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ART. XXIX.—*The Explosive Eruption of Kilauea in Hawaii, 1924*; by T. A. JAGGAR and R. H. FINCH.

It has been plain from recent happenings at the volcanoes on the island of Hawaii¹ that after 1920, the culminating year of the present nine-year cycle for intensity of lava flow, there has been a decline in intensity punctuated by strong collapses at Halemaumau pit. By "nine-year cycle" we follow William Lowthian Green² in a conception of a term averaging about that time for somewhat rhythmic accumulation and release in relation to the pressure of the present volcanic edifices.

Subsidences of the lava in Halemaumau were phenomenally strong beginning November 28, 1919, and May 15, 1922, the latter leading to an enlargement of the pit and extraordinary avalanches making "cauliflower" clouds of sand and dust. At about the same dates of the month in May, 1924, a still greater collapse and enlargement was accompanied by explosions throwing out broken rocks.

The following is a preliminary brief statement of the main facts concerning these explosions, compiled by Mr. Jaggar, largely from notes kept at the Hawaiian Volcano Observatory during the explosive period by Mr. Finch, assisted by Mr. O. H. Emerson, Research Fellow of the Hawaiian Volcano Research Association. We are indebted to numerous volunteer observers who assisted at night and day watches during the crisis, and to several professional photographers. Mr. Jaggar was called back from work in New York and reached Hawaii May 28th.

¹ The lava tide, seasonal tilt and the volcanic cycle, by T. A. Jaggar, R. H. Finch and O. H. Emerson. *Monthly Weather Review*, March, 1924, pp. 142-145.

² *Vestiges of the Molten Globe*, by W. L. Green, Part II, page 287.

The illustrations are selected to give geologists some notion of this remarkable repetition of the 1790 explosions at Kilauea, which had led the workers at the Hawaiian station to watch the years about 1920 with especial interest. This was because of the 130-year interval discussed by Omori, Wood, and Jaggard.³

Journal from April to June, 1924.

At the end of January the liquid lava was vigorously active with a big fountaining lake in Halemaumau pit 105 feet below the rim. In February there was subsidence to a depression of 370 feet. This low condition with a quiet, smoky pit continued through March. There were numerous earthquakes recorded by the seismographs, as located on the Puna rift line east of the volcano. Extremely sudden change of tilt registered on these instruments, after 78 quakes registered during the month, led the seismologists to forecast perceptible earthquakes, probably in Puna, early in April. The line of cones and pits from Kilauea to Kapoho was of interest, because earthquake sources in that direction were appearing on the seismograms. The distances of these sources were progressively increasing, as though the rift were cracking open. This region was doubly interesting because it vented lava in 1922 and 1923 near Makaopuhi pit, about 2500 feet elevation. In those years the possibility of outbreak farther down the rift, as in 1840, was discussed in the Observatory reports, and residents of Kapoho were repeatedly called by telephone to inquire about earthquakes. Earthquakes did not occur there in 1922 and 1923.

April 10, at 10:50 p.m., there was a strongish earthquake in Hilo that broke dishes. On April 13 and April 16 the trail from Kilauea to Kalapana and the district of the Malama homesteads were visited by Observatory parties but no new cracks were found and the natives were not yet disturbed. There was slight steam in

³ F. Omori, *The Eruptions and Earthquakes of the Asamayama*, Bull. Imp. Earthq. Invest. Commission, VI, 1, pp. 20-21.

H. O. Wood, *Cyclical Variations in Eruption at Kilauea*, Second Report Hawaiian Volcano Observatory, Cambridge, Mass., 1917.

T. A. Jaggard, *Index of Danger from Volcanoes*, Bull. Hawaiian Volcanic Observatory, January, 1918, pp. 15-20.

Puulena pit in that district and nothing fresh was found at Puu Aa cone. These places are inland from Opihikao. (See map.) The steam or vapor is nothing new. The number of seismographic earthquakes was increasing.

FIG. 1.

