PREFACE

The Volcano Letter was an informal publication issued at irregular intervals by the Hawaiian Volcano Observatory (HVO) during the years 1925 to 1955. Individual issues contain information on volcanic activity, volcano research, and volcano monitoring in Hawaii. Information on volcanic activity at other locations is also occasionally included.

To increase accessibility of this resource, previously only available in print format, this compilation was scanned from the highest quality Volcano Letter originals in the HVO archives. Optical Character Recognition (OCR) was run on the entire file. In addition, the file size was reduced by making it compatible with only Adobe Reader v. 8 and later. The scanning was done by Jim Kauahikaua and the quality control and posting was done by Katie Mulliken, both current staff at the Hawaiian Volcano Observatory.

Originals of the first three Volcano Letters could not be found so copies plus the Title Page and Index for 1925 have been extracted from an excellent scan of Volcano Letters for 1925 to 1929 available in Books.Google.com

The Volcano Letter was published by HVO through multiple changes in administration, including the Hawaiian Volcano Research Association (1925-1932), the U.S. Geological Survey (1932-1935), the Department of the Interior (1935-1938), and the University of Hawaiʻi (1938-1955). Issues 1–262 were published weekly from January 1, 1925, to January 2, 1930, and consisted of a single page of text. Issues 263–384, also published weekly, from January 9, 1930–May 5, 1932, were generally longer—four-pages—and provided more detail on volcanic activity, including photographs, maps, and plots. Weekly issues 385–387, published May 12–26, 1932, were a single page of text due to budget reductions brought on by the Great Depression. Budget restrictions reduced the publishing frequency to monthly for issues 388–428, covering the period of June 1932 to October 1935; these issues were generally shorter, 1–2 pages, and sometimes featured figures. From November 1935 to July 1938, issues 429–461 remained monthly but increased in length (generally eight pages) and featured figures frequently. Issues 462–530, published over the period of August 1938–December 1955, varied in length from 2–15 pages, but were published quarterly, rather than monthly.

Six of the letters are misnumbered:
Jan. 21, 1926 number is 55 though it should 56
July 29, 1926 number is 82 though it should be 83
Feb. 16, 1928 number is 161 though it should be 164
May 31, 1928 number is 197 though it should be 179
Nov. 29, 1928 number is 204 though it should be 205

For background information on the Hawaiian Volcano Observatory: https://pubs.usgs.gov/gip/135/

The Volcano Letter publications are also available in print:

Fiske, R.S., Simkin, T., and Nielsen, E.A., eds.,1987, The Volcano Letter, No. 1-530. See https://www.si.edu/object/siris_sil_328087

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THE MAUNA LOA ERUPTION OF JANUARY, 1949

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U. S. Geological Survey

HISTORY OF THE ERUPTION

Mauna Loa resumed eruptive activity on January 6, 1949, after a period of quiescence of 6 years and 8 months. The eruption, which was confined to the summit caldera, Mokuaweoweo, and to the uppermost part of the southwest rift zone, is to be classed as a summit eruption. Following the flank eruption of 1942 on the northeast rift, it thus continues the alternation of summit and flank eruptions which has existed since 1926.

At 4:15 p.m. on January 6 a dull rumbling was heard at the Hawaiian Volcano Observatory, apparently originating at the summit of Mauna Loa, 20 miles away. From the Observatory, the summit was hidden by a heavy cloud layer along the southeastern slope of the mountain; but from Hilo to Mountain View, on the eastern slope, the view of the summit was unobstructed. At about 4:00 p.m. B. F. Moomaw of the National Park Service saw, from the highway a short distance southeast of Olaa, a puff of fume rising from the summit. At about 3:45 or 3:50 p.m. Mrs. Walter Eklund observed fume at the summit of the mountain, from the highway in southern Kau. The registration of continuous tremor on the Bosch-Omori seismograph at Kilauea began at 3:47 p.m., indicating the movement of magma in the conduit at that time.

The precise time of beginning of the eruption thus is uncertain. It seems probable that some harmonic tremor may have preceded arrival of the magma at the surface, and therefore the probable time of beginning of surface lava activity may be placed between 3:50 and 4:15 p.m. The arrival of lava at the surface may have been preceded by an increase in the amount of fume being liberated at the summit of the mountain.

The heavy rumbling sounds, audible 20 miles away, indicate that some of the early bursts of gas liberation were of explosive violence. There is no known previous instance of such sounds, originating in summit activity of Mauna Loa, being audible at Kilauea. The audibility may have been partly the result of reflection from a high cloud layer which extended above the summit of Mauna Loa at the time. The strength of the early bursts is further indicated by the finding of pumice at 11,000 feet altitude on the northeastern flank of the mountain, 7 miles from the nearest lava fountains, and of Pele's hair at Kulani Camp, 20 miles east of the fountains.

The lava broke out along a fissure which extended south-southwesterly across the floor of Mokuaweoweo caldera from a point north of its center, up over the boundary cliff of the caldera, and about 1.7 miles down the southwestern flank of the mountain. The distribution of glow, as seen from the Volcano Observatory, indicated that lava fountaining was nearly, if not completely, continuous along this crack, a distance of about 3 miles. On the morning of January 7, D. H. Hubbard of the National Park Service observed the activity from the air and reported that two fountain areas were still active on the southwest rift. However, by the morning of January 9 aviators reported only fume along the fissures outside the caldera, except for very weak intermittent fountaining and short flows at one point. As is usual with summit eruptions of Mauna Loa, activity outside the caldera lasted only a relatively few hours. Within 24 hours it was largely over, and within 72 hours activity was entirely confined within the caldera.

The short-lived fountains, on the upper part of the southwest rift outside the crater, gave vent to a copious outpouring of lava during the first few hours of the eruption. This lava formed several short flows in addition to one long flow which moved rapidly westward just north of, and partly overlying, the lava flow of 1851. (See figure 1.) In its first 24 hours, this flow advanced about 6 miles. It was short-lived, however; with the dying of fountain activity outside the caldera the supply of lava was cut off, and by January 8 the flow appeared to be essentially dead. The lower end of the flow reached an altitude of about 8,500 feet, 6.5 miles from its source.

On the afternoon of January 7, lava fountain activity within the caldera itself had become restricted to two short lengths of the fissure. North of the 1940 cinder cone, near the middle of Mokuaweoweo, a nearly continuous line of fountains half a mile long played to an average height of about 50 feet with occasional bursts up to about 150 feet. As nearly as could be ascertained, these fountains were situated on or close to a zone of fuming fissures which had been observed by Macdonald and Powers in October 1948 (VOLCANO LETTER 502). From these fountains a small lava stream moved westward, forming a pond of lava between them and the western caldera wall; another larger flow was moving eastward.

The other active portion of the fissure was situated at and close to the base of the southwestern wall of the caldera. There a small fountain played intermittently from the fissure directly at the base of the wall, with occasional spurts from the fissure part way up the wall; a much larger and steadier fountain played a short distance out from the wall on the caldera floor. The larger fountain shot constantly to heights of 150 to 200 feet, with occasional bursts as high as 300 feet. The fountains at the southwestern edge of the caldera sent a flow northward into the caldera west of the 1940 cone joining the flow from the more northerly group of fountains, and another flow eastward. The flow to the east divided, sending one branch in the direction of South Pit and another northeastward along the base of the caldera wall. The latter branch joined the flow from the northern fountain-chain, leaving the 1940 cinder cone and part of its surrounding lava shield protruding as an island in the

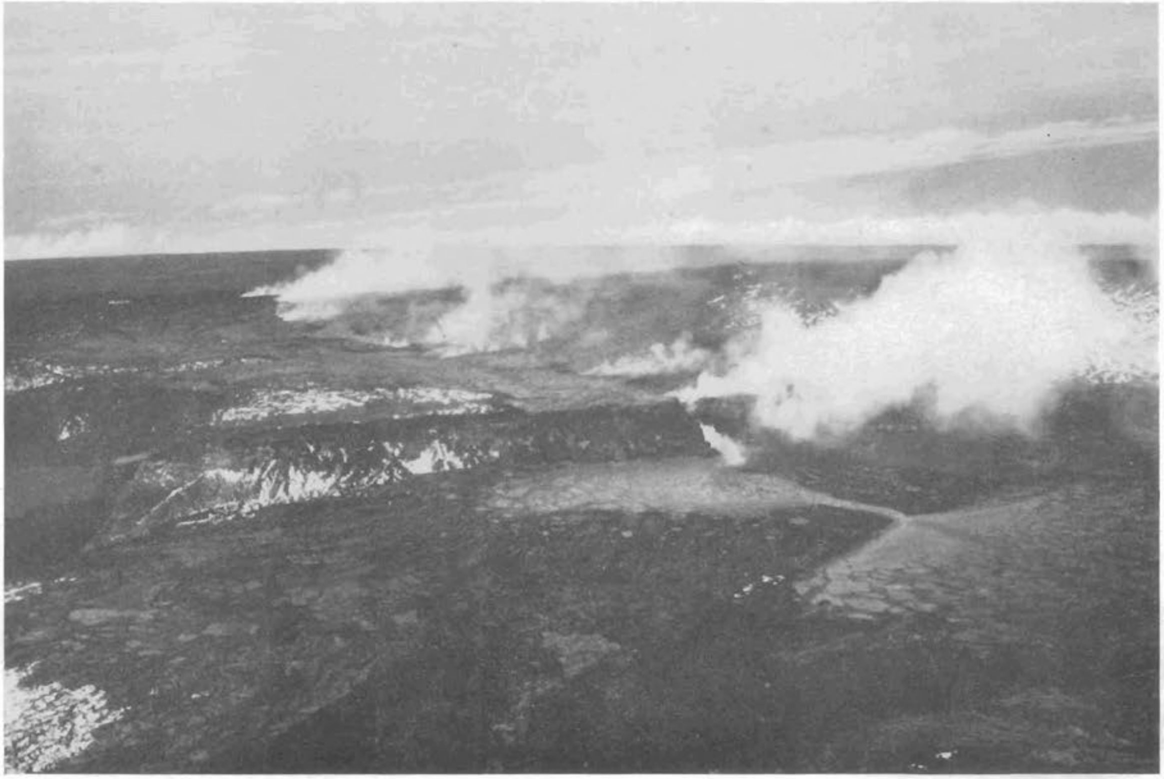

PLATE 1. Eruptive fissure extending up over the southwestern wall of Mokuaweoweo caldera and on down the southwest rift zone of Mauna Loa, on the morning of January 7, 1949. Large lava fountains are playing from the fissure at the base of the caldera wall, and smaller ones can be seen in the background along the southwest rift. In the foreground, new lava is pouring onto the caldera floor, and to the left into South Pit. OFFICIAL PHOTOGRAPH, U. S. NAVY.

PLATE 2. Spatter rampart and small lava fountains along the fuming fissure on the upper part of the southwest rift zone on the morning of January 7, 1949. The upper part of the western lava flow is visible just left of the fissure. Mokuaweoweo caldera and the summit of Mauna Loa are in the background. OFFICIAL PHOTOGRAPH, U. S. NAVY.

new lava. The eruptive fissure split the 1940 cone and the cone was fuming strongly. During the earliest hours of the eruption a small amount of lava spilled from the fissure at the base of the cone, but by the morning of January 7 these flows were dead and had been partly buried by lava from the northern and southwestern fountains. By the afternoon of January 7 more than two-thirds of the caldera floor had been flooded with new lava, largely pahoehoe.

The fountain-chain near the center of Mokuaweoweo was as short-lived as the fountaining outside the caldera. At 2:00 p.m. on January 9 a Navy pilot reported that the fountains in the middle of the caldera had entirely stopped although the spatter rampart built by them was still fuming strongly. At that time, and for the next several days, reports from planes flying over the mountain indicated that the fountains at the base of the southwest wall were continuous but were varying greatly in the strength of their activity. Lava from them continued to pour both into the caldera and into South Pit. Fountain activity was building a cinder cone against the caldera wall.

For a week or more the southwestern fountains appear to have remained of small, although variable, size. After that, however, they greatly increased in height, ultimately becoming what may have been the highest fountains yet observed on Mauna Loa. On January 19, a United Airlines pilot reported two large fountains, 400 to 500 feet high. On January 21, Frank Hjort and James Orr of the National Park Service reported two fountains, one shooting from the fissure in the lower part of the caldera wall, and the other on the caldera floor about 100 feet from the wall. The fountains were building a compound cinder and pumice cone. The wall-fountain was the smaller of the two. The larger fountain they estimated to be 300 to 500 feet high. On January 23, Orr and D. H. Hubbard estimated the height of the large fountain to be well over 500 feet with some of the higher bursts possibly reaching more than 800 feet. These very high fountains, together with strong shifting winds, resulted in wide distribution of Pele's hair over the southern part of the island, from Napoopoo on the western coast, 21 miles from the summit of Mauna Loa, to the Kau Desert and Kilauea caldera, an equal distance southeast of the summit. The high fountains produced an exceptionally large amount of pumice. The accumulation of this pyroclastic pumice around the vent built up a pumice cone which was banked against the caldera wall and eventually overtopped it, projecting approximately 100 feet above the old rim of the caldera at that point, and resting partly on the outer slope of the mountain. (See figure 2.) West of the cone a blanket of pumice covers an area about a mile long and half a mile wide and attains a depth of as much as 20 feet near the base of the cone.

Hjort and Orr report that on the night of January 21 the two fountains were inclined somewhat toward the east and that most of the ejecta fell into a pool of lava at the eastern, breached side of the cone. Thence the lava moved eastward in a pahoehoe river about 75 feet wide, spreading into aa flows about half a mile from the vent. During the afternoon and evening there was no evidence of lava moving into South Pit. At 3:00 a.m. on January 22 there occurred a moderate earthquake, which apparently broke the rim of the pool at the east base of the cone and allowed two new flows of aa to pour into South Pit. At that time most of the early floods of pahoehoe on the caldera floor had been buried by later flows of aa. The South Lunate Platform, which in 1914 formed a conspicuous crescentic bench at the southern end of the caldera, had been almost wholly buried by new flows. Its north-facing escarpment, now totally obliterated, had been progressively lessened in height by infilling of the inner pit of the caldera in 1933 and 1940.

