From:

Eruption of August 1963
Solidification of Alae lava lake, Hawaii

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DESCRIPTION OF THE AUGUST 21–23, 1963, ERUPTION

The first indication of the impending eruption was the onset, at *13ʰ46ᵐ August 21, 1963, of nearly continuous small-amplitude tremor that recorded more strongly on a seismograph near the Makaopuhi Crater than on seismographs near Kilauea Caldera (fig. 5). Beginning at the same time, many small earthquakes, one to four per minute, were recorded. Many of these were from epicenters near Makaopuhi, which yielded *S* minus *P* intervals of 0.5 and 0.6 seconds at Makaopuhi. More than 800 distinct earthquakes were recorded from the upper east rift zone during the remainder of August 21. At 13ʰ50ᵐ, displacement of the traces of the Press-Ewing seismographs in the Uwekahuna vault near the Hawaiian Volcano Observatory indicated the beginning of a distinct tilt to the east and a less distinct tilt to the south. Tremor died down to a low level after 15ʰ00ᵐ, but at 18ʰ00ᵐ it began to increase again. A sharp increase in tremor amplitude at 18ʰ10ᵐ probably marks the beginning of the eruption. A swarm of small earthquakes began at about 13ʰ50ᵐ after three earthquakes of magnitude about 2 on the Richter scale. The frequency of earthquakes increased to about 5 per minute at 14ʰ30ᵐ and then decreased to 0 at 18ʰ15ᵐ.

When the eruption was first observed, shortly after 18ʰ15ᵐ, vigorous lava fountains on the floor of southeast pit and on the north wall had already formed a pool of lava covering most of the floor of the southeast pit. At 19ʰ20ᵐ, the fountains on the floor formed an almost continuous curtain 5 to 10 m high extending 80 m N. 65 E. from near the east

* All times given are in hours and minutes, Hawaiian standard time.

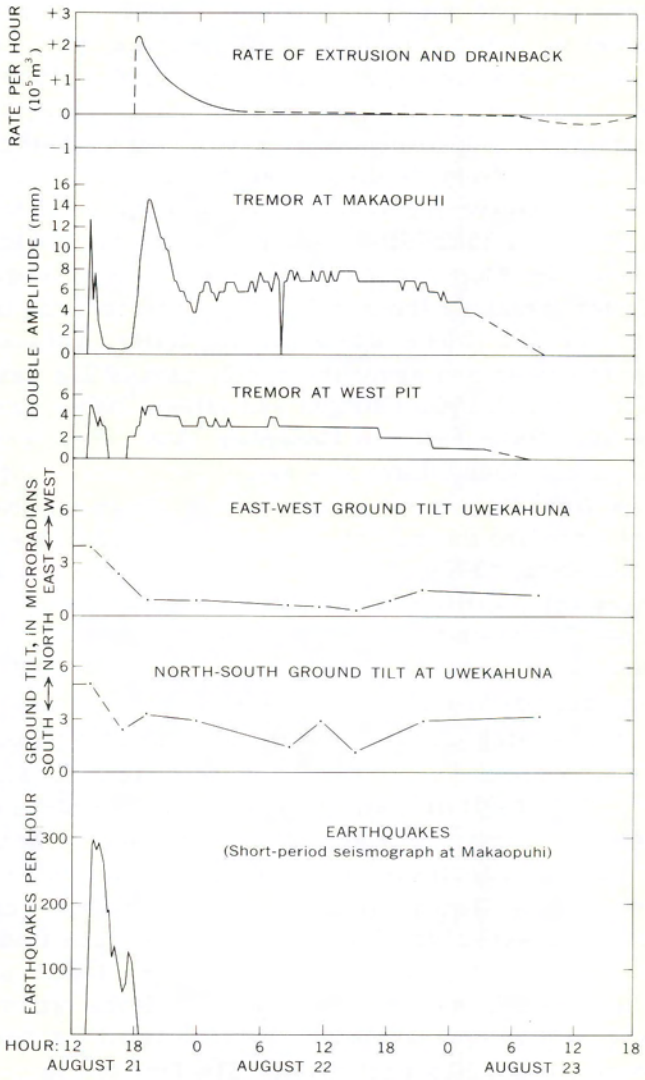

FIGURE 5.—Chronology of events during the August 1963 eruption of Kilauea.