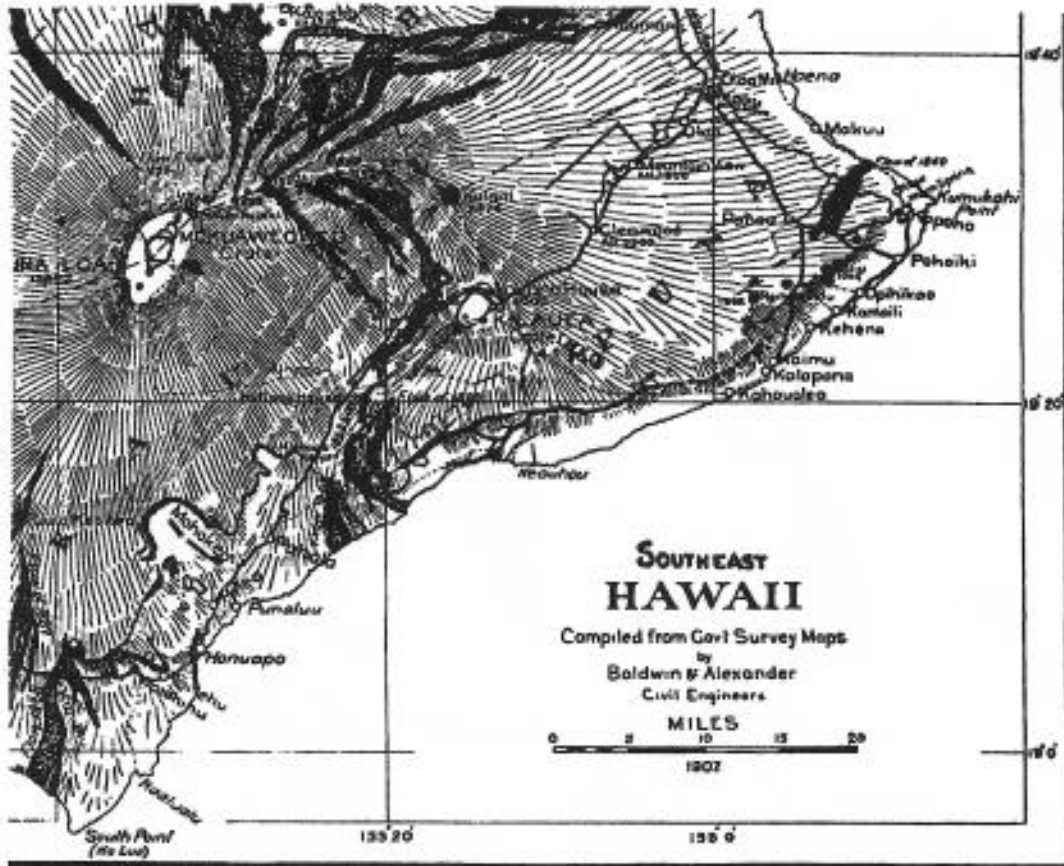


FIG. 1.—Map of Kilauea district. Observatory is at Volcano House. "M" is Makaopuhi pit-crater.

April 22, 1924.

There is no change in the condition of Halemaumau lava pit. Some avalanches from the rim have taken place. During March 78 earthquakes were recorded at the Observatory. Most of these appear to have occurred in Puna at distances varying from 4 to 11 miles from Volcano House.

FIG. 2.



FIG. 2.—Cracks two feet wide, looking southwest toward Kapoho village.
About April 24, 1924.
Photo by Tai Sing Leo.

During April numerous earthquakes have been recorded, and these also were from the Puna district. As time went on the number of earthquakes increased together with increase of distance.

During the twenty-four hours that ended at 11 a.m. April 22, Mr. Henry J. Lyman of Kapoho counted 88 felt earthquakes. During the night of April 22-23 the earth there was quaking mildly almost continuously.

This progressive cracking along a well-known rift line leading eastward from Kilauea indicates the possibility of a lava flow, either in the Puna district, or possibly in the ocean off the Puna coast.

April 29, 1924.

The numerous earthquakes in Kapoho the night of April 21 were followed by cracking open of the ground in the Kapoho district April 23. Most of the cracks trend north sixty east, a direction parallel to the lines of cones and old fissures.

The biggest movements of actual faulting were at the quarry on an old fracture cliff where the railroad crosses the Kula land. From here to the sea the ground south of the fault cliff sank eight to twelve feet, the break crossing and destroying the shore road near Eldart's, and the sunken ground creating a new lagoon by the sea. Here cocconut and hala trees (*Pandanus*) were submerged seven feet or more in salt water. The chasm across the road made by gaping and caving was 15 feet wide.

Other conspicuous yawning chasms developed near the road junction and pavilion at the southeast base of Kukii hill. Here a block of ground 20 feet wide sank six feet carrying down trees and sugar cane. Cinder walls and deep clefts were revealed on both sides. The roads were crossed by many cracks, the widest 3 feet open. Some cracks continued opening and caving until April 29, but most of the crisis was over April 27.

About 200 earthquakes with some rumbling were felt at Kapoho, April 22-23. The shocks were mild, either vertical or in the northeasterly direction of the cracks. Thereafter earthquakes diminished.

May 6, 1924.

The subsidence at Halemaumau that commenced April 29 continued. The depression of the bottom below the rim was now over 600 feet. The actual depth would be greater were it not for avalanche material from the old floor and from the walls continually rolling to the deepest part.

On April 23 the glow from the pit increased and lava could be heard inside the old southeast and south source wells. This increase of glow occurred while the swarm of earthquakes at Kapoho was in progress. On April 28 there was a second small spasm of quaking at Kapoho, though there was no indication of a subterranean lava flow at that place.

Early in May the instrumental frequency of earthquakes increased at the Observatory and tremor suggested underground lava surgings from April 29 to May 4. This, coupled with the subsidence in the pit, indicated the probability of lava drainage. No flow, however, was reported anywhere.

May 13, 1924.

Kilauea volcano entered upon an explosive phase, with broken rocks thrown out from Halemaumau pit, during the early morning of May 11, and the like of this has been unknown here since about 1790.

The dust clouds thrown up from avalanching prior to May 11 were by no means unprecedented, even for recent years, as they have been observed here in 1868, 1894, 1916, 1919, and very strongly during the great subsidence of May, 1922. There are no records of the condition of the pit prior to and after the 1790 eruption, but a lava flow is reported for Puna vaguely dated 1788.