On January 23, Orr reports, the fountains were pulsating, the wall-fountain with a period of about 3 seconds and the larger fountain with a period of about 1 second. The temperature of the wall-fountain appeared to be a little higher than that of the larger fountain.

The lava fountaining was accompanied by the liberation of huge volumes of fume, smelling strongly of sulfur dioxide. On January 26 the pale brown fume cloud could be seen extending at least 30 miles southwest of the summit of the mountain. On February 1 and 2 sulfurous fume was noticed by residents from North Kona to Waimea, 40 miles north of the summit of the mountain.

The lava pouring into South Pit gradually filled it to the point of overflow. On January 25 Ercell Hart of the Hawaiian School of Aeronautics reported that the lava fill had reached the level of the low southeastern rim of the pit; late on the same day the pit overflowed. The lava stream moved southeasterly, and by the evening of the 26th it had attained a length of about 2 miles from South Pit, or 3 miles from its source at the fountains. On the morning of January 27 the flow was moving in three branches, and by the evening of that day the longest of these had reached a point about 3.2 miles from South Pit. Thereafter the speed of advance of the flow greatly decreased, and on the evening of January 28 transit angles from the Volcano Observatory indicated that it had advanced only about 0.2 mile in the preceding 24 hours. By the evening of January 31 the flow-front had reached a distance of about 4 miles from South Pit, but after that day it advanced very little.

On January 29 or 30 a new branch of the flow broke out near South Pit, and this new branch appears to have robbed the older one of its supply of lava. The new stream advanced downslope just east of the older one and partly overlapping it. It moved more slowly than the earlier flow and eventually attained a length of only 2 miles from South Pit. On the morning of February 7 it was still advancing very slowly. Its advance probably ended on February 8, two days after the cessation of lava fountaining at the vent. On February 7 a small amount of movement was still visible in the older flow also. This continuation of movement of the flows after the end of lava extrusion at the vent probably resulted from draining of the still-fluid lava from the feeding tubes in the flows on the upper slopes of the mountain.

During the night of February 4 the fountain activity at the southwestern edge of the caldera was still moderately strong, producing a pronounced glow on the rising fume column. By mid-morning on February 5, however, fountain activity had become very weak and irregular, only occasional small bursts of liquid lava spray being visible in the cone. Lava was moving underground through a tube almost to the wall of South Pit. There it issued in a small amphitheatral depression in slightly older 1949 aa, flowed as a pahoehoe stream to the edge of South Pit, cascaded down the wall, and spread slowly over the floor of the pit as a sluggish aa flow. The speed of movement of the liquid lava in the cascade was estimated to be generally about 10 miles an hour, reaching about 15 to 20 miles an hour in a short steep portion of the descent. On the floor of South Pit the aa flow was spreading at a rate of only a few feet an hour. About 2:00 p.m. a sudden increase in lava liberation greatly augmented the volume of the cascade and caused a brief rapid spreading of aa tongues in South Pit. Within half an hour the voluminous burst of lava was over, and by 5:00 p.m. there was no further evidence of movement of lava down the cascade into South Pit. The flows on the caldera floor also appeared to be lifeless except for many small secondary fumaroles. On the morning of February 6 the cinder cone at the southwestern edge of the caldera was visited; no further signs of activity could be detected, other than slight glow in the fountain pits and voluminous liberation of SO_2-rich fume. Even on its outer slopes, the cone was still red-hot only a few inches beneath the surface. The lava-pool and flow-channel east of the cone had been completely drained, and collapse had exposed the end of the empty lava-tube leading toward South Pit. Thus this phase of the eruption came to an end on the afternoon of February 5, having lasted just 30 days.

From February 6 to the date of writing (March 22) fume frequently has been visible at the mountain top. On several nights observers at scattered points on the southern part of the island have also reported a distinct glow at the summit. This glow may have resulted from brief weak resumptions of lava fountaining or quiet outwelling of lava, or possibly from slumping of portions of the hot cinder cone or of the cascade into South Pit, exposing glowing material. However, at no time when observers were actually present at the summit or flying over it in planes could any glow or lava movement be seen.

THE CONE

During the early hours of the eruption the "curtain of fire" which issued along the upper part of the southwest rift zone outside of the caldera built a long row of spatter ramparts and small spatter cones. These ranged up to about 20 feet in height, but were mostly less than 5 feet. A similar spatter rampart was built by the fountain-chain in the central part of the caldera.

The true cone building was restricted to the big, long-lived fountains at the southwestern edge of the caldera. The cone built there is one of the largest on Mauna Loa, rivaling in size that of the 1940 eruption. The big cone is built on a broad lava shield which overlies the former South Lunate Platform. The cone itself is compound. An outer cone, breached on the eastern side, consists largely of fine cinder and pumice and rests partly on the outer slope of the mountain and partly on the caldera floor and against the boundary cliff. (See figure 2.) The top of the outer cone is about 100 feet above the former rim

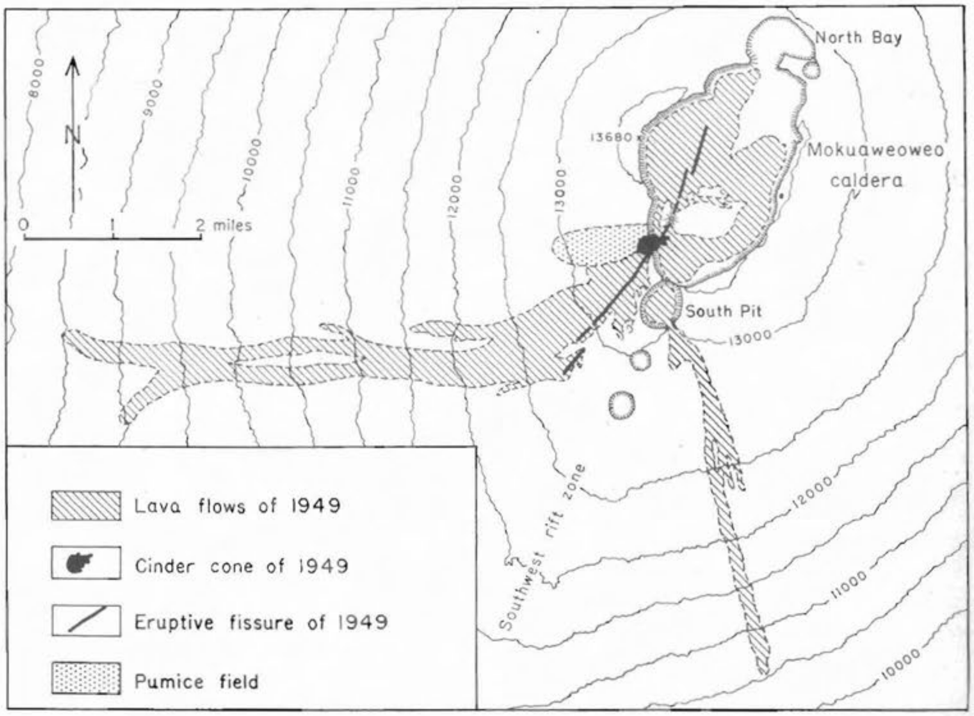

FIGURE 1. Map showing the approximate location of the 1949 lava flows and vents on Mauna Loa.

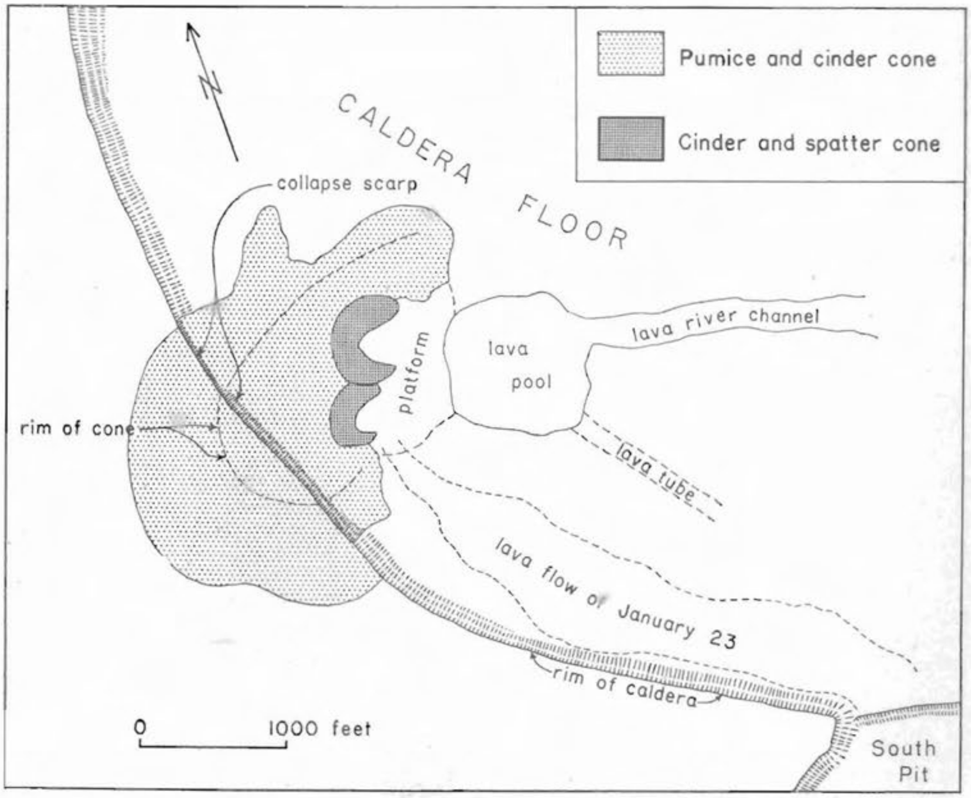

FIGURE 2. Sketch map of the cone area of the 1949 eruption.

of the caldera wall and 250 feet above the lava shield at its base. Its maximum diameter is about 1,500 feet. At the eastern edge of the large cone, and partly enclosed within it, is a small double cone of coarse cinder and spatter, built around the final sites of the two lava fountains. Each crater of the small cone also is breached on the eastern side. The inner cone probably was built during the stage of reduced gas pressure and lower fountains which directly preceded the end of the eruption. This decrease in gas content of the lava in the declining stage also resulted in the deposition of a few rather dense black "pancake" and ribbon bombs on the surface of the pale brown pumice on the southern slope of the outer cone.

The thick accumulation of ejecta against the boundary cliff of the caldera appears to have caused the northeastward migration of the smaller of the two cone-building lava fountains. On January 23, when the cone was visited by Orr and Hubbard, the fountain was situated directly against the caldera wall. By the end of the eruption, however, it had moved outward to the southernmost of the two small cinder and spatter cones, about 150 feet northeast of the base of the wall.

Lava escaping from the cone formed a pool on the lava shield just east of the cone, then drained eastward through an open lava river channel, and southeastward through tubes toward South Pit. At the end of the eruption the lava pool was drained and its walls collapsed, exposing the mouth of a large lava tube, about 35 feet high, leading toward South Pit. (See figure 2.) The large cinder and pumice cone also partly collapsed, producing a northeast-facing scarp 10 to 15 feet high across the top of the cone. The position of the scarp was governed by the underlying caldera wall. Slumping also produced minor scarps on the outer slope of the cone.

THE LAVAS

The early lava flows in Mokuaweoweo caldera were almost entirely pahoehoe, but as the eruption progressed these were largely covered by later flows of aa. The depth of the fill in Mokuaweoweo is difficult to estimate, but probably averages about 20 feet.

The lavas erupted along the upper part of the southwest rift are pahoehoe near the vents, but as the flows moved downslope they gradually changed to aa. The average thickness of the aa in the lower part of the flow is probably about 10 to 12 feet. Near the vents the pahoehoe flows are very thin, averaging from 2 to 3 feet thick. The flows near the vents were very rich in gas and produced typical shelly pahoehoe with many open tubes and blisters covered by a crust only a few inches thick. The surface of much of this pahoehoe is a thin shell of brown pumice, similar to that formed on many pahoehoe flows in the summit region of Mauna Loa. (See VOLCANO LETTER 502.) Downslope the pahoehoe becomes denser and less shelly.

The lava spilling into South Pit was partly pahoehoe and partly aa. In cascading over the cliff which separated South Pit from Mokuaweoweo some of the pahoehoe changed into aa, probably because of the intense stirring of the liquid and loss of gas. Many exotic blocks which tumbled down from the older lava flows exposed in the walls of the pit are recognizable in the aa. The depth of the fill in South Pit is about 50 feet. At the low gap in the rim of the pit, at its southeastern side, pahoehoe issued from beneath the aa. An arcuate ridge of aa, 10 to 15 feet high, marks the underlying buried wall of the pit. This ridge appears to have been pushed up by the pahoehoe which issued from beneath it.

Just southeast of South Pit the lava is pahoehoe, much denser and more massive than that of the earlier flow from the upper end of the southwest rift. The surface of the flow near South Pit is largely a very rough "shark-skin" type; over the major tubes it shows an accumulation of sublimated sulfur and some white sulfo-salts. On the surface of the pahoehoe near the zone where it issued from beneath the aa there was formed a series of minute, tensional fault scarps, up to 8 inches high, facing down-flow. On the faces of some of these scarps there is found a moderately good development of dendritic lava. Downslope the pahoehoe gives place to aa, and most of the southern flow is aa, averaging 10 to 15 feet thick.

The approximate area and volume of the 1949 lava and of each of its principal divisions are shown in table 1. The figures are not of great accuracy, and indicate only an order of magnitude. The total volume of the lava, 71 million cubic yards, is somewhat less than the volume of the lava of the 1940 and 1942 eruptions, each of which approximated 100 million cubic yards.

TABLE 1. AREA AND VOLUME OF 1949 LAVA

DIVISION OF THE FLOW	AREA (SQ. MILES)	VOLUME (CU. YARDS)
Mokuaweoweo	1.9	40,000,000
South Pit	0.2	8,000,000
Western flow	3.1	16,000,000
Southern flow	0.6	7,000,000
Total	5.8	71,000,000

Temperature measurements with an optical pyrometer were made on the glowing interior portion of a thick aa flow in South Pit on the afternoon of February 5. The glowing portion of the flow was well exposed in a large crack. Three observations were made, all yielding readings close to 760° C. This temperature is believed accurate within 50°. The flow was essentially motionless, but was still creeping a little.