edge of the southeast pit (long eruptive vent, fig. 3). Lava was erupting from 11 vents on the north wall along a fissure parallel to the fissure on the floor of the crater but displaced 30 m to the northwest. This lava cascaded down the cliff and plunged beneath the surface of the growing lake of lava (fig. 6). The most rapid discharge was obliquely upward and westward from one of the vents in the middle of the line, about 100 m below the north rim (vent H of fig. 6). The dark crust of the lake was broken by glowing zigzag cracks that splayed outward from the curtain of fire and from the base of the lava cascades. At this time the lake had an estimated depth of almost 10 m and had completely covered the floor of the southeast pit, an area of about 65,000 m², with almost 400,000 m³ of lava (fig. 7). The level was

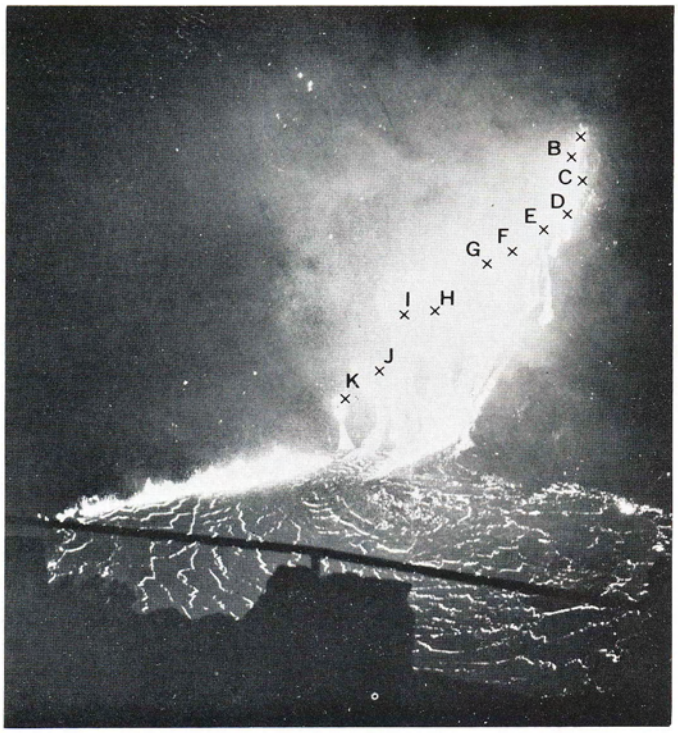

FIGURE 6.—Eruption in Alae Crater at 19^h20^m August 21, 1963, as viewed from overlook at south rim of crater. Letters refer to vents described in text. Fountains extend over a vertical distance of 100 m on the north wall of the crater.

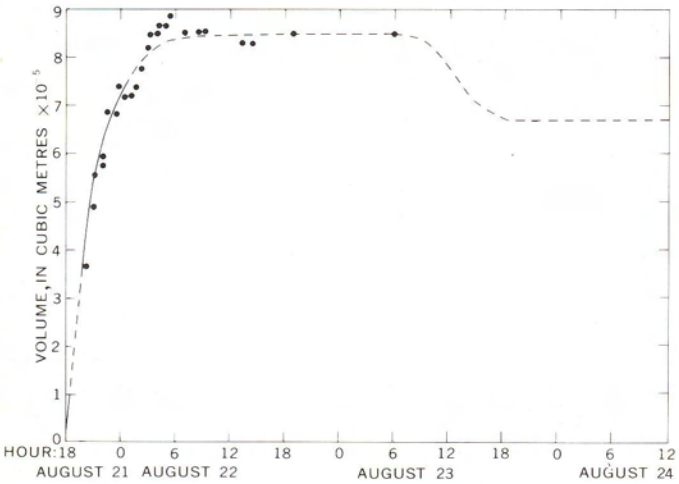

FIGURE 7.—Volume of lava in Alae lava lake during the August 1963 eruption, as determined by transit sightings (dots) from the rim during the eruption and by triangulation and level measurements after the eruption.