On Tuesday, May 13, 1924, the explosions became more frequent, five being observed during the day. One rock weighing about 400 pounds was hurled 200 feet from the pit. The explosion at 4 p.m. May 13 sent up rocks 2500 feet into the air. One of these stones weighing 300 pounds landed in the roadway 1400 feet from rim of pit, and another weighing 100 pounds fell near the road 1800 feet from the pit.

The rocks of each explosion were largely confined to one sector of the ground encircling Halemaumau, but by May 14 nearly all sectors were covered.

During the first few days of this eruption, the clouds above the pit were largely charged with dust from avalanches. Hundreds of tons of dust have been deposited around Halemaumau and in the Kau desert.

The rim of the pit has been greatly changed owing to large segments falling in at the south and southwest, including the long fault bench there.

Numerous earthquakes have been felt at the Observatory, though more of them are perceptible at Uwekahuna bluff.

On May 13 the amount of fume greatly increased and during the afternoon of May 14, prior to an explosion at 3:37 p.m., there was a continuous moaning roar like the noise heard at the source fountains of the Alike flow in 1919.

May 20, 1924.

The explosive eruption of Kilauea continued during the week, reaching a maximum May 18. On that day one man who ventured too near the pit was killed. His leg was crushed by a barrage of ejected stones, and he died on the following day from the effects.

The surf-like, roaring noise preceded explosions and diminished after them. Excessive tremor was recorded during the first few days only. Earthquakes were numerous. Heavy electrical storms accompanied by pisolitic mud rains followed the larger explosions. Brilliant lightnings shot through the cauliflower ash clouds. A marked air concussion was felt before the larger explosions.

Seismographic records of the explosion earthquakings are peculiar in that many of them, instead of starting suddenly as in ordinary local earthquakes, wax gradually to a maximum and die away in the same fashion.

Avalanches continually enlarged the pit. May 15 there was an avalanche from Uwekahuna cliff, and yellowish cascades of mud followed occasionally by a cloudburst.

FIG. 3.

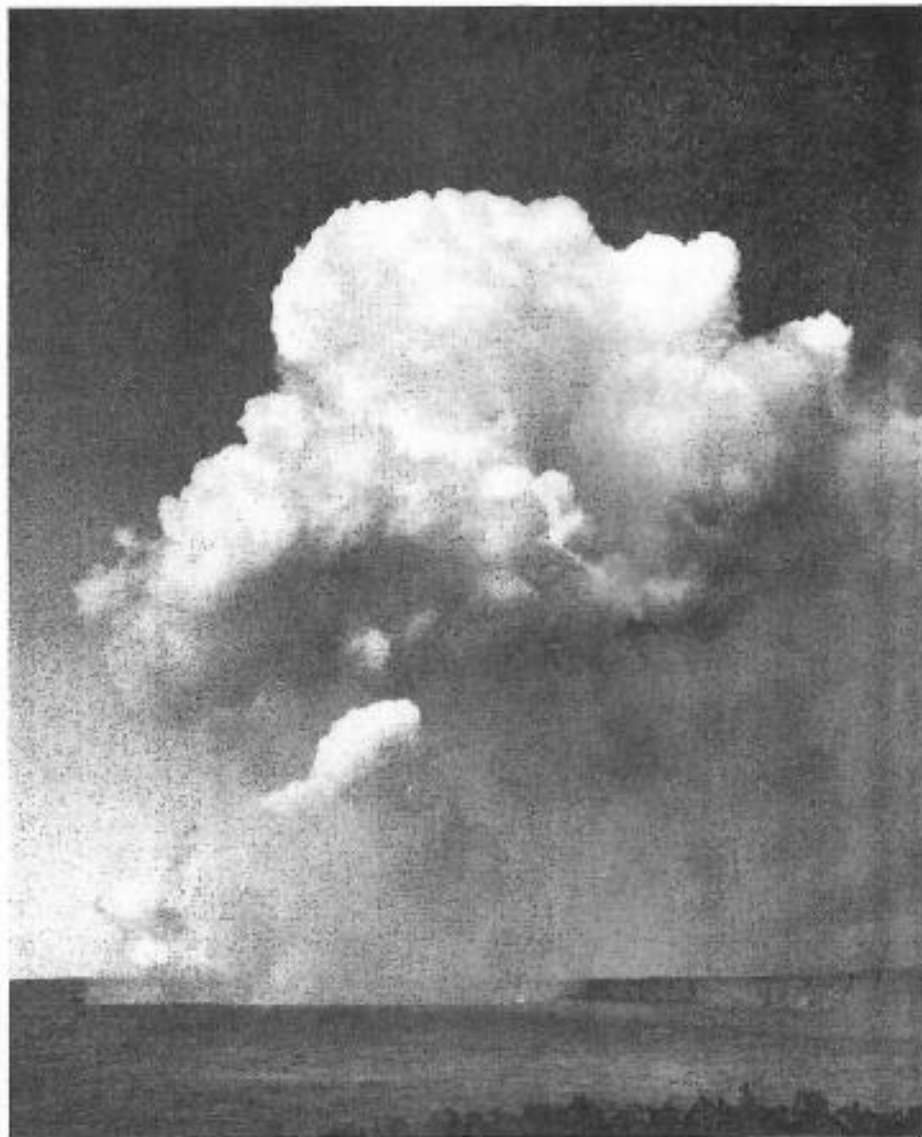


FIG. 3.—Steam cloud over Halemaumau about May 24, 1924. Before May 16 there was much avalanche dust rising continuously. After that the pit cleared as shown here between explosions.
Photo by Tai Sing Loo.