Geiger counter observations were made by D. C. Cox on the hot lava in and close to South Pit on the afternoon of February 5. The number of clicks in the earphones ranged from 38 to 45 per minute. This is of the same order of magnitude as results obtained on the nearby lavas of prehistoric age and only slightly higher than those obtained by Mrs. B. J. Loucks on lavas of Kilauea volcano ranging in date from 1921 to prehistoric. The results are of the order of magnitude to be expected from cosmic radiation, and may have been caused by that alone. Dental X-ray films were mounted on a rock monument at the summit rest-house, 1.5 miles from the lava fountains, and exposed to

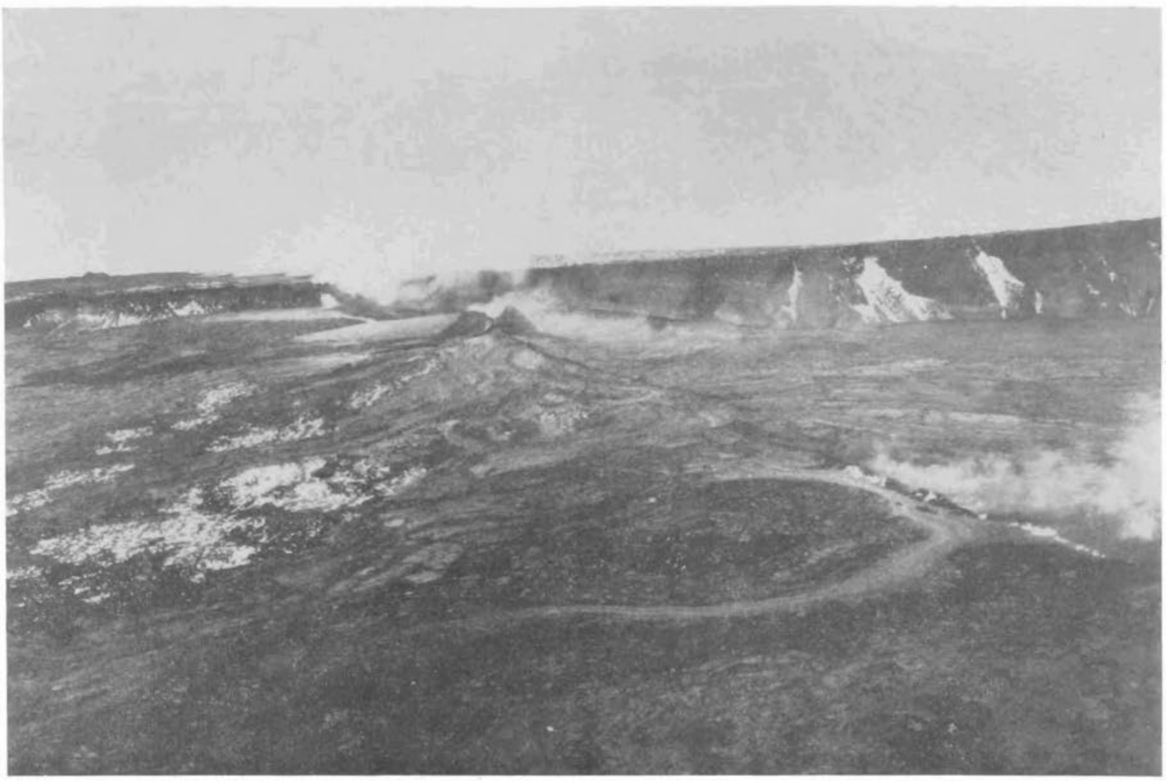

PLATE 3. Mokuaweoweo caldera, looking southwestward on the morning of January 7, 1949. In the right foreground is the northern fountain-chain and the lava flow leading eastward from it. In the middle distance the fissure can be seen cutting through the 1940 cinder cone, which is fuming strongly. OFFICIAL PHOTOGRAPH, U. S. NAVY.

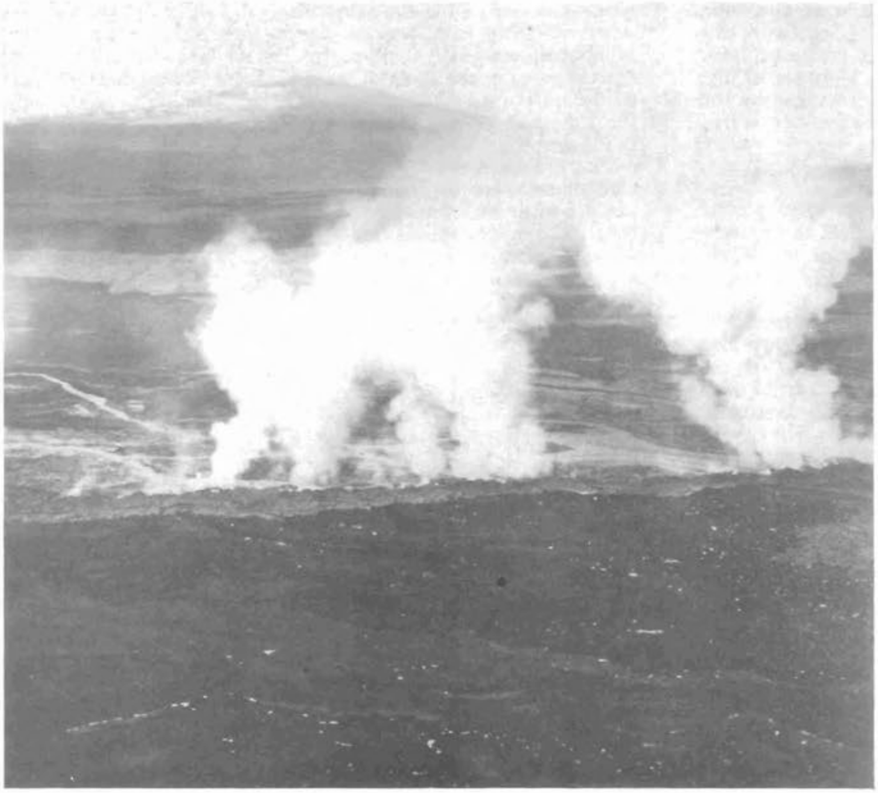

PLATE 4. Lava fountains and upper end of the western flow along the upper part of the southwest rift zone on the morning of January 7, 1949. The spatter rampart and the main lava rivers of the flow are clearly visible. Hualalai volcano is in the background. OFFICIAL PHOTOGRAPH, U. S. NAVY.

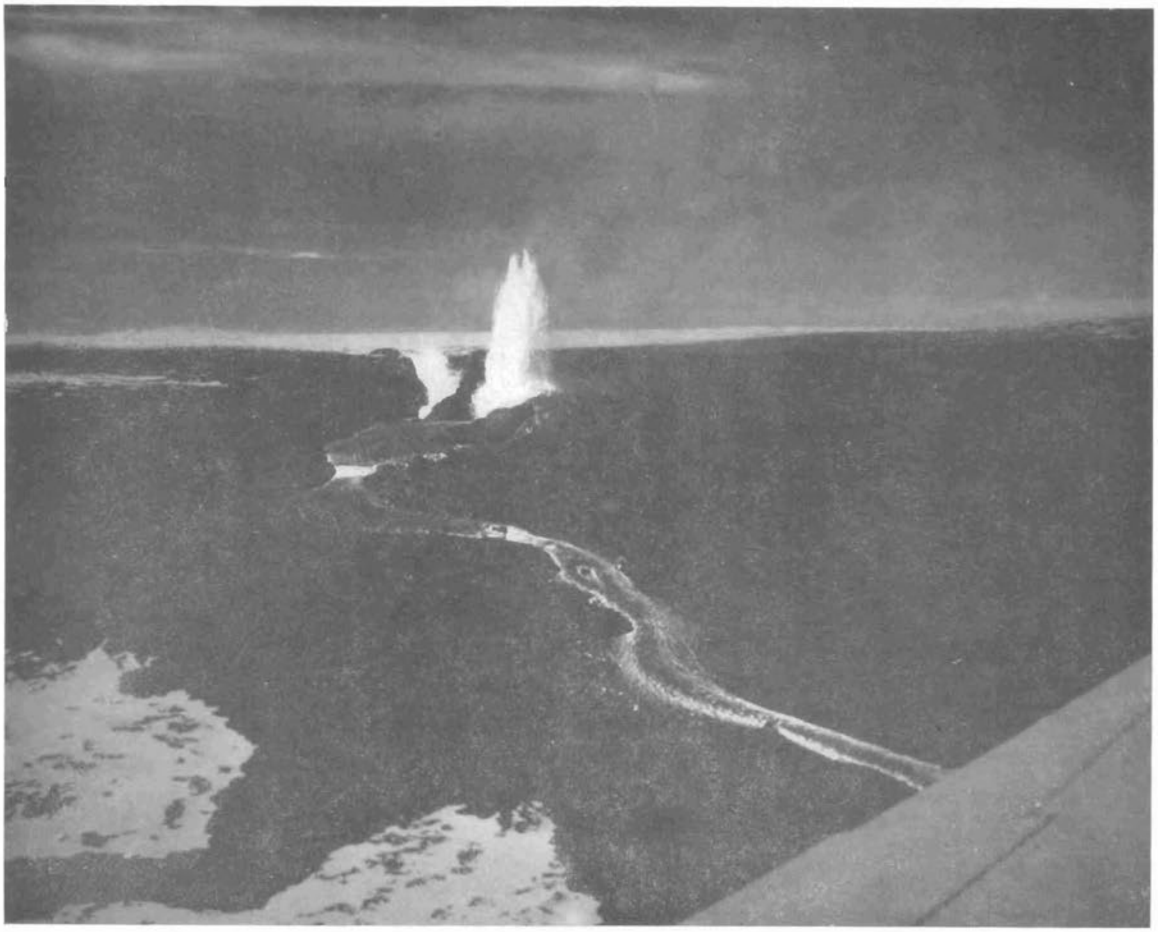

PLATE 5. Lava fountains and flow at the southwestern edge of Mokuaweoweo caldera on the evening of January 19, 1949. The smaller fountain on the left is the wall fountain. The larger fountain is about 500 feet high. PHOTOGRAPH BY K. OTAKI, ACE PORTRAIT STUDIO.

radiation from the fountains for a period of 12 days, from January 24 to February 5. These films showed practically no fogging. Samples of the early lava from Mokuaweoweo and pumice from the fountains were tested for radioactivity by Dr. Harvey White of the University of California, but no radioactivity was found.

PETROGRAPHY

The 1949 lava is a basalt containing approximately 3 per cent olivine. The rock of the more massive central portions of the southern flow, both aa and pahoehoe, is essentially crystalline, containing only a small amount of glass. It consists largely of labradorite and pigeonite (optic angle very small), with less abundant iron ore, olivine, and dark brown, interstitial glass. A roughly stellate arrangement of the feldspar microlites is present in some thin sections. A few of the olivine grains have the dimensions of phenocrysts, with lengths up to 2 mm., but the texture is seriate rather than truly porphyritic.

The rock of the upper portions of the western flow contains a larger proportion of glass, but is otherwise similar to that of the southern flow. The glass of the pumice from the fountains has a refractive index of 1.597 (± .003).

EARTHQUAKES AND GROUND TILT ASSOCIATED WITH THE ERUPTION

No distinct earthquake pattern preceded the 1949 outbreak of Mauna Loa. However, the number of earthquakes recorded in December on the Mauna Loa seismograph, at an altitude of 6,600 feet about 13 miles from the northern end of Mokuaweoweo, greatly exceeded those recorded in any of the preceding 5 months. (See table 2.)

TABLE 2. EARTHQUAKES RECORDED ON MAUNA LOA SEISMOGRAPH DURING 1948

MONTH	NUMBER OF EARTHQUAKES
December	72
November	38
October	47
September	26
August	23
July	37

Most of the quakes during December were tremors with shallow foci. Although a few of them originated under Mokuaweoweo, most of those whose origins were determined originated under the east slope of Mauna Loa or on the northeast rift. The strongest earthquake immediately preceding the eruption occurred on December 13. Its origin was at a shallow focus under the northeast rift about 2 miles from Mokuaweoweo.

Of the approximately 60 earthquakes recorded on the Mauna Loa seismograph in January 1949, 16 occurred on January 6, the day the eruption started. The number of shakes accompanying the outbreak of this summit eruption was less than during flank eruptions. This is to be expected because of the shorter distance of fissuring. During flank eruptions fissuring extends across the summit and also occurs far down the flank, whereas in summit eruptions it is restricted to the summit region. One of the strongest shakes during the eruption occurred at 3:59 p.m. on January 6 at about the time of commencement of surface activity. Its origin appears to have been at a depth of about 5 miles, approximately 2 miles northeast of Mokuaweoweo. If, as seems probable, this quake occurred at the time the fissure across Mokuaweoweo and a little way down the southwest rift was opened, the initial movement must have been at the northeastern end of the fissure.

Continuous harmonic tremor commenced on the Bosch-Omori seismograph at the northern rim of Kilauea caldera, 21 miles from the scene of eruption, at 3:47 p.m. on January 6 and ceased to be apparent at 3:00 a.m. on January 7.

During the year 1948 there was an accumulation of easterly ground-tilt at the northern rim of Kilauea caldera. The eastward tilting was especially strong during the first half of November. Records of several eruptions of Mauna Loa seem to indicate that easterly tilt is an evidence of increase of pressure under that mountain. Despite the easterly tilt and the fact that the average interval between Mauna Loa eruptions (about 4 years) had already been exceeded by more than 2 years, the earthquake pattern did not seem positive enough to justify a prediction of impending activity.