rising at an estimated rate of about 2 m per hour, indicating a rate of extrusion of approximately 230,000 m^3 of lava an hour (fig. 5). Spatter from a 150-m-long en echelon line of fountains in the jungle, 60 m beyond the north rim, was visible above the trees. These fountains died by 19^h45^m after sending thin flows of shelly pahoehoe over an area of 7,000 m^2.

By 20^h00^m, the uppermost vents on the north wall (A, B, and C, fig. 6) had died, and the thin lava streams that had issued from them were dark. During the remaining 4 hours of August 21, many of the other vents on the north wall of the crater died —vent D at 21^h and E and F at 22^h; vent F emitted bluish gases for several hours after it had stopped spattering. By midnight only three vents were still erupting vigorously. The line of fountains on the floor of the crater had become discontinuous; the fountains were playing to a height of 8 m over a length of 40 m, and an isolated fountain at the southwest end of the original line was bubbling weakly. As determined by transit sightings from the overlook, the surface was rising at a decreasing rate—1.5 m per hour at 21^h, 1 m per hour at 22^h, and 0.6 m per hour at 23^h. The rate of extrusion had dropped from about 200,000 m^3 per hour at 20^h to 45,000 m^3 per hour at 23^h. As the rate of extrusion from the vents on the north wall decreased, the apparent viscosity of the lava increased (probably because of a decrease in temperature), and lava cascading down from the fountains formed a noticeable delta at the edge of the lake. At 01^h40^m on August 22, surges in the fountain on the floor of the crater produced waves in the lake with a frequency of 22 cycles per minute; these broke like surf on the shore northwest of the fountain and traveled 70 to 100 m to the southwest in the lake before dying out. Through the night, the lake had been broken by glowing zigzag cracks that radiated out from the vents. Photographs taken at 10-minute intervals between 01^h50^m and 02^h10^m show correspondence in the crack pattern between successive photographs, indicating that the crust of the lake was being rafted outwards on lava flowing from the vents at a rate of about 200 m per hour, to be piled in a narrow slabby levee at the edge of the southeast end of the lake.

By 03^h00^m, the line of fountains on the floor of the crater had become erratic, momentarily dying back to a length of 15 m, and then lengthening to 35 m. The fountains on the north rim continued to diminish in vigor. The lake was about 17 m thick and probably was rising at an hourly rate of about 0.3 m (15,000 to 20,000 m^3 of lava per hour). Transit sightings to the foot of the lava cascade on the north shore of the lake continued to show a decrease in the angle of depression with time, suggesting continued extrusion of 30,000 m^3 of lava per hour until 05^h30^m. However, the later increase in the angle of depression between 05^h30^m and 07^h, indicating an

apparent subsidence of the lake surface, and observations of the north shore the following morning, suggest that the transit sightings were reflecting the slow buildup and lowering of the surface of a broad lava delta at the foot of the cascades, rather than changes in altitude of the surface of the lake.

By 06^h00^m, the lava lake had reached almost its maximum depth (18 m) and volume (8.4×10^5 m^3). The increasing volume of lava in the lake for the rest of the eruption was so small that it was not measurable. The vent on the floor of the crater had begun to fountain irregularly; instead of throwing up a curtain of flowing lava 7 to 10 m as before, it erratically spewed bursts of spatter to heights as great as 50 m, accompanied by great booming noises. The change in activity of the fountains at this time, and the lack thereafter of any substantial increase in volume of the lake, probably recorded a change in the type of material being supplied to the fountains from the rift zone. Before 06^h, this included a significant proportion of lava, the quantity of which steadily decreased with time; after 06^h, it was mostly gas. The lava thrown up by the fountains may largely have been lava from the lake, blown out by expanding gases rising upward through the lake from the underlying vent. The three remaining fountains on the north wall (H, J, and K of fig. 6) were spattering weakly and sending two sluggish rivers of aa down to a small low delta on the lake. In the morning light, we could see that the vents on the north wall had built a row of coalescing spatter cones and that spatter and cinders from the fountains on the floor of the crater had accumulated to form a low spatter and cinder cone along the northwest side of the lake.

