BULLETIN VOLCANOLOGIQUE
Organe de la SECTION DE VOLCANOLOGIE
de l' Union géodésique et géophysique internationale.
Année 1925 N.os 5 et 6 3.e et 4.e Trimestre

I. — NOTICES SUR LES VOLCANS

DOCT. HAROLD T. STEARNS
OF UNITED STATES GEOLOGICAL SURVEY

The explosive phase of Kilauea Volcano, Hawaii, in 1924 (1)

(with 13 Plates)

LOCATION.

Kilauea Volcano is located on the Island of Hawaii, the largest island of the Hawaiian group which lies in the Pacific Ocean between 19° and 22° north latitude, and between 18° and 22° west longitude. The Island of Hawaii has been formed by five volcanoes—Kohala, Mauna Kea, Hualalai, Mauna Loa, and Kilauea. The last three volcanoes have erupted in historic times. The great dome of Mauna Loa rises 13,675 feet above sea level and is crowned by the giant caldera of Mokuaweoweo. Kilauea forms a low dome 4,040 feet high on the southeast side of the dome of Mauna Loa. On the summit of Kilauea is a shallow lava-floored basin about 3 miles in diameter. The map, Plate I, shows this great Kilauea Caldera, the location of the Hawaiian Volcano Observatory, and Halemaumau, the " Pit of Everlasting Fire „. The broken line (Pl. I) shows the approximate outline of Halemaumau after the 1924 explosions.

(1) Published by permission of the Director, United States Geological Survey.
Delivered before the Geological Society of Washington, Washington, D. C., U. S. A., April 22, 1925.

PRELUDE TO THE EXPLOSIONS.

The disappearance of the lava. — The height of the molten lava in Halemaumau had fluctuated rapidly for two months previous to its disappearance from view on February 21, 1924. On the date of its disappearance the bottom of the pit was 380 feet below the northeast rim station of Halemaumau. Thirty-six local earthquakes occurred during the month of February. (1)

Earthquakes in the Puna District. — During the month of March, no molten lava was visible and the floor of the pit of Halemaumau remained practically unchanged during the entire month. Seventy-eight earthquakes were recorded during March, many of which originated along the northeastern rift of Kilauea at distances varying from 6 to 27 miles from the observatory. (2)

Until the 29th of April, Halemaumau continued to be a fuming empty pit in practically the same condition as during the month of March. On the 29th, there was a marked subsidence accompanied by small avalanches and on the 30th, the bottom of the pit had sunk to 500 feet below the rim. (3)

During the month of April seismic activity increased and the center of the disturbance was soon located in the Kapoho District, approximately 30 miles in an easterly direction from Kilauea near the east point of Hawaii. On the night of April 22-23, pronounced cracking and faulting of the ground began at Kapoho. As the cracks opened gently no great damage occurred, and after several days the faulting ceased. Fault scarps 8 to 12 feet higt and fissures 15 feet wide had developed. The trend of these cracks is N. 60° E., and hence is parallel to the Puna Rift of Kilauea, a narrow zone about 1 mile wide extending easterly from Kilauea, covered with cones, craters, and fissure erup-

---

(1) *Mon. Bull. Hawaiian Volcano Observatory*, vol. XII, No. 2, p. 10. Feb., 1924.

(2) *Idem*, vol. XII, No. 3, p. 14. March, 1924.

(3) *Idem*, vol. XII, No. 4, p. 23. April, 1924.

tions. In some places this rift becomes a shallow graben as a result of the subsidence along the rift. The faulting and fissuring during this seismic crisis was limited to this rift zone and is simply a renewal of the sinking of the graben. Three hundred and fifty eight earthquakes were recorded at the observatory during the month of April. (1)

No lava outbursts accompanied this subsidence and fissuring and no new steam vents were formed. The Puna Rift of Kilauea has been the scene of outbreaks in 1922 and 1923, and hene it is reasonable to assume that this rift was filled with lava until the recession of the lava in Halemaumau in February. When the lava columm of Kilauea subsided it is probable that the lava in the Puna Rift drained downward also. The writer, therefore, fully concurs with Doctor Jaggar's opinion (2) that the Kapoho faulting resulted from the draining downward ot the lava under Kilauea.

The exceptional faulting in Puna, and the subsidence of the lava and the accompanying collapse of the pit of Halemaumau indicate that the lava column of Kilauea was rapidly sinking. This subsidence of the lava column played a major rôle in the great explosion of Kilauea.

Avalanching at Halemaumau. — The " pit of everlasting fire „ of Halemaumau had become a black smoking hole when the lava disappeared from view on February 21. It had remained in this condition until the 29th of April when the bottom began to drop and avalanching of the walls began. This is definite proof that the lava column of Kilauea had begun to subside rapidly. Accompanying this subsidence, talus slopes began to build up at the foot of the walls of Halemaumau.