ACKNOWLEDGMENTS

We wish to express our thanks to all those many persons who have contributed information or otherwise aided in the study of the eruption. Deserving of special mention are: Superintendent Frank R. Oberhansley and Chief Ranger Frank A. Hjort of Hawaii National Park, who greatly aided us by the loan of riding horses and packing equipment up the mountain; Ranger James B. Orr, who kindly permitted the use of his field notes on the eruption; Naturalist Douglass H. Hubbard and Ranger V. R. Bender, who contributed ground and air observations; Pilot Ercell Hart, of the Hawaiian School of Aeronautics, who made repeated reports on the progress of the eruption; Harry M. Blickhahn, editor of the Hilo Tribune-Herald, who promptly passed on to the Volcano Observatory the information which came to him; Doak C. Cox, geologist for the Hawaiian Sugar Planters' Association Experiment Station, who operated the Geiger counter at the summit of the mountain; and Dr. Harvey E. White of the University of California Physics Department, who made radioactive determinations on several lava specimens.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY–MARCH, 1949

VOLCANOLOGY

January

An eruption of Mauna Loa started on January 6 and continued through the rest of the month. History and a lack of a definite earthquake pattern had led members of the Observatory staff to believe that the next eruption would be at the summit. There was but little positive data upon which to forecast an impending eruption, however. A strong easterly tilt of seven seconds of arc near the northern end of Kilauea Caldera in November 1948 was but little greater than similar tilts in 1946 and 1947. Such a tilt could be taken only as a suggestion and not as a good indication of a pressure increase under Mauna Loa that might lead to surface activity. The November tilt and the distinct blue fumes observed in Mokuaweoweo during October 1948 do give some indications that lava was rising in Mauna Loa 3 months prior to its appearance at the surface.

Sixty-seven earthquakes were recorded during the month. Fifty-eight shakes were recorded at Kilauea and 51 at Mauna Loa. The Mauna Loa total is incomplete because the seismograph was dismantled by earthquakes on two occasions. The records of at least eight shakes were lost.

Strong southerly tilt continued throughout the month. Easterly tilt continued until January 16 and then westerly tilt a little stronger than normal set in.

February

The Mouna Loa eruption, except for fuming, came to an end on February 5.

Sixty-four earthquakes were recorded during the month. Of these 47 were recorded at Kilauea and 52 at Mauna Loa.

Strong southerly tilt was continuous in February except for distinct northerly tilt accompanying the strong earthquake on February 26. Normal easterly tilt continued throughout the month.

March

Fuming from Mokuaweoweo was continuous throughout the month.

Thirty-one earthquakes were recorded in March. Thirty of the shakes were recorded on the Mauna Loa seismograph and 16 at Kilauea.

Northerly tilt set in March 6 and continued through the end of the month. Westerly tilt was about normal for March.

CRACK MEASUREMENTS

A few of the cracks near the east rim of Halemaumau opened slightly. The other cracks that were measured showed no appreciable movement.

SEISMOLOGY

Earthquake Data, January–March 1949

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
January	2	6	3	0	0	0	0	2.50	0
	9	17	2	0	1	0	0	7.25	0
	16	5	0	0	2	0	0	5.25	0
	23	5	1	1	0	0	0	2.75	0
	30	13	3	1	0	3	0	14.75	0
February	6	5	1	0	0	0	0	1.75	0
	13	1	1	0	0	0	0	0.75	0
	20	6	8	2	0	0	0	5.50	1
	27	12	3	2	0	0	1	10.50	0
March	6	0	3	2	1	0	0	5.50	0
	13	4	1	0	0	0	0	1.50	0
	20	1	0	0	0	0	0	0.25	0
	27	3	1	0	0	0	0	1.25	1

* For definition of local seismicity, see Volcano Letter 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

1. January 4, 20:20, very feeble.
2. January 6, 15:59, moderate. Near Mokuaweoweo.
3. January 7, 03:10, very feeble.
4. January 8, 00:49, moderate. 10–15 miles deep under Alae Crater area.
5. January 15, 00:40, moderate. 20–25 miles deep above Wood Valley.
6. January 15, 11:16, slight. Under ocean west of Kohala.
7. January 16, 14:30, slight. 9 miles deep. Kau Desert near Kilauea.
8. January 20, 14:27, very feeble. Deep. 10 miles southwest of Waimea.
9. January 20, 18:09, feeble. Northeast rift Mauna Loa.
10. January 26, 13:06, feeble. Deep. 10 miles southwest of Waimea.
11. January 26, 11:45, very feeble. Deep under east slope of Mauna Loa.
12. January 26, 23:57, moderate. 5 miles deep near Ohaikea.
13. January 27, 00:04, slight. 6 miles deep, east slope of Mauna Loa.
14. January 27, 00:16, very feeble.
15. January 28, 15:50, moderate, E-W dismantled. 5 miles deep, east slope of Mauna Loa.
16. January 28, 19:45, moderate, E-W dismantled. 8 miles deep, east slope of Mauna Loa.
17. January 29, 03:29, very feeble. East slope, Mauna Loa.
18. February 4, 22:16, very feeble.
19. February 7, 18:08, very feeble. Mauna Loa.
20. February 17, 07:33, very feeble.
21. February 19, 01:13, feeble.
22. February 19, 04:34, very feeble.
23. February 19, 12:04, very feeble.
24. February 19, 14:47, very feeble.
25. February 19, 17:06, very feeble. Kilauea.
26. February 20, 08:45, very feeble. Mauna Loa.
27. February 20, 09:32, very feeble. Mauna Loa.
28. February 20, 09:46, very feeble.
29. February 20, 21:16, feeble. Kilauea.
30. February 21, 16:22, very feeble.
31. February 22, 04:48, feeble. Kilauea.
32. February 23, 23:55, very feeble.
33. February 24, 01:02, very feeble.
34. February 26, 13:20, very feeble. Felt at Kapapala.
35. February 26, 13:54, strong. Instruments dismantled. Strongly felt from Hilo to Naalehu. Shallow focus, northeast rift Mauna Loa at 7,000 feet.
36. February 27, 05:13, very feeble.
37. February 27, 10:28, slight. South slope, Kilauea.
38. February 27, 13:45, feeble. Felt at Pahala.
39. February 27, 17:18, feeble. East slope, Mauna Loa.
40. February 28, 16:58, very feeble. Northeast rift Mauna Loa.
41. March 2, 14:20, very feeble.
42. March 11, 09:31, very feeble.
43. March 23, 11:35, very feeble. Kilauea.
44. March 29, 10:58, very feeble.

TELESEISMS

February 14, 08:30, slight.
March 24, 11:11, moderate. Off north California coast.

MICROSEISMS

Microseisms were strong from January 5–7 and from February 28 to March 1. On other days they were weak to moderate.

TILTING OF THE GROUND

There was a rapid easterly tilt from January 1 to 10 when seasonal westerly tilt set in and continued until March 24. There was a slight easterly swing from March 25 to 28, then a recovery to the west. With the exception of a sharp northerly tilt accompanying the strong earthquake of February 26, southerly tilt was continuous from January 1 to March 6. From March 7 to 31 there was a slight accumulation of northerly tilt.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
January	2	1.3″	S 25° W
	9	3.1″	S 36° E
	16	2.9″	S
	23	2.4″	S 49° W
	30	4.1″	S 68° W
February	6	1.8″	S 19° E
	13	1.2″	S 62° W
	20	0.9″	S 23° E
	27	2.4″	N
March	6	1.6″	S 39° W
	13	0.6″	N 45° W
	20	1.0″	N 45° W
	27	1.4″	N 59° E

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter,** a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

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UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

ACTIVITY OF MAUNA LOA DURING APRIL, MAY, AND JUNE, 1949

By GORDON A. MACDONALD and RUY H. FINCH

The 1949 eruption of Mauna Loa commenced on January 6, and the major activity continued until February 5. This activity consisted of outpouring of lava flows on the caldera floor and down the western and southern flanks of the volcano from vents near the summit, and building of a large cinder and pumice cone at the southwestern margin of the caldera. The activity and cone have been described in VOLCANO LETTER 503.

Following the end of lava fountaining on February 5, fume rising from Mokuaweoweo was visible almost constantly during the remainder of February and March. It was obvious that the magma column must be standing at a very high level in the conduit. On several different nights a distinct glow was reported at the summit of the mountain. Thus, at 2 a.m. on February 19, Charles Hoeppel of the U. S. Coast and Geodetic Survey observed a strong reddish reflection on the fume column. However, at no time when observers were able to see into the caldera was there any sign of lava fountaining or flow. At the time, there was some doubt whether the observed glow was the result of weak resumptions of lava extrusion, or of slumping of surficial parts of the cinder cone or lava cascades, revealing hot glowing material beneath. In view of later developments, there is now little question that the glow resulted from brief quiet outwellings of lava.

The following table lists the dates on which fume or glow was reported and the place from which the observation was made. During many days the summit of the mountain was cloud-covered and invisible to persons at low altitudes. On some days when it was visible, winds at the summit may have been strong enough to dissipate small amounts of fume and make it undetectable from a distance.

OBSERVATIONS ON ACTIVITY OF MAUNA LOA FROM FEBRUARY 7 TO APRIL 7, 1949.

DATE	LOCATION OF OBSERVER	TYPE OF ACTIVITY
Feb. 15	Summit	Weak fume but no glow
17	Kilauea	Weak fume
18	Pahala and Naalehu	Weak glow and fume
19	Near Pahala	Two conspicuous puffs of fume in early morning
19	Planes over summit	Fume but no glow
21	Kilauea	Thin fume during morning
21	Kulani Camp	Glow in evening
22–27	Kilauea	No fume visible
28	Kilauea	Light fume
Mar. 1	Kilauea	Light fume during day
1	Naalehu	Distinct glow in evening
16	Kilauea	Strong fume column in evening
18	Kilauea	Strong fume column in evening
19	Kilauea	Weak fume
20–21	Kilauea	Strong fume in evening
22–23	Kilauea	Weak fume
28	Humuula	Pulsating fume cloud in morning
28	Kilauea	Glow in evening
April 1–6	Kilauea	Conspicuous fume

During late March or early April the quiet outflow of lava became essentially continuous, and was observed at close range by staff members of Hawaii National Park. The account of the activity on April 7 to 9 and May 5 to 7 is based largely on the excellent reports of Ranger James B. Orr, and the writers wish to thank Mr. Orr for making the reports available. The results of the activity were examined on the ground by Macdonald, in company with Orr, on the second and third of June, after lava extrusion again had ceased.

The precise date when lava extrusion again became fairly continuous is uncertain. On March 28 the fume column rising from Mokuaweoweo was unusually conspicuous, and on the evening of that day the glow was intense. On April 1, harmonic tremor was recorded for

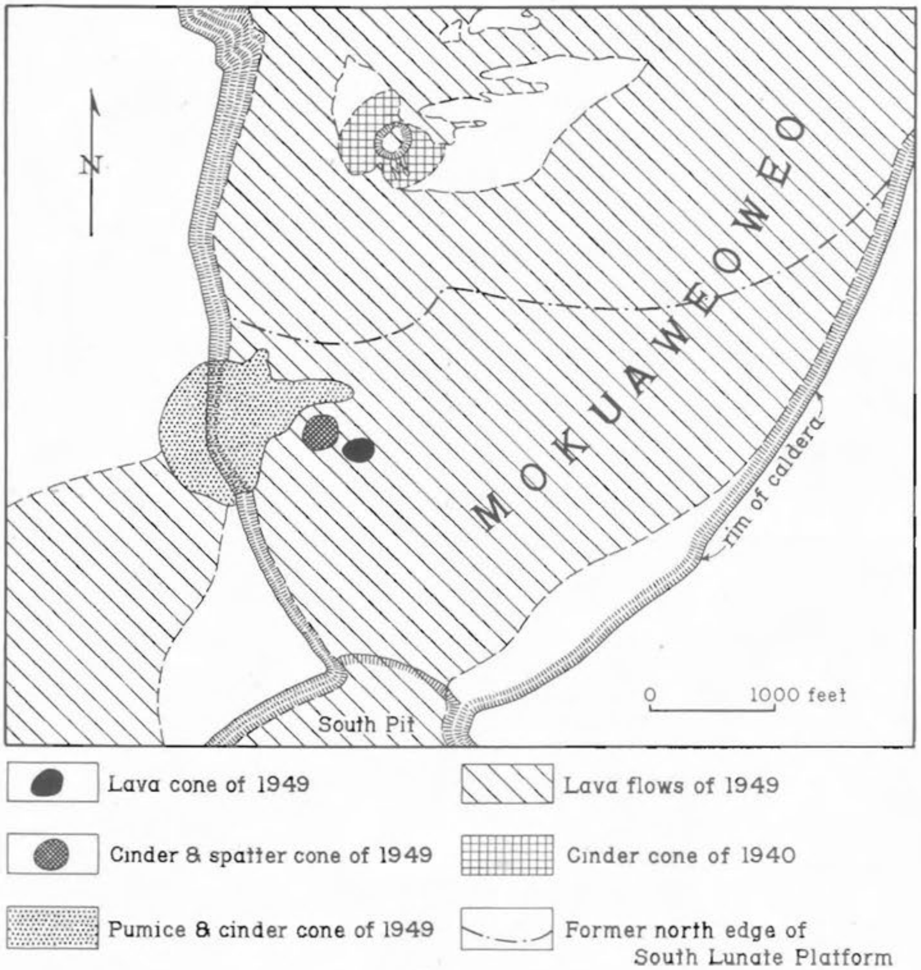

FIGURE 1. Sketch map of the southern portion of Mokuaweoweo caldera on June 3, 1949, after the end of lava extrusion.

a few minutes on both the Mauna Loa seismograph and the Bosch-Omori seismograph at Kilauea. Orr's observations at the summit on April 7 indicate that at that time lava extrusion must already have been in progress for several days. It appears probable, therefore, that fairly continuous lava extrusion was resumed sometime between March 28 and April 1.

The activity of April and May was confined entirely to the vent area on the floor of Mokuaweoweo caldera close to its southwestern wall. The large-scale lava fountaining of late January had built up a big cone of fine cinder and pumice resting against the caldera wall and on the outer slope of the mountain. (See figure 2, VOLCANO LETTER 503.) Within the breached crater of this large cone, diminished fountain activity in early February had built a smaller double cone of coarse cinder and spatter.