The eruption continued at a diminishing rate during the morning. At 11^h, a party circled around to the north side of the crater, where they could look down directly into the two remaining active vents on the north wall. One, vent K (fig. 6) was spattering weakly within its cone and sending a red ribbon of lava down to the lake. The other, vent H, was emitting much fume but only a little lava. This lava formed a sluggish stream which at times had a rough dark aa crust that first formed at the lower end and appeared to grow upstream, only to be repeatedly dislodged and carried downstream by the red lava.

Two major fountains and several minor ones played on the floor of the crater (fig. 8). The lava lake was impounded behind a slab levee, but occasionally it overflowed or undermined the levee, producing festooned flows or tumuli on the lake margin.

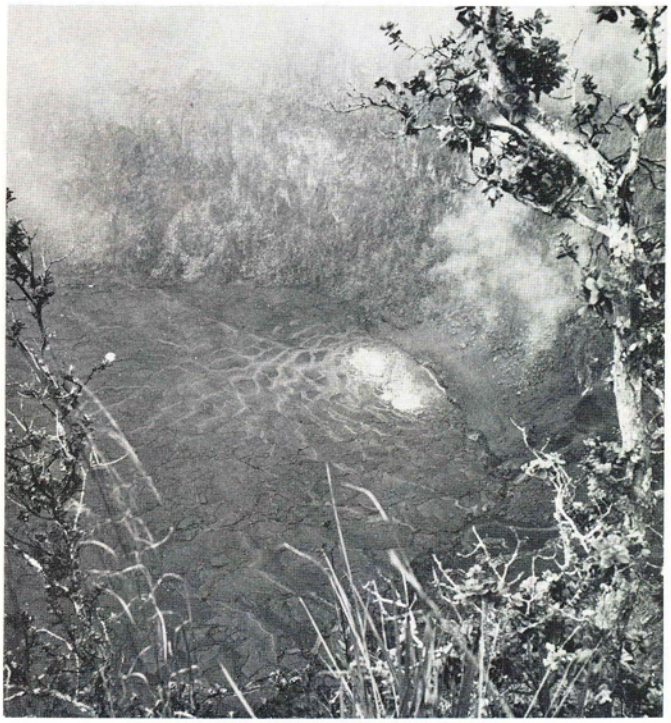

FIGURE 8.—Eruption in Alae Crater at 11^h10^m, August 22, 1963, as viewed from the north rim. Incandescent bubbling areas (light colored) are about 10 m in diameter.

The crust of the lake continued to founder locally, mostly along cracks near the edge of the lake or above the former southwest end of the curtain of fire. Pumice that had been erupted during the night was collected from the ground near the north rim, and samples were gathered from the spatter rampart and shelly pahoehoe flows in the jungle beyond the north rim of the crater.

By 15^h, the line of fountains on the floor of the crater had shortened to 30 m; they bubbled to an average height of 3 m but sent occasional bursts of spatter to 50 m. The vents on the north wall were almost dead, and lava rivers from them were crusted over. The slabby rim of the lake increased in width from the new slabs of crust that were continually added to it from the lava lake. The crust of the lake had a distinctive mosaic appearance (fig. 9) caused by patterned differences in surface texture that appeared as alternating light and dark bands parallel to the glowing cracks. These textural differences are discussed on page 22.