The collapse of Halemaumau increased, and by the end of the first week of May the bottom was over 700 feet below the rim. (3) The avalanching continued to tear hundreds of tons of rock from the rim of the pit and to pile the debris on the subsiding bottom. By May 10, large clouds

(1) *Mon. Bull. Hawaiian Volcano Observatory*, vol. XII, No. 4, p. 24. April, 1924.

(2) *Idem*, p. 22.

(3) *Idem*, vol. XII, No. 5, p. 39. May, 1924.

of dust rose from the pit as the avalanching went on unabated and during the night of May 10-11, a small explosion occurred which threw out rocks. One rock, weighing about 100 pounds, was found 750 feet back from the rim. (1).

The explosions.

This small explosion of May 11 was the beginning of the first explosive phase of Kilauea ever witnessed by white men. Avalanches continually thundered to the bottom and were accompanied by seismic disturbances. On May 12 more small explosions occurred and continued at frequent intervals with increasing violence until they reached a maximum on Sunday morning, May 18. The maximum earthquake frequency, however, did not occur until May 24. (2).

On Sunday morning, May 18, at 11,02, an explosion occurred in the pit of Halemaumau which sent up a huge cauliflower explosion cloud. (See Pl. II) Explosion after explosion occurred each one accompanied by tight cauliflower clouds until 12,15 p. m., when mist and fog obscured the wiew. During the explosion spasm, the ground was almost continually in vibration and sharp earthquakes were frequent.

Enormous rocks were hurled skyward by the explosions and one 10-ton block fell 3,500 feet from the center of the pit. (See Pl. III) One man, who had ventured too near the pit, was knocked down by a barrage of stones and died that night from internal hemmorhages (3). The cauliflower dust clouds accompanying the great explosions of May 18 probably rose at the rate of 75 to 100 feet a second. It is estimated that they reached a heighf of over 4 miles. A severe electrical storm began about noon, and about 5 miles away 21 consecutive telephone poles were destroyed by lightning. There was also a heavy downpour of rain which corrugated the new ash deposits southward from

---

(1) *Mon. Bull. Hawaiian Volcano Observatory*, vol. XII, No. 5, p. 40. May 1924.

(2) *Idem*, p. 44.

(3) Stearns, Harold T., *The 1924 eruption of the Hawaiian Volcano* · Scientific American, vol. 132, No. 4, p. 242. April, 1925.

Halemaumau. A heavy fall of ash occurred at Pahala, 21 miles southwest of Kilauea.

Another great explosion accompanied by rock showers began at 7,14 p. m., on the same day. Observers at the Hawaiian Volcano Observatory noted that most of the ejections were northward toward Uwekahuna Bluff at this time. The writer later found a 60-pound rock on the lower bench of the bluff which was doubtless hurled out during this explosion. It is located 5,000 feet northeastward from the center of the pit and 200 feet above the rim.

At 8,07 a. m., May 22, the Volcano Observatory, about 2 miles from Halemaumau and located on the rim of the outer crater, was set into vibration by an earthquake. At 8,10 a. m., only 3 minutes later, a cauliflower explosion cloud began to rise from the pit of Halemaumau. With it were a large number of rocks, and one minute later rocks could be plainly seen falling on the north side of the pit. The continual din of falling rocks upon the lava surrounding the crater could be heard distinctly at the observatory. The main part of the shower fell during the first two minutes. One minute after the beginning of the explosion, the tight cauliflower cloud had attained an altitude of 3,200 feet and showed by its fork shape that it had resulted from two major explosions. The one on the north side, however, brought with it the larger portion of the rocks. (See Pl. IV) Explosion after explosion occurred, and at the end of another minute it was evident that the north side of Halemaumau was the source of most of the explosions. By 8,12 the north fork of the cloud had gained approximately 1,800 feet in height over the south fork. At this time the rock shower reached its maximum, and convection clouds began to form around the dust column, increasing in size as the column mounted higher. (See Pl. V).

At the end of four minutes the sound of falling rocks had practically ceased and the cauliflower cloud had begun to expand laterally. The explosions continued, however, but with less violence. (See Pl. VI) By this time the dust column had risen about 8,000 feet, and measured over 4,000 feet in diameter and still was not affected by the wind. The awesome silence that existed after the rocks had ceased falling was soon broken by detonations of thunder. Several

short flashes of lightning shot through the dust column and then it began to rain.