On April 8 the small cinder and spatter cone was rhythmically emitting voluminous puffs of fume, but no lava. About 250 feet east of the fuming cinder cone a small lava cone had been built, about 80 feet high and 150 feet across at the base, with a crater 40 feet in diameter containing a small, surging pond of molten lava. The lava composing the cone was notably denser than the highly vesicular lavas which had characterized the earlier phases of the eruption. The lava pond in the crater heaved slowly up and down, the depth from the rim to the pond surface ranging from a few inches to 15 feet during the few hours it was under observation. However, no overflow of lava occurred while Orr was there, from April 7 to 9, although the cone obviously had been built up by repeated overflows previous to April 7 and continued to grow by additional overflows later. From the vent area liquid lava moved through tubes beneath the surface, emerging about a mile east–northeast of the cones to feed two sluggishly advancing flows of aa. Another small sluggish aa flow was moving southeastward into South Pit.

On May 5 the height of the lava cone had increased to about 95 feet, as measured from its southeastern base. The lavas composing it were still relatively dense, and the pond of molten lava was still present in its crater. The cinder and spatter cone was the principal source of fume and had liberated some short flows of lava which partly veneered its flanks. Some of this lava was dense, but some was highly vesicular and shelly. A small pahoehoe flow was spreading near the base of the lava cone; another larger flow moved through tubes, issuing about a mile northeast of the cone to form a moderately active pahoehoe flow.

The activity at the cones on May 7 showed a distinctly cyclic pattern, the cycles being repeated at approximately 3½-hour intervals. Successive cycles were essentially identical, except for minor variations in the duration of the parts of the cycle. The cycle commenced with a loud hissing and roaring within the cinder and spatter cone, accompanied by copious liberation of pale brown to white fume. This lasted for 5 minutes, and was followed by rapid outpouring of gas-rich pahoehoe accompanied by a little fume. The lava effusion lasted about 45 minutes, the rapidity of extrusion gradually decreasing until all flows ceased. Within about 5 minutes after the lava ceased to flow, the hissing and roaring within the cone started again. At the summit of the cone the escaping gas tilted large slabs of partly cooled pahoehoe, lifting some of them a foot or two, then dropping them back into place. This relatively violent escape of gas continued for about 10 minutes. Immediately afterward the lava cone, which had been quiescent with its crater empty, started to fume copiously, and shortly thereafter fluid lava entered the bottom of the crater from an opening on its west–southwest side. Within 10 minutes the crater was completely filled. With the entrance of lava into the crater fuming was greatly diminished, and by the time the crater was filled fuming had practically ceased. The fluid lava bulged up above the crater rim as a broad flat dome a foot or two high, then the confining crust ruptured and the lava poured down the flanks of the cone. The crust of the bulge of lava at the summit of the cone was continually broken up, forming large irregular plates of still flexible pahoehoe which coasted down the flows on the flank of the cone, crumpling and twisting as they encountered obstacles. This phase of overflow from the lava cone continued with varying intensity for about an hour. Then the lava in the crater drained away, accompanied by liberation of large volumes of fume at the lava cone and by the renewal of the hissing and roaring in the cinder and spatter cone. This was followed by a period of quiet lasting about an hour, after which the entire cycle was repeated.

The date of final cessation of the lava extrusion is uncertain. Flows still were moving actively on the caldera floor east of the vent on May 19, when the summit was visited by H. Whitten. When Orr and Macdonald reached the summit on June 2 there was no sign of movement in any of the flows, although a weak glow still was visible on the cinder cone. The cone still was fuming copiously on June 2, but by the afternoon of June 3 the fume was very light and consisted almost entirely of steam. During the remainder of June no glow, and only weak fuming, were reported. Lava extrusion ended sometime between May 20 and June 2, probably about the end of May. The eruption appears to be over, although it is still possible that another resumption of activity may occur.

On June 3 both the cinder cone and the lava cone were climbed and examined in detail. The cinder cone was an irregular dome, about 80 feet high, with no sign of a crater. It was largely veneered with very late flows of frothy pahoehoe. (See plate 1.) The lava cone was about 110 feet high, with a crater some 30 feet across and 50 feet deep. (See plate 2.) The late lavas, erupted at the lava cone after Orr's visit on May 5, were shelly gas-rich pahoehoe, in contrast to the denser, partly degassed lavas which built most of the cone.

It is estimated that the volume of lava extruded in the late phase of the eruption after February 5 was about 4 million cubic yards, bringing the total volume for the eruption to about 75 million cubic yards. The late lavas were restricted to the southern end of Mokuaweoweo caldera, and completed the burial of the northward-facing scarp of the South Lunate Platform, which had already been partly buried by the lavas of 1933 and 1940. Only at its western end is there still visible a topographic expression of the scarp, mantled by cascades of the 1949 lavas. (See figure 1.)

It has already been pointed out that the pahoehoe lava which formed most of the lava cone was strikingly dense, as compared to the highly vesicular and shelly pahoehoe which characterized the earlier lavas of the eruption in the area close to the vents. It resembled much more closely the pahoehoe which forms in long flows which have traveled through tubes many miles from the vents. In the case of the 1949 lava, the denseness resulted from loss of gas before the lava reached the surface. The change from gas-rich to gas-poor lava as the eruption progressed might have been explained by assuming a gas-enriched "head" on the magma column which was released during the early stages of the eruption and gradually exhausted as activity continued. This explanation might be acceptable if the change in gas content had been entirely unidirectional. But it was not. The latest lavas of the eruption, instead of being as dense as or even denser than those which built the bulk of the lava cone, were again frothy and gas-rich like the earliest lavas. The change was from gas-rich to gas-poor, and then back again to gas-rich lavas.

A possible explanation of the changes in density of the erupted lavas is suggested by the time relationships of the density types to the character of the rest of the activity. The dense lavas which built most of the lava cone, and also were erupted in early May or late April at the cinder and spatter cone, were erupted following a period of nearly 2 months duration during which there was very little surface outflow of lava, but nearly continuous liberation of large volumes of fume. Possibly during this period the upper part of the magma column stood undisturbed at levels high enough to permit vesiculation, and for a period long enough for a large proportion of the gas bubbles to escape, supplying the gas for the fume cloud. However, at levels

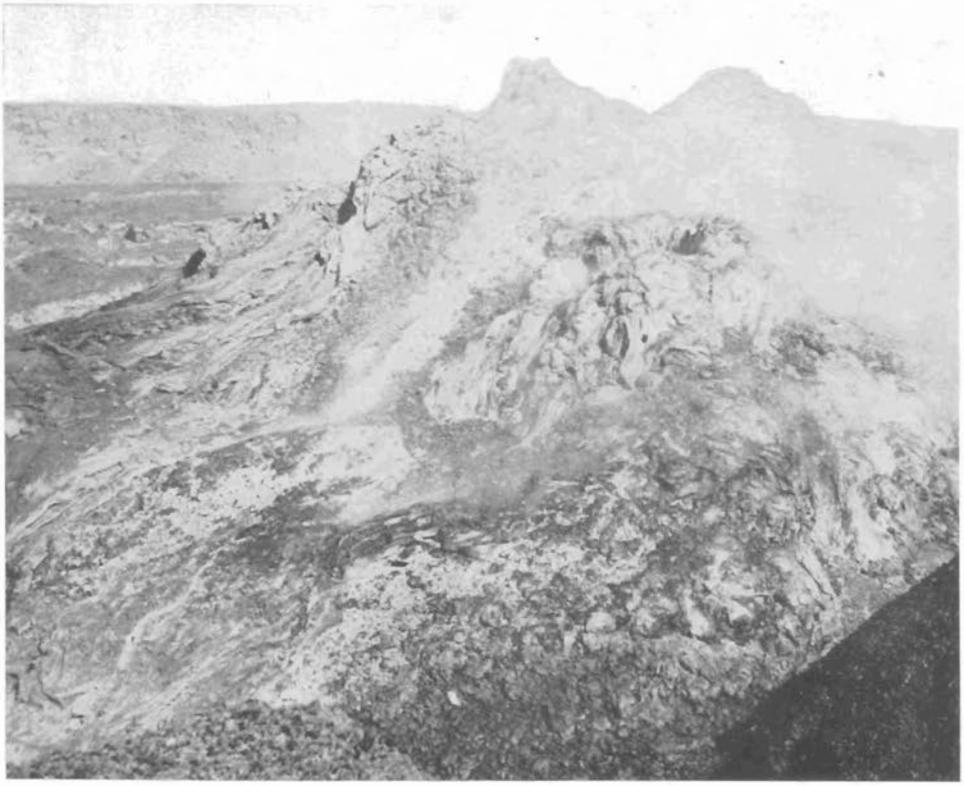

PLATE 1. The small cinder and spatter cone, largely veneered with thin lava flows, seen from the northern rim of the pumice cone, June 3, 1949. PHOTOGRAPH BY G. A. MACDONALD.

PLATE 2. Lava cone, seen from near the summit of the cinder and spatter cone, June 3, 1949. PHOTOGRAPH BY J. B. ORR, NATIONAL PARK SERVICE.

below the depth at which appreciable vesiculation could occur the magma lost only the small proportion of gas which was dissipated upward by diffusion. Convection probably would not be very effective in the narrow feeding fissure which led the lava to the surface. When lava extrusion was resumed after the 2-month period of quiet, the first erupted, upper part of the magma body was gas-poor and produced dense lavas. But as time went on the upper, partly degassed portion of the magma was exhausted, and lavas reaching the surface were again as rich in gas, or nearly so, as had been the earliest lavas of the eruption.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL–JUNE, 1949

VOLCANOLOGY

April

About the end of March, quiet lava extrusion became fairly continuous in Mokuaweoweo, and continued through April. The activity is described in the foregoing article. Fume rising from Mokuaweoweo was visible from the Volcano Observatory on many occasions during April.

Thirty-two earthquakes were recorded in April. Sixteen of these were recorded at Kilauea and 23 at Mauna Loa.

There was a small accumulation of northwesterly tilt during April, possibly indicating a slight increase of pressure under Kilauea and a decrease under Mauna Loa.

May

Quiet lava effusion in Mokuaweoweo continued through most of May. It came to an end sometime between May 20 and June 2, probably about May 30.

Forty-three earthquakes were recorded during May. Of these 31 were recorded at Kilauea and 38 on Mauna Loa. In addition, about 225 tremors of Mauna Loa origin were recorded on the Mauna Loa seismograph on May 20 and 21. These resembled the records produced by small explosions, rather than by ordinary small earthquakes. Many of them were recorded also at Kilauea, and some on the Hilo and Kona seismographs.

Three earthquakes were felt locally during May. The strongest occurred at 5:02 a.m. on May 2. It originated in Kona, where some objects were shaken from shelves, and the seismograph at Kealakekua was broken. As in October and November, 1947, several of the larger shakes originated under the west slope of Mauna Loa, inland from Kealakekua Bay.

There was an accumulation of south tilt, and a little east tilt during May. The latter is normal for this time of year.

June

Both Mauna Loa and Kilauea remained quiet throughout June. A total of 32 earthquakes were recorded, 28 of them at Kilauea, and 27 of them on Mauna Loa. Of these, a moderate earthquake originated at a shallow depth on the northeast rift zone of Mauna Loa on June 8, and two feeble earthquakes at a depth of about 10 miles under the southern slope of Mauna Loa, near Punaluu Kahawai, on June 25.

A small accumulation of southerly tilt occurred during June, probably indicating either a slight decrease of pressure under Kilauea or a slight increase under the northeast rift of Mauna Loa. Almost no net change in tilt in an east–west direction was recorded during the month.

The average interval between summit eruptions of Mauna Loa and following flank eruptions during the past century has been 20 months. On this basis, assuming the 1949 summit eruption to have ended about the end of May, a flank eruption of Mauna Loa might be expected about the end of January, 1951. However, it is important to realize that the average interval means little. Sometimes a summit eruption of Mauna Loa is followed by another summit eruption, not by a flank outbreak. Even when a summit eruption has been followed by a flank eruption, the interval between them has ranged from 6 to 38 months. Prediction of Mauna Loa eruption entirely on the basis of historic precedent is highly uncertain, and thus far there is little else on which to base a forecast of the next eruption.

SEISMOLOGY

Earthquake Data, April–June, 1949

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Mod-erate	Strong	Local Seis-micity*	Tele-seisms
April	3	15	3	0	0	0	0	5.25	0
	10	7	3	0	0	0	0	3.25	0
	17	9	0	0	0	1	0	5.25	1
	24	3	0	0	0	0	0	0.75	0
May	1	8	0	0	0	0	0	2.00	1
	8	3	0	0	0	2	0	6.75	1
	15	3	2	1	0	0	0	2.75	0
	22	266	0	4	0	0	0	70.50	0
	29	13	1	3	0	1	0	9.75	0
June	5	7	2	0	0	0	0	2.75	0
	12	3	3	0	0	1	0	5.25	0
	19	3	3	0	0	0	0	2.25	0
	26	5	1	2	1	0	0	5.75	0

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

45. April 4, 02:59, very feeble.
46. April 7, 09:55, very feeble. Mauna Loa.
47. April 8, 16:30, very feeble. Mauna Loa.
48. April 11, 18:40, moderate, both components dismantled at Mauna Loa. Kaoiki fault. Felt at Naalehu.
49. May 2, 05:02, strong, Kona seismograph broken. West slope of Mauna Loa. Intensity about 4 on Rossi-Forrel and modified Mercalli scales. Felt in Hilo, strongly at Puu Ulaula, and generally from Holualoa to Naalehu. Many sleepers wakened, some rushed out doors. Some objects thrown from shelves in the area from Honaunau to Kealakekua.
50. May 2, 12:55, feeble. Mauna Loa. Felt at Kapapala.
51. May 7, 23:26, strong, both components dismantled at Mauna Loa. Focus at about 12 miles depth beneath Mokuaweoweo. Felt at Holualoa, Kealakekua, Naalehu.
52. May 9, 03:26, very feeble.
53. May 9, 17:02, very feeble.
54. May 14, 10:54, very feeble.
55. May 21, 01:06, feeble. West slope of Mauna Loa. Felt at Holualoa.
56. May 21, 02:25, feeble. West slope Mauna Loa.
57. May 21, 08:38, feeble.
58. May 21, 10:01, feeble.
59. May 23, 10:24, moderate, both components dismantled at Mauna Loa. South slope Mauna Loa near Kapapala. Felt at Kilauea and Hookena, strongly at Pahala.
60. May 25, 15:10, very feeble.
61. May 26, 14:44, very feeble.
62. May 28, 17:30, feeble. West slope Mauna Loa. Felt at Holualoa.
63. May 29, 01:04, feeble. Kaoiki fault near Ainapo.
64. May 30, 04:18, feeble.
65. June 3, 04:05, very feeble.
66. June 8, 14:12, moderate, both components dismantled at Mauna Loa. Northeast rift of Mauna Loa, shallow.
67. June 9, 18:07, very feeble.
68. June 11, 05:41, very feeble. Northeast rift of Mauna Loa.
69. June 11, 08:05, very feeble.
70. June 17, 05:49, very feeble.
71. June 19, 05:05, very feeble. Mauna Loa.
72. June 19, 12:53, very feeble. Mauna Loa, northeast rift.
73. June 23, 15:34, feeble.
74. June 25, 15:45, feeble. Focus at about 10 miles depth under south slope of Mauna Loa near Punaluu Kahawai.
75. June 25, 19:27, slight. Location same as number 74.
76. June 26, 08:43, very feeble.
77. June 27, 01:57, feeble. Mauna Loa.
78. June 28, 04:53, very feeble. Mauna Loa.
79. June 30, 07:03, very feeble. Kilauea northeast rift, shallow.