At 17^h, the fountains on the floor of the crater were seen from the mezzanine to bubble vigorously with whooshing and thundering noises from two large and several small intermittent centers along a length of 35 m (fig. 10). At each center, the activity

FIGURE 9.—Eruption in Alae Crater at 15^h, August 22, 1963, as viewed from overlook at the south rim of the crater. Behind and to the left of the vent is a 50-m cliff at the end of the forested mezzanine. The degassing vents on the far wall are almost dead, but the inconspicuous line of fountains on the far floor are bubbling to an average height of 3 m. The lake surface looks like a mosaic because of patterned differences in surface texture parallel to glowing cracks.

resembled the bubbling of a mud pot; a bubble of lava 1 m or so in diameter would appear, grow rapidly larger as the gas inside expanded, and then break into long ribbons of lava that were cast as high as 50 m. Gases rising from below the lake apparently provided the driving force for the fountaining. Spatter was not thrown evenly in all directions; more than half fell to the west on the lakeshore behind the fountains, forming a spatter and cinder cone that was about 2 m high at this stage. Possibly this unevenness reflected only the prevailing wind direction, which is typically a counter-trade wind direction on the floor of the crater; from the mezzanine, however, the fountaining appeared to be inclined in that direction, perhaps because lava in the lake impinged on the breaking lava bubbles.

The dark surface of the lake was broken by glowing cracks; these consisted of two sets, one of concentric cracks near the fountains and the other of thin cracks that radiated out from the fountains. The latter cracks diverged farther away and divided the lake surface into distinctive lobate areas (fig. 11). The outer margins of the lobate areas were bordered by wider glowing cracks, which were the sites of foundering at many localities.

We scrambled down the talus to the southwest edge of the lake and found that the lake was brim full behind a 15-m-wide levee of folded and faulted pahoehoe slabs. The surface of the lake was not flat; it rose as much as 0.5 m from the edge of the lake to the site of the fountains, reflecting the hydraulic gradient of the viscous fluid. Small outflows and foundering took place at the distal end of the lobate areas, which were commonly about 0.3 m higher than the lake surface at its margin. Foundering was related to outflows of fresh lava from these cracks. The weight of the outflowing lava would cause a slab of crust to bend down and break off. This slab would glide inward and tilt down toward the center of the lake until the leading edge would sink and the trailing edge rise up in the air—looking for all the world like a sinking surfboard. Crustal foundering on a much larger scale was observed during the formation of Makaopuhi lava lake (Wright and others, 1968, fig. 10).

The levee was separated from talus mantling the crater walls by a moat 15 m wide and about 3 m deep. Inside the moat were several small tumuli about 8 m long and 2 m high; the medial crack of each was filled by a snakelike mass of lava, still glowing red in marginal cracks. At many places the levee had been breached and overflowed by small festooned flows of pahoehoe. We marked the level of the lake surface on the talus mantling the walls of the crater by sighting with a compass level. Later surveying with a transit from the floor of the lake fixed this level at 785.5 m (2,577 feet), 3.0 m above the present floor of the lake and 18.0 m above the base of the crater before the eruption.

Beginning at about 21^h, the glowing cracks at the south and east edges of the lake began to darken (fig. 12) as the actively circulating part of the lake shrank because of diminished vigor of fountaining. By 22^h45^m (fig. 13), the southeast half of the lake was dark; by 23^h16^m (fig. 14), only two small lobate areas were left; and by 23^h55^m, the lake was dark except for the fountain. The position in plan of the glowing cracks was later determined by examination of photographs taken during and after the eruption and by mapping the surface features of the lake. These studies provide clues to the pattern of lava circulation in the lake during the evening of August 22, as discussed on pages 22–24.

The activity of the line of fountains on the floor of the crater decreased through the evening of the

FIGURE 10.—Fountain in Alae Crater at 17^h45^m, August 22, 1963, as viewed from the mezzanine. Height of fountain about 5 m. Ribbon spatter on top was produced by bursting of a bubble of lava an instant before the photograph was taken (compare with fig. 23). Photograph by S. Aramaki.