There were two main explosions May 15, four on the 16th, five or six moderate explosions in the night May 16-17, three big ones and many small ones on the 17th, at least five heavy explosions on the 18th followed by a

FIG. 4.

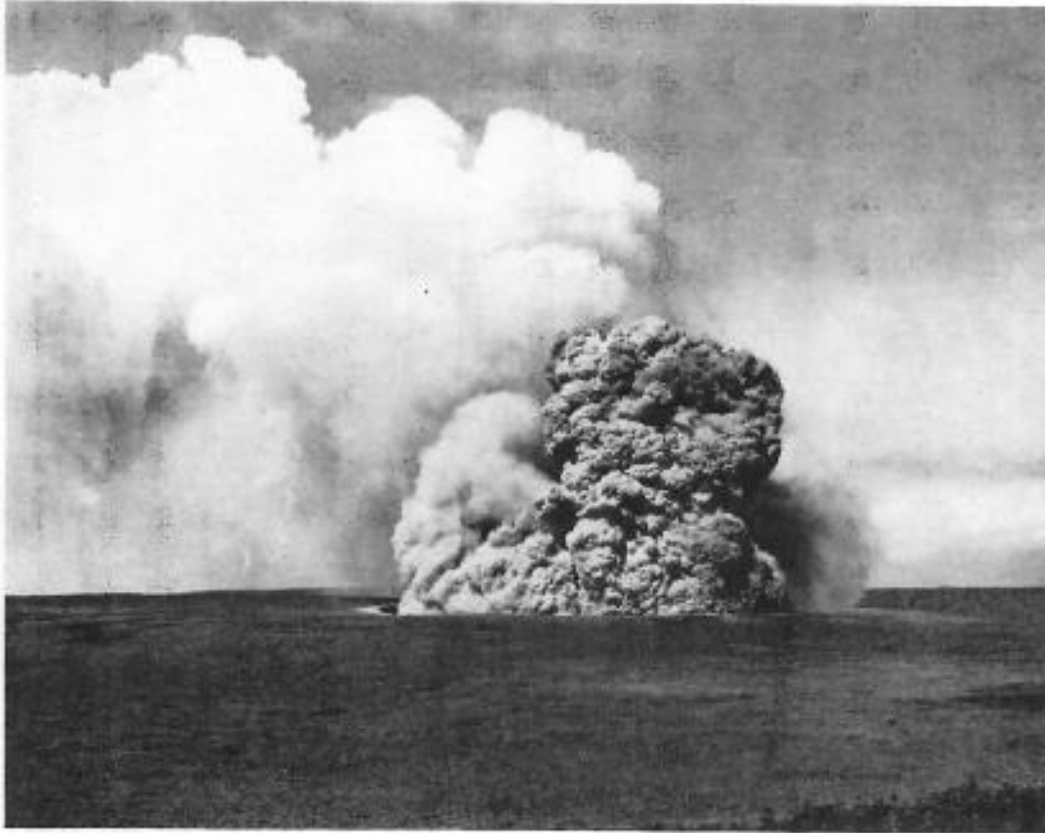


FIG. 4.—Explosion from Halemaumau pit, Kilauea Crater, 8.15 A.M. May 22, 1924. First stage. Steam clouds being displaced by rising cauliflower cloud of ejecta.

Photo by Tai Sing Loo.

night of steam clouds and avalanches, eight moderate explosions on the 19th, and five smaller ones on the 20th.

This record appears to indicate a clogged throat, at first with fewer and more violent coughings, while at the end the vent was more open.

At the noon eruption of the 17th, there were fifteen explosions in 11 minutes, sand fell at the Observatory for

twenty-five minutes, and that which fell at the edge of the pit was very hot. In the evenings the rocks ejected were very hot to the point of incandescence, and the ground glowed with these deposits.

New cracks across the Halemaumau road near the gravel flat appeared on the 16th. The boulders cover

FIG. 5.

