly colored lava slopes, has a summit crater 3 miles long by 1½ miles wide, with walls 700 feet high, and when in action fountains of fire froth are here jetted 500 feet into the air. Every five or ten years splendid spectacles of lava eruption are staged on the mountain, sometimes from the lower flanks.

There are trails on the Kona side, and also from the southwest, but the usual and best route is with saddle mules from the Kilauea section to Puu Ula-ula (9800 feet), a ride of six hours. Here there is a fully equipped cottage with stables and water supply. From this point on the second day a four-hour ride takes the visitor to the summit crater, where there is water. A right of way within the park connects Kilauea with Mauna Loa, where eventually a road will be constructed. The views are glorious and the chasms, cones and contorted lavas indescribably chaotic.

Kilauea Section—The lakes of foaming fiery lava within the crater of Kilauea form the most spectacular exhibit in the Hawaii National Park, if not in the world. The pit of fire, Halemauau, is inside of the main crater, at the apex of a broad, flat, inner cone. Kilauea is a dome volcano 4000 feet high, overriden by the lava slopes of Mauna Loa on the west, so that it seems but a spur of the greater, and perhaps younger, slag-heap mountain.

The Kilauea Park and the inner pit itself are both reached directly by automobile from Hilo, the second city of the Territory of Hawaii, and there are excellent hotel accommodations. The distance from Hilo is 30 miles. Within the park there are 15 miles of roads and about 20 miles of trails. As shown on the map, there are a dozen ancient pits within the area of the park, as well as cones, caverns and hot solfataras and a strange desert where lava flows have poured out of cracks as recently as 1920.

The live pit of Halemauau is easily accessible and not dangerous. Frequently one can walk to the actual edge of the splashing, fountaining lava lakes, the lava column rising and falling from year to year so that its most distinctive character is ceaseless change. At night the spectacle is full of marvelous color, and the region is a paradise for artists, photographers and naturalists.

The several sections are under the control of the National Park Service of the Department of the Interior. The United States Weather Bureau maintains the Hawaiian Volcano Observatory, which stands on the brink of the greater crater within the Kilauea Park.