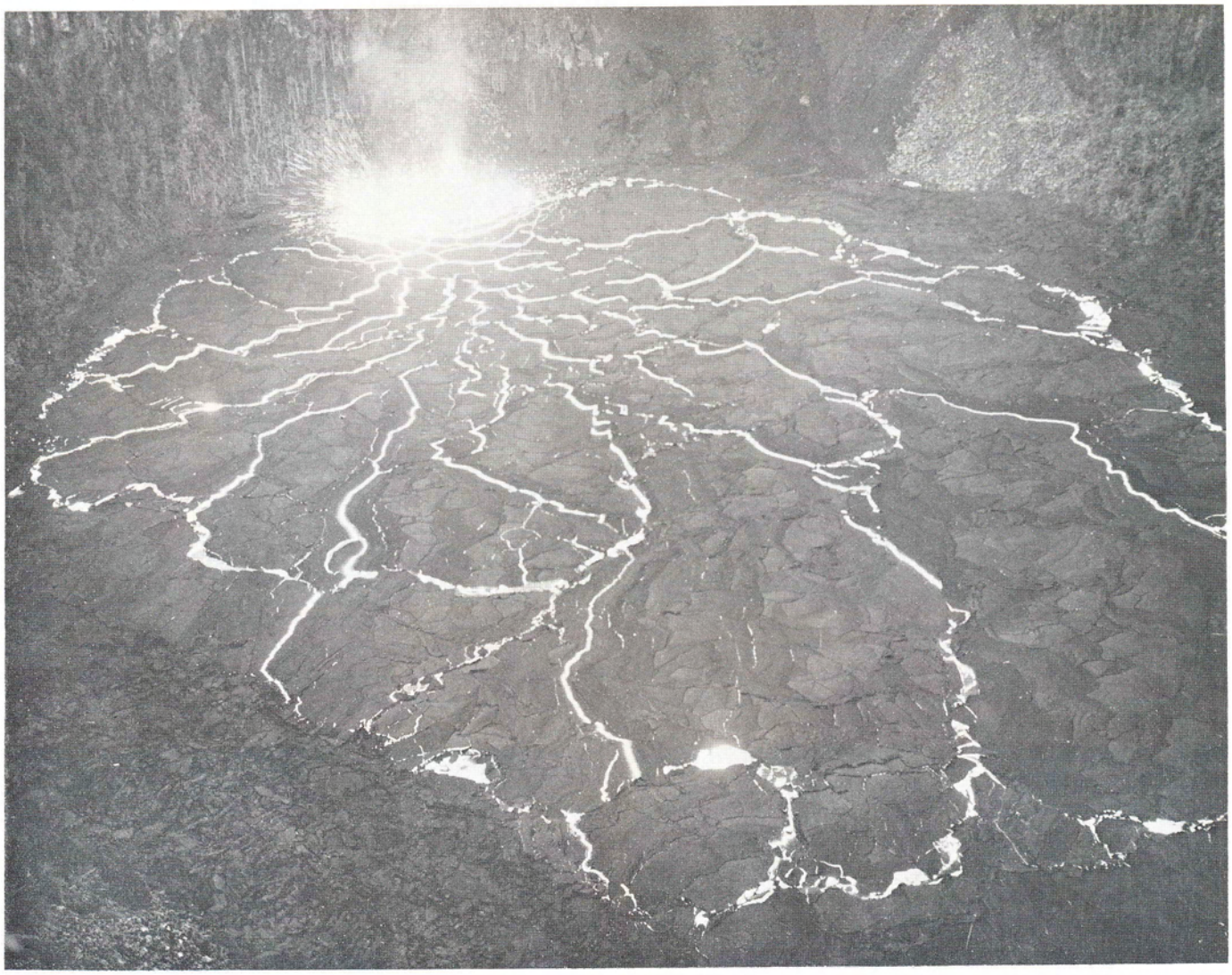

FIGURE 11.—Eruption in Alae Crater at about 18^h, August 22, 1963, as viewed from overlook. Two sets of glowing cracks break the dark crust, one near to and concentric with the fountain, which was about 35 m long, and another radial to the fountain which outlines lobate areas of crust. Crustal foundering (light spots) occurs at the distal ends of the lobes. A marginal levee of slabs and small festooned flows can be dimly seen in the left foreground. Photograph by T. Miyasaki.