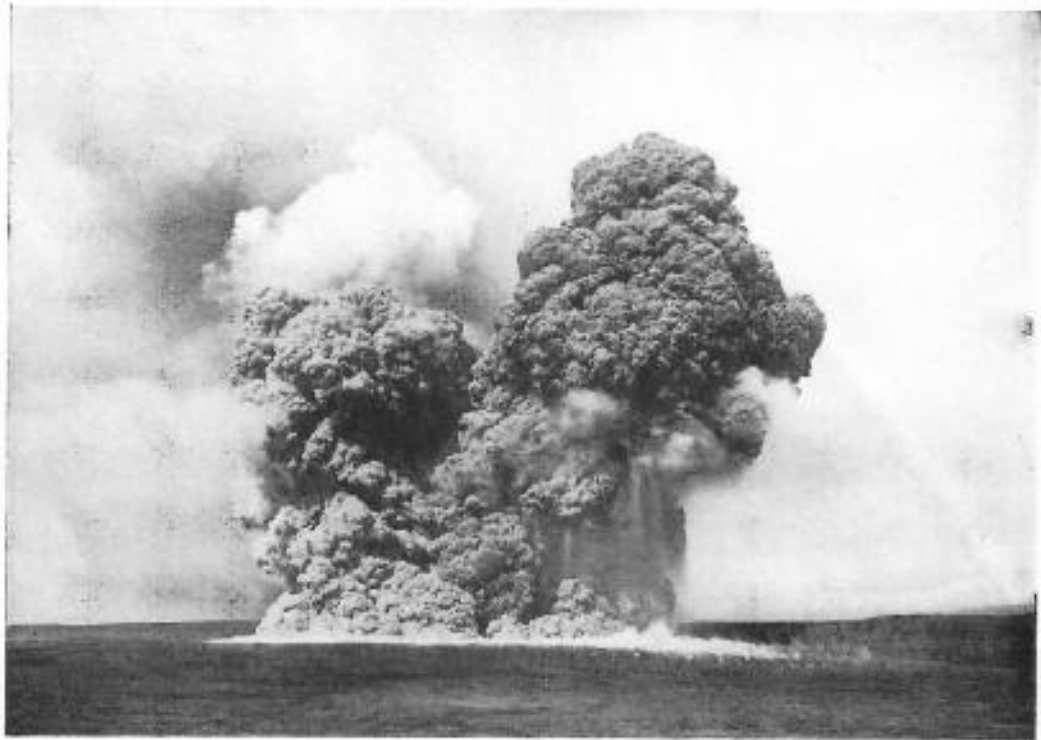


FIG. 5.—Explosion, May 22, second stage, a minute or two after stage one. Fall of rocks to the right.
Photo by Tai Sing Loo.

the flat, also the region surrounding Halemaumau to a distance of a half-mile, and some stones at 7.18 p.m. on the 18th reached the lower Uwekahuna terrace. The three greatest eruptions were respectively on May 17 at 12:32 p.m., May 18 at 11:09 a.m., and the same day at 7:14 p.m.

The rocks ejected are notably without a trace of new lava or bombs encased in lava. There are no pumice

FIG. 6.