TELESEISMS

April 13, 10:03, slight. Between Olympia and Tacoma, Washington.

April 29, 15:36, slight. South coast of Mindanao, Philippine Islands.

May 2, 20:05, slight. Kurile Islands.

MICROSEISMS

Microseisms were slight from April 1 to 9, moderate on April 10 and 11, slight from April 12 to 19, moderate from April 20 to 28, and slight from April 29 to June 30.

CRACK MEASUREMENTS

Most of the cracks measured showed no appreciable movement. However, the crack at the observation area at the east rim of Halemaumau opened 2 millimeters at its northern end during the interval from March 31 to June 30. During the interval since August 31, 1948, it has opened 12 millimeters. The amount of opening decreased southward, reaching essentially zero at the southern end of the crack.

TILTING OF THE GROUND

From April 1 to 22 there was very little tilting of the ground surface in a north–south azimuth. From April 22 to May 4 there was a slight northerly tilting, from May 4 to 29 a distinct southerly tilting, from May 29 to 31 a small northerly tilting, and from May 31 to June 30 a small accumulation of southerly tilting. In the east–west azimuth, there was a small accumulation of westerly tilt between April 1 and 29, a nearly equal accumulation of easterly tilt between April 29 and May 27, and a slight accumulation of westerly tilt from May 27 to June 30. The net westerly tilting is normal for this quarter of the year, although the tilting during June is normally slightly to the east instead of slightly westward. The accumulation of southerly tilt during May and June is abnormal, tilting during these two months generally being distinctly northward.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
April	3	0.9″	N 45° W
	10	0.7″	S 83° W
	17	0.0	——
	24	0.7″	N 39° W
May	1	0.6″	N 80° W
	8	0.7″	S 56° E
	15	0.6″	S 19° W
	22	0.5″	S 45° E
	29	0.4″	S 34° E
June	5	1.0″	N 19° W
	12	0.5″	S 45° W
	19	0.6″	N 22° W
	26	1.1″	S 56° E

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THE VOLCANO LETTER

No. 505 | **U. S. Geological Survey** | **July–September, 1949**

PUBLISHED BY THE UNIVERSITY OF HAWAII

REPORT ON PRELIMINARY WORK FOR RADIATION SURVEY

By RUTH C. LOUCKS

INTRODUCTION

In August, 1948, a series of experiments was initiated to determine to what extent available materials could be used to make a survey of radiation from volcanic sources. At that time available materials consisted of X-ray film and a small spectrograph. Later a Geiger type survey meter was made available to the Hawaiian Volcano Observatory.

X-RAY FILM

Since X-ray film registers radiation both longer and shorter than the X-ray range, it appeared to be a possible medium for recording any short-wave radiation that might be present. No X-rays are expected because of their nature, but ultraviolet radiation and gamma radiation may be recorded on X-ray film. Dental pack film was selected for this work because of the ease of handling.

The first series of films, exposed for 10 weeks at Red Hill (10,000 feet) and the rim of Mokuaweoweo, showed heavy fogging of unshielded films and no fogging of slightly shielded films. By accident two films were exposed back to back. The front one was fogged, while the one which was shielded by the two lead foil backing sheets was unfogged. The fact that even masking tape, with which the films were taped to rocks, produced a shadow on the films indicated that the radiation recorded was of relatively long wavelength. Temperature changes from below freezing to above 70° F. apparently did no damage. One film was left for a year deep in a crevice in the roofed cave near the rim of North Bay known as Hotel de Jaggar. It showed slight darkening, possibly due to the small amount of radioactivity in Hawaiian lavas. Film exposed to Hawaiian lava for 12 weeks showed no darkening, but the longer exposure of a year may have recorded the slight amount of radioactivity present (Piggot: Amer. Jour. Sci., 5th Ser., 22(127) : 1931).

The second series was tested at the Kilauea region to determine whether the film pack was actually light tight (for visible light) and whether any of the darkening could be attributed to cosmic rays. The film tested for light tightness was unfogged. Cosmic rays produced no measurable darkening on any of the films tested. The only darkening was due to radioactive lead in the masses of the tiltmeter in the Uwekahuna vault. The radioactivity of the lead was later checked with the Geiger counter. The exposure of 5 weeks produced slight darkening on the film at a distance of 12 to 15 feet from the radioactive lead. This darkening served as a check of the sensitivity of the film to gamma radiation.

The third series of tests was made at Red Hill using unshielded film and film shielded by aluminum foil and various thicknesses of lead. Film was placed in four slots of a lead-covered box. One film was uncovered, one covered by 0.11 mm. of aluminum foil, one by 3.5 mm. of lead, and one by laminations so arranged that one third was uncovered, one third covered by 1.75 mm. of lead, and one third by 3.5 mm. of lead. These were exposed nearly 6 months. The unshielded film was darkened, while the film shielded by aluminum foil and the lead was undarkened. Thus it appears that the darkening encountered was due to ultraviolet radiation and may be eliminated by encasing the film in aluminum foil. The writer wishes to acknowledge the assistance given by the dispensary of Kilauea Military Camp in developing all X-ray films.

SPECTROGRAPH

The spectrograph (Gaertner, Model L 250-W) was checked and calibrated in the laboratory by Harvey E. White of the University of California Physics Department, during a visit to the Volcano Observatory. This is a low-dispersion instrument mounted so as to be used with a tripod in the field. It appeared that an easy way to record the exact object, toward which the spectrograph slit was pointed, would be by the use of a small camera mounted on the tripod with the spectrograph. D. C. Cox donated a camera for this purpose.

GEIGER COUNTER

A Geiger-Mueller counter (El-Tronics, Inc., Survey Meter SGM-18A) was received by the Observatory early in 1949. A few tests were made to determine what might be expected in the way of background radiation (cosmic rays).

1949 ERUPTION

Two series of X-ray films were exposed at the summit of Mauna Loa during the 1949 eruption. Both were exposed near the rest house, about 1 mile or more from the nearest activity. Twice during January, 1949, film was taped to the stone monument in front of the rest house and exposed for periods ranging from 17 hours to 17 days. Since the films were unshielded, there was no noticeable darkening other than that which might be expected from ultraviolet light. At that distance one could not expect to record gamma radiation.

G. A. Macdonald and D. C. Cox took the Geiger counter to the summit of Mauna Loa and made some observations. Their readings were no higher on new lava than on the old lava. However, when they attempted to make readings in a hot crack, they got no reading because the counter does not register correctly above 125° F.

The field conditions were such that it seemed best not to take the spectrograph to the summit.

CONCLUSIONS

It appears that none of the work done during the 1949 eruption constitutes a conclusive test of radiation associated with volcanic activity, particularly the possible presence of short-lived radioactive substances in the gases liberated in the big lava fountains. The films exposed were too far from activity to be significant, and the Geiger counter readings were not complete enough to be conclusive. However, the work done so far serves to point out what should be done to make such tests valid. The year's work shows that among the three recording devices the radiation spectrum from cosmic rays down through the visible range is covered.

THE HOLLOW CINDER CONE OF THE 1949 ERUPTION OF MAUNA LOA

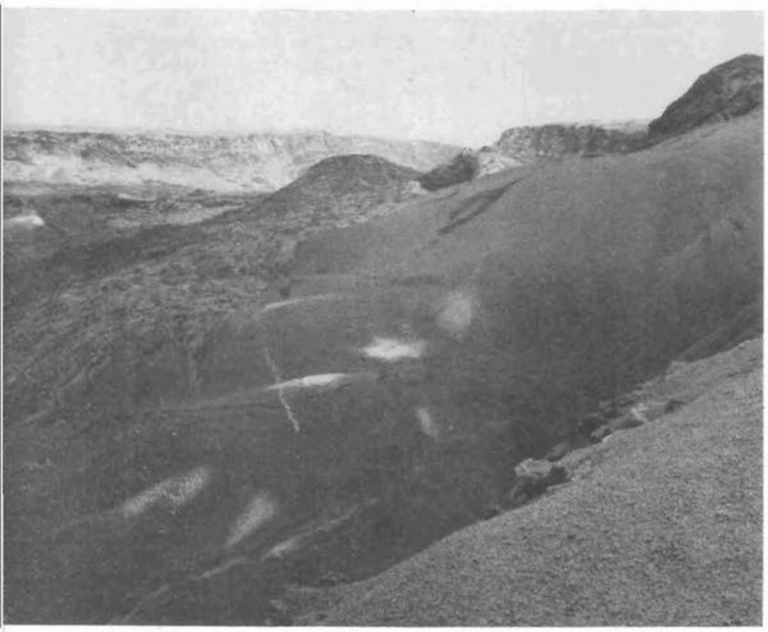
By GORDON A. MACDONALD

The small cinder and spatter cone, which developed within the breached crater of the larger cinder and pumice cone during the late stages of the 1949 eruption of Mauna Loa, has been described in previous issues of the VOLCANO LETTER. Previous to mid-April the cone had consisted entirely of coarse cinder and spatter. Between April 9 and May 6 the cone started to erupt short thin lava flows, which by early June had almost entirely covered its slopes, hiding the cinder core.

Mokuaweoweo caldera was again visited by the writer on July 26, in company with Ranger J. B. Orr of Hawaii National Park, and Tad Nichols, photographer. It was then found that the cinder and spatter cone had partly caved in, revealing a large cavity in its center. The hole formed by the collapse was on the northeastern side of the cone, and its walls clearly displayed a cross section of the cone. At the surface was the veneer of lava, averaging 6 to 8 feet thick, and consisting of a complex of many thin pahoehoe flows lying parallel to the surface of the buried cinder cone. Many of the flows showed cross sections of filled or partly filled pahoehoe tubes. Beneath the lava veneer the cone consisted of coarse cinder and spatter, largely welded together, and crudely bedded. The fragments ranged up to about 2 feet in length, although most were less than 1 foot. Most were irregular, although some were fairly regular Hawaiian type ("cow-dung") bombs.

By far the most interesting feature of the cone was the open chamber at its center. The chamber was roughly the shape of an artillery projectile, about 25 feet across, with nearly vertical walls which arched inward to a point at the top. The opening was about 40 feet high, but had been higher, as the visible floor was formed of loose rubble which resulted from the collapse of the cone. The walls of the chamber were lined with a layer of pahoehoe 2 to 4 feet thick, in which the flow-lines and flow-planes were disposed parallel to the walls of the chamber and nearly vertical. At the apex of the chamber the pahoehoe lining was continued upward as a 3-foot dike which led to the two small spatter conelets at the summit of the cone.

Apparently the lava rose into the cone, making room for itself by removing the material which in earlier stages formed the core of the cone. There is no evidence whether the removal was by stoping or by redissolving the hot cinder, or both. At the end of the eruption the magma column withdrew, leaving the center of the cone empty, but the walls of the cavity veneered with a thin layer of lava.

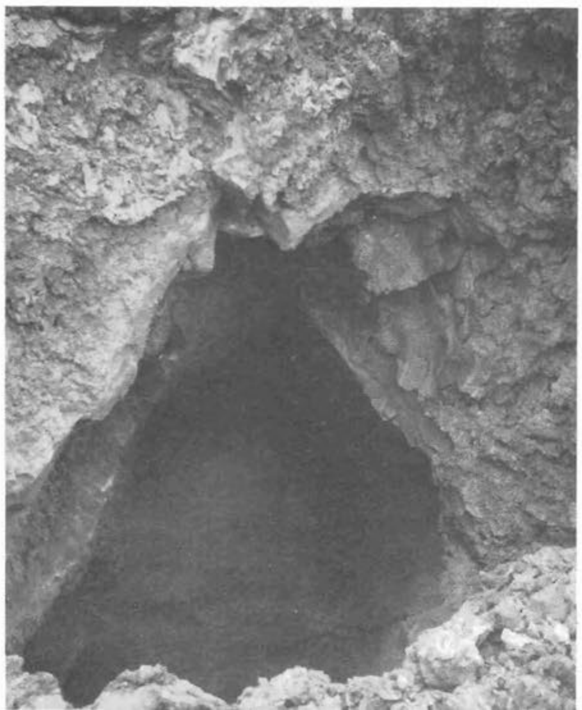


LEFT

PLATE 1. View of the cone area of the 1949 eruption, from the top of the caldera wall to the north. In the foreground and on the right can be seen the big pumice cone built on and against the caldera rim during early stages of the eruption. The fissures are the result of partial collapse of the cone, and the white areas are the result of alteration and deposition by escaping gases. In the middle distance can be seen the hollow cinder and spatter cone, and to its left the lava cone. PHOTO BY G. A. MACDONALD.