22d and the early morning hours of the 23d. By 23^h30^m of the 22d, fountaining was taking place at 5 centers along a length of 25 m. By midnight, the fountains became more erratic and died completely for a second or two before resuming again. By 02^h10^m of the 23d, only three areas were bubbling, and the periods of quiet had increased to 5 seconds. By daylight, at 05^h30^m, only one bubbling area was left; it burst slowly about every 5 seconds. At this time the lake surface was at the same level as at 19^h the previous evening, when the level of the lake surface had been marked with a sample bag on the talus mantling the lower crater walls after sighting on the lake surface with a brunton compass level. By 07^h30^m, the vent was still bubbling every 5 to 7 seconds; drainback had lowered a semicircular area about 30 m (100 ft) in diameter around the vent. By 08^h10^m, the bubbling at the vent had stopped. The eruption was over. Slow drainback into the orifice beneath the lake at the vent, however, apparently continued for several hours.

Vertical-angle transit sights from the rim of the crater on August 24 showed that the surface of the flow had been lowered about 3 m by drainback since the end of the eruption. Later, precise level measurements from the flow surface to the marker on the talus and more precise triangulation from the rim

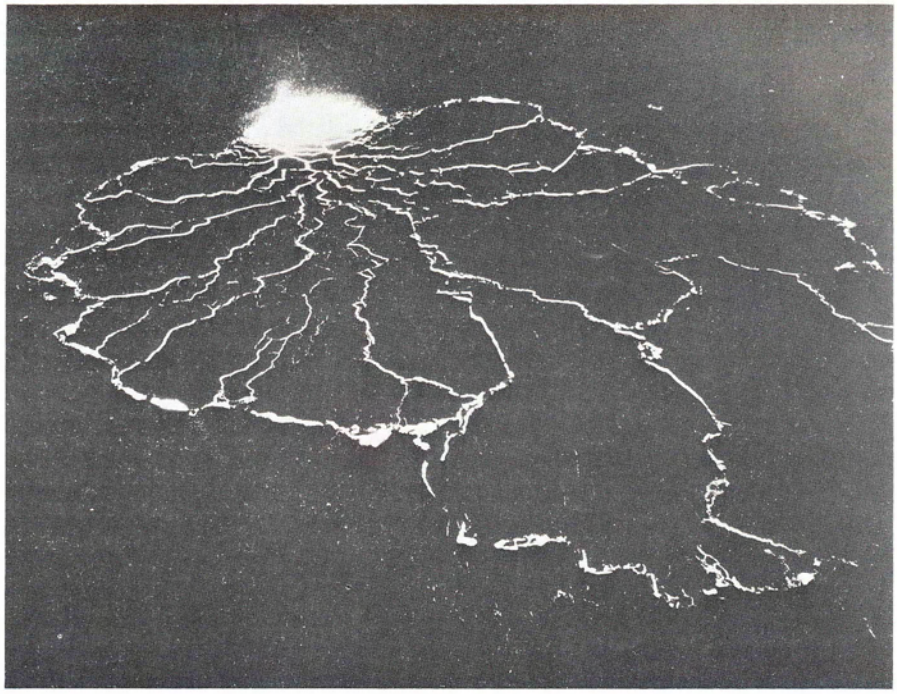

FIGURE 12.—Eruption in Alae Crater at about 21^h, August 22, as viewed from the overlook. Stagnation of the lava lake in the foreground has resulted in the nearly complete darkening of glowing cracks visible earlier there (fig. 11).