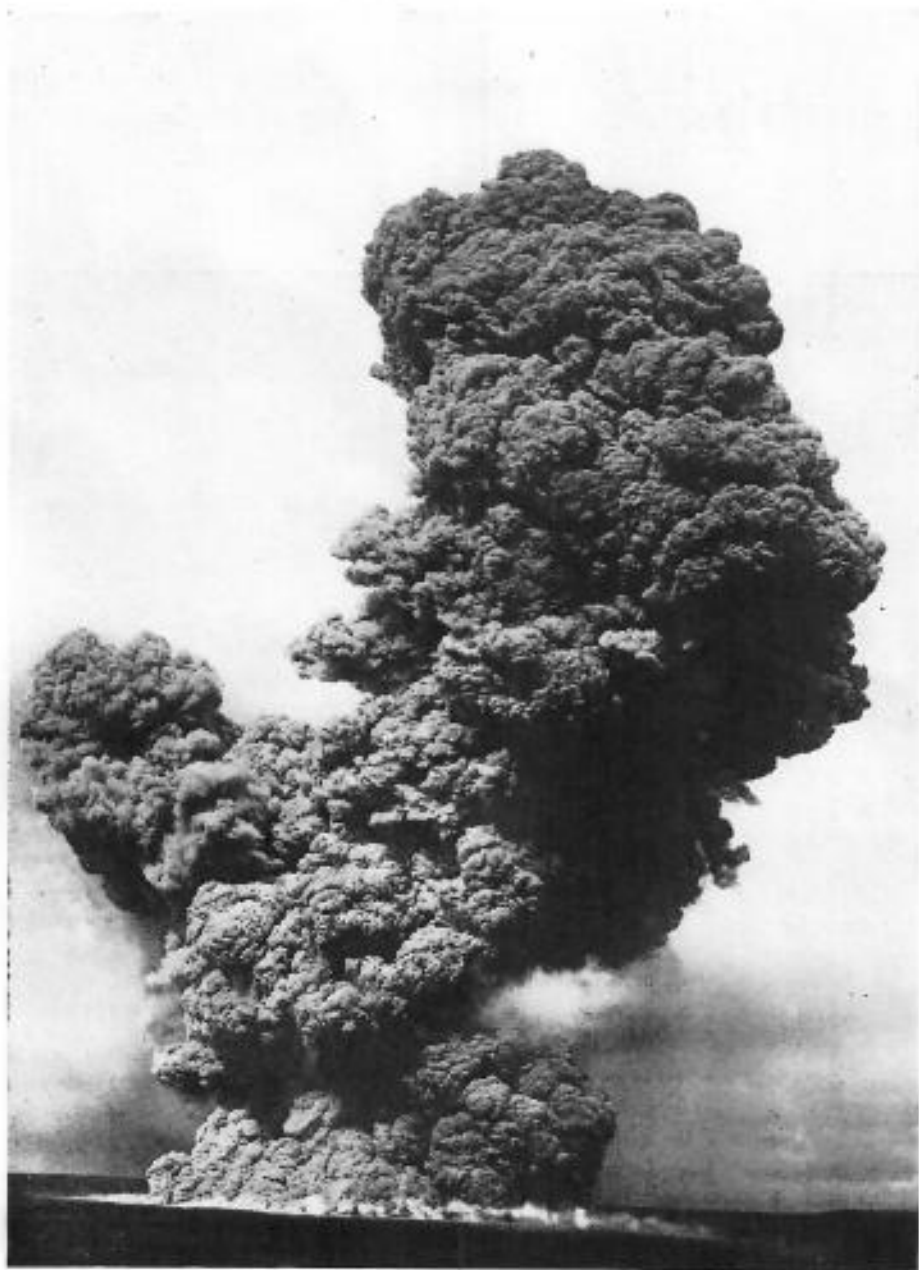


FIG. 6.—Explosion May 22, third stage, a few minutes after stage two. Ten or twelve successive exploding volumes of gas here shown.
Photo by Tai Sing Loo.

fragments or droplets of lava glass or Pele's hair. The rocks are fine or medium grain granular crystalline trap, olivine rock or gabbro, and there are many fragments of old lava from the walls of pit. Many of the fragments are notably heavy, and occasionally they show sign of heating in the "bread-crust" cracking of their surfaces.

FIG. 7.



FIG. 7.—Halemauana, south side. 11 A.M. May 11, 1924. Shows rising dust clouds from avalanche and a few stones fallen during the previous twenty-four hours.

Photo by Finch.

May 27, 1924.

The week was marked by the decline of the explosive eruption. Avalanching was very pronounced May 21. Rock showers signifying deep explosion were seen May 22, 23 and 24. Thunder and lightning developed in the eruption clouds twice on May 22, twice May 23, once

May 24, and a last time May 25. Small earthquakes were numerous.

Inspection of the pit at night, May 27, revealed no glowing matter. Luminous flashes had been seen over the pit the evening of May 21, suggesting gas combustion, but not thereafter except as attributable to lightning.

FIG. 8.



FIG. 8.—Floor of Kilauea north of Halemaumau, 11 A.M. May 13, 1924. Shows more fallen stones than in Fig. 7. Locality close to Halemaumau rim.

Photo by Finch.

Roarings were numerous, largely due to avalanches. A detonation was heard at 3:22 a.m. May 24. White steam was increasingly replacing the dark dust clouds of the week before.

The last conspicuous explosion throwing rocks began at 9:14 a.m. May 24. The rock trajectories made tails of

vapor or dust to a height estimated at 3000 feet. The dust cloud was over 6000 feet high. There were lightnings in the middle of the dense black cloud, and short cracks of thunder were heard. There were four or five major explosions in this eruption, the ground trembled, and a heavy deposit of ash was added to the country immediately north and south of the pit. By 9:35 a.m. the eruption was over.

June 3, 1924.

After the explosive eruption there were numerous small quakings at the Kilauea rim, recorded during the week to the number of from twenty to sixty per day by the instruments, the numbers decreasing. Some of these were felt as moderate earthquakes to the number of three or four per day, but most of those felt merely rattled doors or windows, perceptibly only at night. Some earthquakes of this period were felt generally over the island of Hawaii.

The pit had now become a large cauldron of oval shape floored with broken rocks, its longest diameter 3400 feet, its width 3000 feet and its depth about 1330 feet.

The walls showed horizontally bedded lavas in the upper sections and large platy intrusive bodies of whitish aspect near the bottom, especially north and northwest. The lower walls exhibit dykes or fissure fillings of lava, twelve or fifteen of these being in evidence below, petering out upward so that only two are to be detected in the upper wall. The two dyke exposures rising through the upper beds appear to be the same fissure on opposite sides of the pit, and that is the southwest rift of 1920. Along its course up and down the southwest wall this dyke in two places becomes a cavern leading away underground toward the 1920 flows in the desert. In the upper hundred feet even this dyke thins out to nothing.

The bottom area was steaming vigorously and from the rock walls avalanches fell frequently. Some purring noise could be heard from gas vents in the bottom. A flat area of the bottom appeared to be partly mud. Much of the debris slope was wet.

FIG. 9.



FIG. 9.—Floor of Kilauea north of Halemaumau, 11 A.M., June 1, 1924. The gravels are only 5 to 10 inches thick beneath the boulders. Locality close to Halemaumau rim.
Photo by Emerson.

FIG. 10.



FIG. 10.—South rim of Halemaumau, June 5, 1924, showing layer of volcanic sand a foot or more in thickness; boulders few.
Photo by Emerson.

FIG. 11.



FIG. 11.—Eight-ton boulder that fell May 18th, 3500 feet from volcanic center of ejecta. Shows impact pit and broken fragments southeast from Halemaumau, looking southeast.
Photo by Emerson.

FIG. 12.