RIGHT

PLATE 2. The open chamber in the center of the small cinder and spatter cone. The chamber is lined with a thin layer of pahoehoe lava, and on the right the nearly vertical flow-banding in the pahoehoe lining is clearly visible. At the top a flow-banded dike leads upward through the cinder. The chamber is approximately 20 feet across. PHOTO BY G. A. MACDONALD.



HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY–SEPTEMBER, 1949

VOLCANOLOGY

July

Since the end of lava extrusion about the end of May, Mauna Loa has remained quiet. Mokuaweoweo was visited on July 26. No signs of lava activity could be detected although the new cone built during the early months of 1949 was still hot and fuming weakly and a faint pall of bluish fume hung over the crater of the 1940 cone. The small cinder and spatter cone within the crater of the larger cinder and pumice cone of the 1949 eruption had partly collapsed, and the center of the cone was seen to be occupied by an open chamber lined with a thin layer of pahoehoe.

Forty-six local earthquakes were recorded on the seismographs of the Volcano Observatory during the month of July. Of these, 31 were recorded at Kilauea and 34 at the seismograph on the eastern slope of Mauna Loa. (The total is not the same as the sum of those recorded at each of the stations, because many earthquakes were recorded at both stations.) On July 5 a moderately strong earthquake occurred at a depth of 10 to 15 miles on the east rift zone of Kilauea volcano, in the vicinity of Kapoho. At 8:52 p.m. on July 29 a strong shallow earthquake occurred on the northeast rift of Mauna Loa near the summit of the mountain. This earthquake, which dismantled both components of the Mauna Loa seismograph, was felt strongly at Kapapala and much less strongly by many persons in the area from Kilauea crater to Hilo.

On July 23, at 12:35 a.m., the Bosch-Omori seismograph recorded the long waves of a heavy earthquake with its origin near the New Hebrides Islands.

During the month of July the tiltmeter at the northeastern edge of Kilauea caldera accumulated a small amount of northerly tilt of the ground surface, but there was little change in tilt in the east–west direction. There is generally weak but pronounced easterly tilting and moderately strong northerly tilting at this season of the year. Hence the absence of appreciable easterly tilting and less than normal northerly tilting probably result from a slight decrease in pressure beneath Mauna Loa and Kilauea.

August

Mauna Loa and Kilauea remained quiet during August, although light fume was observed at the summit of Mauna Loa late on the afternoon of August 30.

Forty-seven local earthquakes were recorded on the seismographs during the month of August. Of these, 33 were recorded at Kilauea and 44 at the station on the eastern slope of Mauna Loa. A moderately strong earthquake which was felt in the area east of Kilauea crater at 2:26 p.m. on August 30 had its origin at a depth of 20 to 25 miles, about 8 miles south-southeast of Apua Point. An earthquake, which originated at a depth of about 30 miles under the southwest rift of Mauna Loa at 7:22 p.m. on August 31, was felt weakly in Kona.

On August 5 the seismographs recorded the great earthquake which caused tremendous damage and several thousand deaths in the region around Ambato, in Ecuador. On August 21 they recorded the great earthquake in British Columbia. This earthquake was of considerably greater magnitude than that of August 5 in Ecuador, and the smaller amount of damage must be attributed to its occurrence in an unpopulated area. It was so violent that it dismantled the seismographs, of comparatively low sensitivity, at the Volcano Observatory, 3,000 miles from its origin. It probably is the strongest distant earthquake thus far recorded at the Volcano Observatory. Aftershocks of the British Columbia earthquake were recorded until August 23.

During August the tiltmeter at the northeastern edge of Kilauea caldera recorded moderately strong northerly tilting of the ground, which is normal for this season of the year. There was almost no tilting in the east–west direction. Because there is normally an easterly tilting during this season, the lack of tilt in the east–west direction probably indicates a decrease of volcanic pressure under Mauna Loa.

September

The Hawaiian volcanoes remained quiet during September. The morning of September 6 marked the anniversary of the beginning of the last eruption of Kilauea. The 15 years since that eruption constitute the longest quiet period in historic record. The 13 years from 1894 to 1907 saw little lava activity, but fuming was almost continuous, and glow in Halemaumau was frequent, and one brief period of lava extrusion in Halemaumau appears to have occurred in 1902 (see VOLCANO LETTER 497, 1947). There is no indication that the end of the quiet period is near. Neither ground tilting nor earthquakes appear to indicate activity of Kilauea or Mauna Loa in the close future.

Forty-seven local earthquakes were recorded on the seismographs of the Hawaiian Volcano Observatory during September. Of these, 40 were recorded at Kilauea and 41 at the Mauna Loa station. On September 1 a sharp earthquake was felt strongly from Kapapala to Naalehu, and weakly in Kona and from Hawaii National Park to Hilo. It originated 3 to 4 miles northeast of the Kapapala Ranch headquarters, on the Kaoiki fault zone. A smaller earthquake, less generally felt, originated a little farther northeast on the same zone of faulting on September 14. An earthquake felt by a few persons in South Kona on September 16 had its origin near the coast about 5 miles south of Hookena, possibly on the Kiholo Pali fault.

On September 27, the seismographs recorded a distant earthquake which occurred in or near southern Alaska.

During the month of September the tiltmeter at the northeastern edge of Kilauea caldera recorded a slight easterly and a moderate northerly tilting of the ground surface which is normal for this season of the year.

G. A. MACDONALD

SEISMOLOGY

Earthquake Data, July–September, 1949

(Based on Bosch-Omori seismograph on rim of Kilauea caldera.)

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
July	2	6	1	0	0	0	0	2.0	0
	9	13	2	0	0	1	0	7.25	0
	16	3	0	0	0	0	0	0.75	0
	23	5	1	0	0	0	0	1.75	1
	30	3	1	0	0	1	0	4.25	0
August	6	6	1	0	0	0	0	2.0	1
	13	7	2	0	0	0	0	2.75	0
	20	2	4	0	0	0	0	2.5	0
	27	9	2	1	0	0	0	3.25	2
September	3	1	2	0	1	0	1	7.25	0
	10	11	0	0	0	0	0	2.75	0
	17	4	2	1	0	0	0	3.0	0
	24	9	3	0	0	0	0	2.75	0
October	1	6	2	0	0	0	0	2.5	1

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

80. July 5, 00:44, moderate. East rift of Kilauea near Kapoho, about 12 miles deep. Not reported as felt.
81. July 5, 17:13, very feeble.
82. July 8, 12:42, very feeble.
83. July 19, 09:55, very feeble.
84. July 28, 17:36, very feeble.
85. July 29, 20:52, moderate. Both components of Mauna Loa instrument dismantled. Felt strongly at Kapapala, weakly from Hawaii National Park to Hilo. Focus about 6 miles deep about 3 miles ENE of Mokuaweoweo.
86. August 5, 14:49, very feeble.
87. August 8, 18:35, very feeble. On west flank of Mauna Loa near Kaunene, 12 to 15 miles deep.
88. August 12, 19:05, very feeble. Southeast slope of Mauna Loa between Ainapo and Ohaikea, shallow.
89. August 16, 02:20, very feeble. Southeast slope of Mauna Loa about 7 miles northwest of Pahala.
90. August 16, 16:23, very feeble. About 2 miles south of Poliokeawe Pali, south of Kilauea caldera.
91. August 19, 07:15, very feeble. About 10 miles deep, near the shore northwest of Huehue Ranch.
92. August 19, 19:24, very feeble. Northeast rift of Mauna Loa at about 7,500 feet.
93. August 21, 18:49, feeble. Felt by a few persons in Volcano district. Offshore, southeast of Kilauea caldera.

94. August 24, 06:03, very feeble.
95. August 24, 14:18, very feeble.
96. August 30, 14:27, slight. Beneath ocean, about 8 miles SSE of Apua Point, 20 to 25 miles deep. Felt in Volcano district.
97. August 31, 19:23, very feeble. Felt at Holualoa. Under southwest rift of Mauna Loa, about 30 miles deep.
98. Sept. 1, 12:53, moderate. Both components of Mauna Loa instrument dismantled. Felt strongly from Kapapala to Naalehu, weakly from Volcano district to Hilo and in Kona from Pahoehoe to Holualoa. Origin on Kaoiki fault, about 3 to 4 miles northeast of Kapapala Ranch headquarters.
99. Sept. 2, 02:31, very feeble.
100. Sept. 12, 03:46, very feeble.
101. Sept. 14, 16:47, feeble. About 6 miles deep, on Kaoiki fault about 3 miles west of Uwekahuna. Felt in Hilo.
102. Sept. 16, 14:08, very feeble. Felt in South Kona. Origin near coast, about 5 miles south of Hookena.
103. Sept. 18, 20:38, very feeble.
104. Sept. 22, 01:31, very feeble. Under southwest edge of Kilauea caldera, about 8 miles deep.
105. Sept. 23, 21:08, very feeble.
106. Sept. 26, 08:27, very feeble.
107. Sept. 28, 12:13, very feeble.

TELESEISMS

July 23, 00:35, slight. New Hebrides Islands; provisional epicenter.

August 5, 14:43, moderate. Central Ecuador, centering around Ambato.

August 21, 18:09, very large. Both components of Bosch–Omori seismograph at Kilauea, and the north–south component of the Mauna Loa seismograph were dismantled. Queen Charlotte Islands, off coast of British Columbia. Caused 2-foot tidal wave at Ketchikan, Alaska.

August 23, 10:38, slight. Probably an aftershock of the British Columbia earthquake.

Sept. 27, 05:38, slight. Origin probably near Juneau, in southern Alaska.

MICROSEISMS

Microseisms were slight from July 1 to 10, moderate from July 11 to 22, slight from July 23 to 29, moderate from July 30 to August 6, slight from August 7 to 20, moderate from August 21 to 27, slight from August 28 to September 1, moderate from September 2 to 10, strong from the afternoon of September 10 through September 14, and moderate for the remainder of the month of September.

CRACK MEASUREMENTS

Most of the cracks measured showed no appreciable movement. However, the crack at the observation area on the east rim of Halemaumau continued to open slightly. During the interval from June 30 to September 30, stations near the northern end of this crack showed opening of 2 to 3.5 millimeters, and stations near the southern end showed opening of about 0.5 millimeter.

TILTING OF THE GROUND

There was a net northerly tilting of the ground surface of 3.5 seconds of arc at the northeastern rim of Kilauea caldera between July 1 and August 21. Minor reversals to southerly tilt occurred during the periods July 9 to 12, 25 to 30, and August 9 to 10. There was slight southerly tilting from August 21 to 23, slight northerly tilting from August 23 to September 17, and slight southerly tilting from September 17 to October 1. The net change from July 1 to October 1 was a northerly tilt of 3.4 seconds of arc. In the east–west azimuth, there was an accumulation of 0.5 second of easterly tilt from July 1 to July 5. From July 5 to September 1 there were minor oscillations from easterly to westerly tilt, but no net accumulation of either. From September 1 to 4 there was a sharp westerly tilting, followed by a moderate easterly tilting during the remainder of the month. The net accumulation of easterly tilt from July 1 to October 1 was 0.9 second of arc.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera

Week Ended		Amount	Direction
July	2	1.4″	N 40° W
	9	0.6″	N 12° W
	16	0.4″	S 64° E
	23	0.9″	N 32° E
	30	0.7″	S 16° W
Aug.	6	1.1″	N 16° W
	13	0.1″	N 45° W
	20	1.1″	N
	27	0.3″	S 70° E
Sept.	3	0.2″	N
	10	0.1″	E
	17	0.4″	N 32° E
	24	0.6″	S 18° W
Oct.	1	0.8″	N 76° E

TEMPERATURE MEASUREMENTS

Weekly measurements of the temperature at the steam well at Sulfur Bank were resumed on September 10. The following uniform procedure has been adopted. The ½-inch plug at the top of the casing of the more easterly of the two drill-holes is removed, and the well is allowed to blow freely for 10 minutes. A maximum thermometer is then completely inserted into the aperture and allowed to remain 5 minutes. To date, the measured temperature has been uniformly 206° F.

Measurements at steaming cracks at Sulfur Bank have ranged from 203° to 208°, probably because of non-uniform exposure. Changes in the amount and direction of the wind appear particularly effective in altering the measured temperature.

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THE VOLCANO LETTER

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BOMBING TO DIVERT LAVA FLOWS

By RUY H. FINCH and GORDON A. MACDONALD

Probably the first attempt to alter the course of a lava flow by artificial means occurred during the 1669 eruption of Etna volcano. The flow was advancing toward the city of Catania and seemed likely to destroy it. In an attempt to save the city, several dozen men covered themselves with wet cowhides for protection against the heat and dug a channel through the wall of hot lava at one edge of the flow. The operation was initially successful. A stream of lava escaped through the gap thus created and moved away at a high angle to the direction of the original flow, partly relieving the pressure on the stream moving toward Catania. Unfortunately, however, the new flow moved toward the town of Paterno, and some 500 irate citizens of that town descended upon the men of Catania and drove them away from the newly dug lava channel. Left unattended, the gap in the flow wall soon clogged up with cooled lava, and the main branch of the flow continued toward Catania, partly destroying it (Rittmann, 1929, pp. 95–96). This early attempt, although it ended in failure, demonstrated the possibility of diverting part or all of a lava flow to a new course by artificially breaking down the confining wall of the flow.

Digging away of the edge of the flow, by hand or by machine, is a difficult and possibly dangerous procedure. It is easier and quicker to blast away the lava by means of explosives. The late Lorrin A. Thurston suggested orally in the early 1920's that in the case of pahoehoe lava flows descending gentle slopes, high explosives might be thrust out over the flow on long poles and dropped through windows in the feeding tube near the flow source, shattering the tube, forcing the lava to spread out again near the source, and removing the supply of lava from the advancing lower end of the flow (Thurston, 1929). Similar methods had been under discussion for several years by members of the staff of the Hawaiian Volcano Observatory. Thurston's suggestion was accepted and advocated by Jaggar (1931), and during the Mauna Loa eruption of 1935 Jaggar introduced the method of emplacing the explosive by dropping military bombs from airplanes (Jaggar, 1936). This is generally the most practical way of transporting and emplacing the explosive. In some instances shells from nearby big guns might be more effective because of the greater accuracy with which they can be directed; but for the most part potential diversion sites are too inaccessible to be conveniently or quickly reached by artillery.