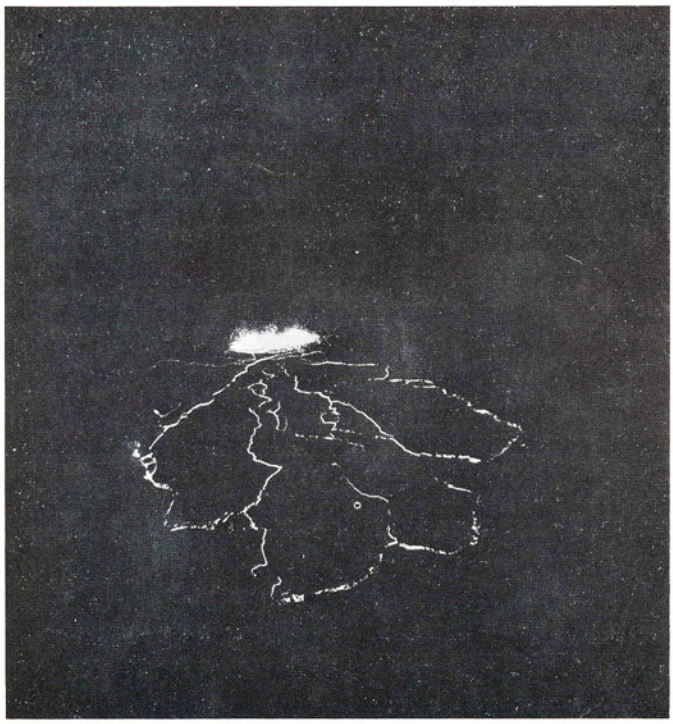

FIGURE 13.—Eruption in Alae Crater at 22^h45^m, August 22, as viewed from the overlook. Glowing cracks in the entire outer part of the lake have darkened because of continued stagnation of the lake.

FIGURE 14.—Eruption in Alae Crater at 23^h16^m, August 22, as viewed from the overlook. The actively circulating part of the lake has become restricted to an area less than 100 m long adjacent to the fountains.

showed that the average elevation of the surface had fallen 3.0 m below the marker—a loss of 180,000 m^3 of lava. The lake was left with a volume of 660,000 m^3. An additional 30,000 m^3 of flows, spatter, and pumice had accumulated in the jungle beyond the north rim of the crater and in the low spatter ridge that covered and bordered the northwest side of the lake and continued as coalescing spatter cones up the north wall of the crater (fig. 15).

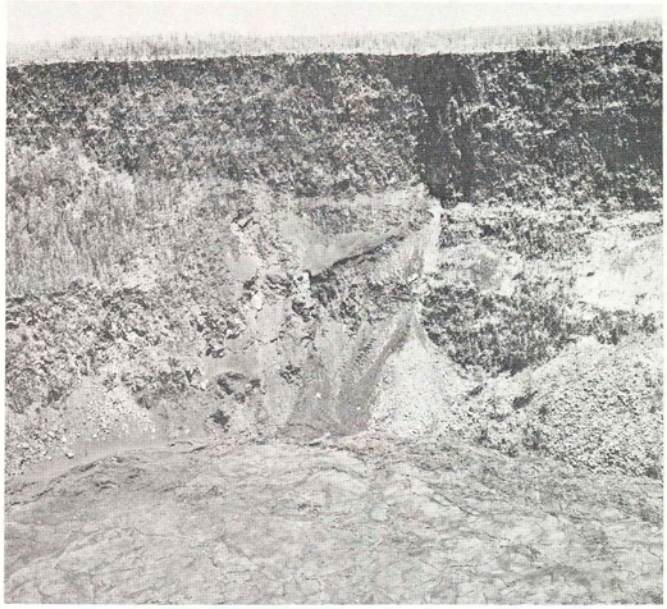

FIGURE 15.—Northwest part of Alae lava lake as viewed from overlook on August 31, 1963, showing low spatter ridge near former vent on floor of crater and coalescing spatter cones marking positions of former vents on north wall. Forested mezzanine atop a 50-m-high cliff can be seen to the left of the spatter cones on the north wall of the crater.