FIG. 12.—East rim of Halemaumau, looking north, June 1, 1924. Shows transition from sand to boulders south to north.
Photo by Tai Sing Loo.

The floor of Kilauea crater outside Halemaumau showed the most boulders east and northwest, and on the south there were rill-marked sand surfaces with few stones. These surfaces in the hollows held pools of rain water with reddish mud bottoms, that tended to dry up and crack in the sunshine. The cliffs and floors of Kilauea everywhere were dusty with ash and dried mud.

June 10, 1924.

A spell of increased numbers of small earthquakes June 8-10 was accompanied by several puffs of dust-laden clouds from Halemaumau. The most notable was at 4:25 p.m. June 8, and was accompanied by roaring noise. There had been a mud rain earlier in the day producing pisolitic dust balls. At 4:40 p.m. there were dust showers on the Kau desert out of the volcanic cloud. A notably strong earthquake shock at 2:20 p.m. that day had made avalanches at the pit and at Uwekahuna.

Avalanches increased at the pit, especially along certain upright cracks in the walls that seem to "work" from top to bottom with evolution of dust clouds. Cracks back from and parallel to edge of pit were widening. Slight sulphur patches making blue fume were seen amid the steam on the bottom of Halemaumau and the purring noise was a little louder. The white vapor is strikingly absorbed by the air in sunny and dry weather, visibly thickening in damp weather and at night.

On the early afternoon of June 9 there was a series of rapid reddish brown puffs of heavy cloud from the northeast side of the pit, accompanied with deep growling noise and dust-fall to the south.

June 17, 1924.

About 9 p.m. June 12, glow from below on the steam cloud above Halemaumau was visible at a distance. The pit was at once visited. The long platy intrusive body on north wall of pit was glowing in dull fashion and its surface made trickling powdery slides of red-hot stones that collected below in fiery talus cones.

The glowing area in the wall was about 6000 feet long, east and west, by 300 feet high and its top was some 600

feet below rim of pit. Quiet steam rose as usual from the bottom of the pit, and the glow wall appeared to be remnant incandescence, not new lava.

When this was examined June 13, no glow whatever was visible in daylight. The powdery slides from the big intrusive body would send up hot clouds of dust.

FIG. 13.



FIG. 13.—Lower interior northeast walls of Halemauuan, June 16, 1924. Shows eastern prow of laminated whitish intrusive body and some of the dykes. The intrusive body and talus below were red hot at night at this time. Intrusive appears to suffuse old bedded lavas.

Photo by Emerson.

The rock appears fine-grained and of light-gray slaty appearance, about 2000 feet long, with the big dyke of the Kau rift cutting it, and other dykes above and below apparently not cutting through it, and the upper ones definite offshoots from it. There are other big intrusive bodies low down the northwest wall.

FIG. 14.

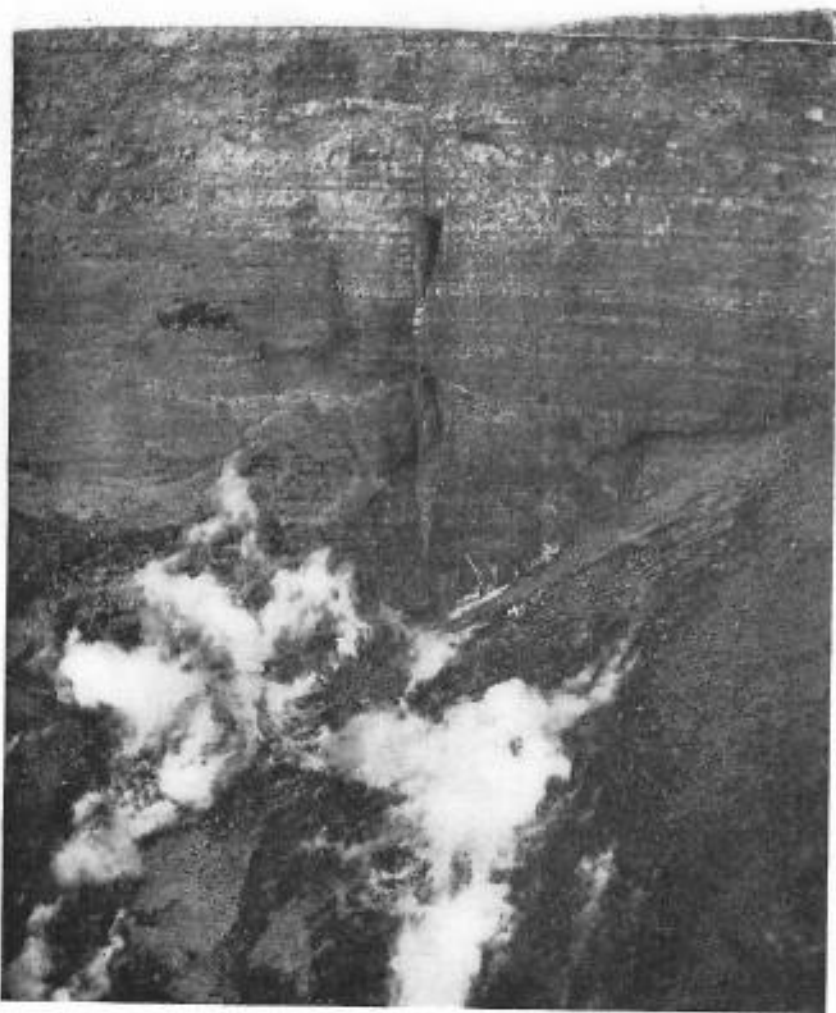


FIG. 14.—Southwest interior wall of Halemauuan, June 5, 1924. Shows vertical dyke fissure of 1920 with remnant tunnels of Kuu dust flow. Also bedded lavas of upper walls and steaming talus. Photo by Emerson.