There are three principal ways in which bombing can bring about diversion of the fluid lava, thereby robbing the older flow below the point of diversion of its supply of lava and causing stagnation of the lower end of the flow. These are: (1) bombing of the natural levees along the open lava river of an aa flow or a young pahoehoe flow in which tubes have not yet formed; (2) bombing of the main feeding channel of a mature pahoehoe flow in which tubes have become well developed; and (3) bombing of the walls of the cinder cone at the source of the flow.

In well-established lava flows on little-dissected terrane the liquid lava of the main feeding channels commonly is confined within tubes or between natural levees and is at a level several feet higher than that of the land surface adjacent to the flow. Where the lava river is still open and confined between levees, breaking down of the levee therefore will allow the liquid lava to escape to one side and form a new flow, robbing the old flow of part or all of its supply of liquid lava. If topographic conditions are favorable, the new flow may move off at a high angle to the direction of the older flow, and reach some entirely different destination. More commonly, however, because the older flow was guided by the direction of steepest slope or pre-existing topographic depressions, the new flow follows the same direction and moves downslope along the edge of the older one. If it does so, it may eventually reach the same place at which the older flow terminated. However, the advance of the lava as a whole is greatly delayed, because the diverted flow may take days, or even weeks, to reach the point attained previously by the older flow. When the second flow has reached the danger point, it also can be bombed, thus still further delaying the advance of the lava front.

A long stretch of the flow, or several separate points on the flow, may be suitable for bombing. If so, in general it appears advisable to select the lowest suitable site for bombing first. If it then becomes necessary to bomb the flow again at a later date the higher sites are still available. On the other hand, if the higher sites are bombed first the new lava streams advancing along the edges of the older one may so alter conditions that the lower sites are no longer suitable. In general, it appears desirable to wait as long as is safely possible before bombing the flow. Every day which bombing is delayed brings the eruption that much closer to an end, and, in general, sees the rate of extravasation diminished. Premature bombing may result in the process having to be repeated, whereas a single bombing might have sufficed had it been delayed a little longer. Care must be taken, however, to allow a sufficient margin of time to cover the possibility of periods of bad weather with low visibility (when bombing is impossible) and rapid forward spurts of the flow.

The practicability of breaking down the levee of an open lava stream by aerial bombing was demonstrated during the 1942 eruption of Mauna Loa (Finch, 1942, p. 4). Disruption of the levee by bombs resulted in at least one new lava stream which poured out through the break in the wall. Topography was not favorable to direct the new flow away from the course of the older one, and consequently it flowed along the edge of the older one for a short distance and then rejoined it. Even such a brief diversion may have some effect in retarding the advance of the front of the major flow, owing to the rapid cooling of the channel of the main flow below the point of diversion, and consequent chilling of the next lava to enter it, with the accompanying tendency to clog the channel.

The method of bombing the main tubes of a pahoehoe flow was tried during the 1935 eruption of Mauna Loa (Jaggar, 1936). Bombs dropped on the roof of the tube may break in the roof and cause the tube to become clogged with solid fragments. Or bombs dropped into the liquid lava within the tubes through the roof or through windows in the roof may cause sufficiently violent stirring of the liquid to transform it from pahoehoe to aa, with increase in viscosity or even local congelation. If it is not swept away with the current, this mass may cause a plugging of the tube. If in either way the tube becomes clogged, the result is an overflow of liquid lava from the tube at the point of clogging and a partial or total removal of the supply of liquid from the tube farther downslope. The lava which overflows at the break forms new tongues which advance downslope on top of, or alongside of, the older flow. If the eruption continues long enough these tongues may develop new major tubes, and may in time reach or pass the terminus of the older flow, but the advance of the lava as a whole will have been delayed and the end of the eruption will be that much closer. It may be possible to repeat the bombing if necessary.

The cinder and spatter cones formed at the source of lava flows commonly contain pools of lava which are held at levels several feet above the surrounding land surface. Likewise, the liquid surface of a mature lava flow issuing from the cone is generally several feet above the adjacent terrane. Breaking down of the cone walls, either naturally or induced by bombing, therefore will allow the liquid in the cone to escape over the surrounding ground, robbing the established lava flow of part or all of its supply of new lava. Many of the cones on the rifts of Mauna Loa have a form especially favorable for bombing. They are built by rows of lava fountains spurting from fissures, and are long and narrow, with relatively thin walls which probably would be quite easy to break down by bombing. Bombing of the walls of the source cone has been suggested (Finch, 1942, p. 6; Macdonald, 1943, p. 255), but has not yet been tried. However, during the 1942 eruption of Mauna Loa there occurred a natural breakdown of the cone walls liberating floods of pahoehoe. A new flow advanced seaward parallel to the older channel. A day later, forward movement at the front of the older flow had practically ceased.

Successful diversion of lava flows by bombing depends upon a combination of several favorable circumstances, including: a lava river flowing in a channel or lava held in the source cone at a level higher than the adjacent land surface; narrow levees, thin cone walls, or thinly roofed tubes which can be broken open by bombs; and favorable topography. The first two conditions are commonly present during eruptions of basaltic lava, but favorable topography is not so general. On the slopes of volcanoes which have been appreciably dissected by erosion, flows may be confined within valleys and diversion may be difficult or impossible. Even under those conditions, however, it may be possible to delay greatly the advance of the flow front by repeated bombing and spreading of the lava in the upper reaches of the valley. On the undissected or little-dissected slopes of young volcanoes, where erosion has not yet cut valleys, bombing to divert the flow is both possible and practical.

It must be pointed out that successful diversion is only possible where the flow has continued long enough to establish well-defined channels, or build at least moderate-sized cones. Probably little can be done with the voluminous bursts which occur during the early hours of Mauna Loa eruptions when the flows are spreading rapidly in several directions and moving through many shifting and anastomosing channels. Fortunately, these early floods are generally high on the mountain where they constitute no danger. Likewise, it must be realized that time is required to prepare the planes and load the bombs, as well as to select the targets and put the plan into operation. Therefore, diversion by bombing may not be possible in time to avert catastrophe where the flow is advancing rapidly down steep slopes, or where the point of outbreak of the flow is too close to the area it is desired to save. It is difficult to place any definite limit on the distance of the vent from the endangered area within which time is insufficient to permit bombing to divert the flow. This depends on the fluidity of the particular lava stream, on the slope, and on the general character of the terrane. For average Hawaiian eruptions, with average slope conditions, it may be about 7 miles. Where the distance is less than that, or where slopes are steep and flow of the lava rapid, only lava barriers such as those suggested by Jaggar (1945) can furnish protection.

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HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER–DECEMBER, 1949

VOLCANOLOGY

October

A total of 39 earthquakes was recorded in October. Of this total 31 were recorded at Kilauea and 37 at the Mauna Loa station. Two of these earthquakes, whose origins were determined, originated under Mokuaweoweo. The stronger of these two shakes was felt at Pahala at 07:55, October 22. Four shakes occurred in less than 15 minutes during the evening of October 26. Three of the shakes were plainly felt at the Kapapala ranch house. They originated along the Kaoiki fault near Kapapala.

The accumulation of northeasterly tilt at the northern end of Kilauea caldera during October was in about the usual amount for this season of the year.

November

An unusual feature of this month was a swarm of earthquakes under Mauna Kea. Sixteen shakes occurred between 09:46 and 20:31 on November 4. A few of the stronger shakes were felt by hunters who were at an elevation of 10,000 feet on Mauna Kea, and they were perceptible at scattered points on the island. An earthquake which occurred at 07:58, November 28, was felt over most of the island. It originated under the east slope of Mauna Loa near Mokuaweoweo at a depth of 20 miles and was strong enough to dismantle seismographs at Hilo, Kilauea caldera rim, and on the east slope of Mauna Loa.

There was about the usual accumulation of northeasterly tilt during the month.

A land slide from the walls of Halemaumau at 14:21, November 24, produced a large brown dust cloud.

December

A distinct feature of the month was the recording of 262 earthquakes on the Mauna Loa seismograph on December 28. Four of the shakes were registered as very feeble and the rest were small tremors. About 80 of the shakes were recorded on the Bosch-Omori seismograph under the Volcano House and 47 on the Kona instrument at Kealakekua. In at least two instances 3 distinct tremors were recorded in 30 seconds. Shortly before the shaking ceased, or at 23:02, continuous tremor started and lasted for 18 minutes.

The frequency of the tremor and the rather uniform small amplitude suggest an intrusion at moderate depth under the northeast rift of Mauna Loa at about 12,000 feet or above.

In addition to the swarm of earthquakes on December 28, 42 shakes were recorded during the month. Of this total 39 were recorded on the Mauna Loa instrument and 25 at Kilauea. Two of the earthquakes were strong enough to be perceptible and both originated under Kilauea. The first occurred at 03:06, December 11. It originated deep under Kilauea and was recorded on seismographs on Oahu. The second occurred at 15:09 also on December 11. It originated at a shallow depth under the northern end of Kilauea caldera and was accompanied by a distinct roar.

R. H. FINCH.

SEISMOLOGY

Earthquake Data, October–December, 1949

(Based on Bosch-Omori seismograph on rim of Kilauea caldera.)

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
October	8	7	2	1	0	0	3.75	0
	15	5	0	0	0	0	1.25	0
	22	7	2	0	0	0	2.75	1
	29	2	3	1	0	0	2.00	0
November	5	14	6	3	0	0	9.50	0
	12	2	0	0	0	0	0.50	1
	19	0	0	0	0	0	0.00	1
	26	3	1	0	0	1	4.25	2
December	3	2	0	0	0	0	0.50	0
	10	5	0	0	0	0	1.25	0
	17	5	1	2	1	0	5.75	3
	24	3	0	0	0	0	0.75	0
	31	88	0	0	0	0	22.00	1

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

108. Oct. 2, 01:28, very feeble. South edge Kilauea caldera.
109. Oct. 3, 08:44, very feeble. 4-5 miles deep on Hilina-Paliokeawe fault 8 miles southeast of Volcano House.
110. Oct. 3, 16:57, very feeble.
111. Oct. 22, 03:51, very feeble. East slope Mauna Loa.
112. Oct. 22, 07:55, very feeble. Felt Pahala. South end Mokuaweoweo.
113. Oct. 23, 10:14, very feeble. East slope Mauna Loa.
114. Oct. 26, 17:58, feeble. Felt at Kapapala.
115. Oct. 26, 18:12, very feeble. Felt at Kapapala.
116. Oct. 27, 03:56, very feeble.
117. Oct. 30, 10:56, very feeble.
118. Nov. 4, 10:37, very feeble.
119. Nov. 4, 10:52, very feeble.

120. Nov. 4,	11:44,	very feeble.
121. Nov. 4,	12:00,	very feeble. 118 to 121 probably same location as 122.
122. Nov. 4,	12:12,	feeble. Felt by hunters at 10,000 feet on Mauna Kea. At a depth of 20 miles under summit of Mauna Kea.
123. Nov. 4,	13:02,	feeble. Same as 122.
124. Nov. 4,	14:10,	feeble. Same location as 122.
125. Nov. 5,	18:45,	very feeble. Under east slope of Mauna Kea.
126. Nov. 23,	02:49,	very feeble. Mauna Loa.
127. Nov. 25,	07:58,	moderate. Instruments dismantled. Felt locally and from North Kona to Hilo. 20 miles under east slope of Mauna Loa near Mokuaweoweo.
128. Dec. 11,	03:06,	feeble. Felt locally. Deep under Kilauea.
129. Dec. 11,	15:08,	slight. Felt locally and accompanied by roar. Under north end of Kilauea caldera.
130. Dec. 12,	18:56,	feeble. Kilauea.
131. Dec. 16,	07:35,	very feeble.

TELESEISMS

Oct. 19,	11:11,	slight. Solomon Islands.
Nov. 9,	13:32,	slight. North of Easter Island.
Nov. 19,	22:29,	slight. Gulf of California.
Nov. 21,	15:02,	slight. Kermadec Islands.
Nov. 26,	22:52,	slight. Tonga.
Dec. 16,	21:46,	slight.
Dec. 16,	22:16,	slight.
Dec. 17,	05:58,	slight. Near southern tip of South America.
Dec. 25,	20:45,	slight.

MICROSEISMS

Microseisms were slight October 26-28 and November 17-21 inclusive, strong from November 12-14, and moderate on other days.

CRACK MEASUREMENTS

The northern end of the crack at the observation area on the east rim of Halemaumau opened 2 millimeters during the 3 months ending December 31. All other cracks that were measured showed little or no movement.

TILTING OF THE GROUND

There was an accumulation of north tilt amounting to 3.3 seconds of arc between October 1 and November 21. The seasonal change to southerly tilt occurred earlier than common, and from November 22 to December 31 there was an accumulation of 2.2 seconds of south tilt. The 4.8 seconds of east tilt between October 1 and December 31 was about the usual for this season of the year.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera

Week Ended		Amount	Direction
Oct.	8	0.7″	N 9° E
	15	2.1″	N 47° E
	22	0.3″	N 26° E
	29	0.7″	N
Nov.	5	0.4″	S 34° W
	12	1.1″	N 26° E
	19	1.5″	N 76° E
	26	0.6″	S 54° W
Dec.	3	1.0″	N 70° E
	10	1.1″	S 12° E
	17	1.3″	S 73° E
	24	1.5″	S 39° W
	31	0.6″	N 53° E

TEMPERATURE MEASUREMENTS

There was a positive decrease in the temperature of the steam well at Sulfur Bank. The decrease amounted to 2° F.—from 206° F. on October 1 to 204° on November 30. The temperature in December appeared to be nearly constant at 204° F. A vent in the Sulfur Bank showed a similar drop from 205° F. on October 1 to 203° F. on December 28. The decrease does not show a good correlation with heavy rainfall and perhaps is a regular seasonal change.

The highest temperature found in the Kokoolau steaming area on November 4, 1949, was 190° F., or a little less than was common for several years after it was noted that trees were being killed there in 1938.

At the Aloi crater steaming area the highest temperature found on November 4 was 194° F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The Hawaiian Volcano Research Association was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.