Avalanches were still numerous and earthquakes continued to be noticeable until June 15.

At 12:40 a.m. June 13 a strongish earthquake seemed to be occasioned by movement on a fault plane back of Kilauea military camp. This was on old cracks newly opened at the big fissures concentric with Kilauea crater. Other such cracks showed motion June 9 across the Halemaumau road west of Keanakakoi crater.

June 24, 1924.

A feature of the landscape at Kilauea which is quite new to old-timers is the dust, blown in simoon whirls and sent up in clouds continuously over the Kau desert, along Uwekahuna bluff, and on the Kilauea floor, at times of high wind and dry weather.

This was marked about June 12 and 23. The whole country is gritty with the new-fallen ash of the May explosions, and this clings like cement, on the ground, on foliage, and on houses. It consists indeed of the ingredients of cement heated by the eruption.

A night inspection of Halemaumau June 18, showed the incandescent northern intrusive body as before, and another glow spot appeared in a similar intrusive in the west wall. There was much blowing noise audible in the quiet night air from the bottom of the pit. An avalanche from the glowing north body left a red-hot wall of estimated temperature 750 degrees Cent. Possibly this great mass fills a gash more or less horizontal that was connected with the lava in the pit of last January, and with the deep lava source through intrusive bodies now under the bottom of the funnel.

Seismic conditions were now nearly normal. Kapoho was visited June 19, and all activity there of cracking, etc., had ceased. At Mauna Iki in Kau desert the ash is less than $\frac{1}{8}$ inch thick, six miles to leeward of Kilauea.

R. H. Finch visited the summit crater of Mauna Loa June 17, and found no change there. The Postal rift cavern northwest of Halemaumau was broken in at new places by bowlders of the explosive eruption. Southwest of Kilauea at the 1920 chasm near Cone Hill the ash and gravel are 8 inches deep, covered with feathery rill-pattern. At Makaopuhi there is only a film of ash.

July 1, 1924.

All activities of Kilauea volcano, such as seismic shakings measured with instruments, volume of steam in pit, number and volume of avalanches and occasional avalanche clouds now seemed to be decreasing. The pit Halemaumau was very clear on sunny days, a huge natural rock quarry with steam jets on its bottom. There has been growth of the longer talus heaps with accompanying recession of upper rim of pit. There are four larger talus slides.

On June 26 it was found that large pieces of rim of pit had fallen in and some of the survey flags had been carried in. A fummy sulphur-yellow patch appeared in one place on the bottom flat, amid many tails of rising steam.

By this time the vapor clouds above rim of pit on sunny days had so much thinned as to disappear entirely in the dry air above, though the bottom steam jets were always to be seen by an observer on the rim.

On the afternoon June 28 there were avalanches, after a preceding night when the seismographs registered some earthquakes. At 3:45 p.m. there was a sudden puff of brown dust that rose rapidly and silently leaving a clear pit below. Usually the avalanche clouds leave the air dusty.

A visit to Pahala June 29 showed the May dust from Kilauea on the ground there to be a film only, thickening along the Volcano road northeastward to $\frac{1}{8}$ inch at Kapapala gate and $\frac{1}{2}$ inch at Prison Camp. Pahala has had abundant rain and all vegetation there was very fresh and green. New dust at the plantation was estimated 4 tons to the acre.

July 9, 1924.

During the week there have been no other changes in Halemaumau pit than occasional avalanches from the walls and a lessening of the steam from the bottom.

The latest measurements of the pit, now being compiled into a sketch map, indicates that the cauldron is 3400 feet long northeast-southwest by 3000 feet wide northwest-southeast. It is an oval with pointed end southwest and an extra corner extending it west.

The lowest part of the bottom area is at the north 1335 feet below rim. The bottom is diamond shaped and gravelly of dimensions 1000 by 700 feet. Outside of this and including it is a large area of talus slopes 2800 by 2000 feet.

The rock walls above funnel inward with flattest angle at the east, where the horizontal distance from rim of pit to top of talus is 800 feet. Across the north side of bottom of wall passing under the talus there are revealed intrusive whitish bodies of dense crystalline rock 1550 feet across. In the walls higher up there are red-hot crystalline bodies northeast and west, the former at least 1800 feet long resembling a sill, and the latter crescent-shaped and 400 feet in diameter, with rugged red masses, in the crescent, of ferruginous.

It thus appears as though the deepest part of the pit where the explosions came from were probably bordered with massive gabbroid rocks like those the explosions threw out.

The site of the new pit is identical with that of the old Halemaumau, but greatly enlarged.