At 8,16, or six minutes after the explosions began, the cauliflower cloud was still tight and moving upward at an approximate speed of 16 feet per second. At this time it had reached a height of 10,000 feet and convection clouds were forming around its summit. Sand could be seen falling out of the cloud in long wispy streaks. (See Pl. VII).

About 8,17, another large explosion occurred which sent up a tight reddish brown cauliflower cloud that ascended rapidly in the wake of its predecessors, and at 8,18 the dust column was about 11,500 feet high. (See Pl. VIII). At 8,19, the tight explosion cloud of 8,17 was distinctly outlined against the soft column of dust of the previous explosions. (See Pl. IX). At the end of ten minutes, the cloud reached a height of nearly 3 miles, and the force of the explosion had reached its maximum for a few seconds later the top of the column bent over and soon the whole cloud was blown southward over the Kau Desert. (See Pl. X). Minor explosions continued for several minutes, and then the pit of Halemaumau returned to the same steaming condition as before the explosions. About twelve major explosions had occurred.

Meausurements from the photographs of the cloud indicate that the explosion ascended at the rate of about 55 feet per second for the first minute, 35 feet per second the second minute, 28 feet per second the third minute, and about 17 feet per second for the remaining seven minutes of the explosion.

The interludes between explosion spasms were characterized by avalanches, earthquakes, dust and steam clouds. On the afternoon of May 21, the writer descended by way of the Halemaumau road to an advantageous position a few hundred feet from the floor of Kilauea, hoping to view an expected explosion. No explosion occurred. However, the following notes taken at that time give a vivid conception of the events at Halemaumau between the times of the explosions. Steam was issuing from peripheral cracks a foot or more wide, adjacent to the rim of Halemaumau. A column of steam, colored brown by dust, was rising fully 500 feet above the pit. It was too dense for light to

pass through. At 2,15 p.m., there was an avalanche of the rock forming the rim of the pit. (See Pl. XI). One minute later, out of the pit there arose a dense cloud of dust formed by the pulverized material of the landslide being carried upward by the rapidly rising steam. (See Pl. XII). When the column of dust had risen about 200 feet, one could see a down draught of air carrying with it considerable dust. At 2,19 a slight tremor was felt by those sitting on the ground, but those standing up were not aware of it. A slightly stronger one at 2,23 p.m. was felt by all. Two minutes later, a column of reddish dust rose from the pit, evidently tinted by the color of the particular lava that fell into the pit at the time. At 2,26 another avalanche could be heard roaring to the bottom of the pit. This was followed by another larger one at 2,30.

The dust column that started at 2,15 reached a maximum height of about three quarters of a mile in seven minutes. At 2,30 fog clouds settled down over Halemaumau and obscured everything. The explosion that was due at this time on the basis of a 12-hour interval, failed to occur. The activity just described may have been a little more continuous than average because it occurred near the time when an explosion was due.

Explosions continued at more or less regular intervals with decreasing intensity until May 27 when the pit returned to a condition of steaming, avalanching, and dust making, similar to the period before May 11. The Hawaiian Volcano Observatory records show that the explosive spasms occurred at an average interval of two hours on the 13th, and from that date until the 23d, 6 to 12 hours. Some of the explosions were predicted nearly to the minute on the basis of these regular intervals. (See Pl. XIII).

Phenomena accompanying the explosions.

Earthquakes. — During the month ending midnight, May 31, 1924, 3,961 local earthquakes and one teleseism were registered at the observatory. Most of them seem to have originated near Halemaumau although a few occurred in the vicinity of nearby faults. The maximum seismic activ-

ity occurred on May 24 , when 467 earthquakes were recorded. Sharp shocks usually occurred a short time before each explosive spasm.

Lightning. — Flashes of lightning usually accompanied each explosion spasm, and as the cauliflower clouds ascended they usually set up powerful convection currents. These currents frequently caused thunder storms accompanied by heavy downpours and mud rains.

Erosion. — The heavy downpours of rain accompanying the eruption rilled the surface in the vicinity of the crater, cut many new gullies, and deepened those already existing in the ancient ash beds on the south rim of Kilauea caldera.

Ejectamenta. — Surprising as it may seem, no juvenile or essential ejectamenta, no pumice, no cinders, nor Pele's hair were thrown out during the explosions. The projectiles consisted entirely of blocks of rock torn from the throat of Halemaumau or old talus debris. The fine material consisted entirely of pulverized rock, as no ash could be found even by a microscopic examination.

The glowing ejecta frequently seen in the rock showers proved, upon examination, to be hot blocks torn from various partly cooled intrusive bodies in the walls of Halemaumau. These intrusive bodies glowed at night, but during the day time appeared perfectly solid and one of them exhibited beautiful columnar jointing. Frequently blocks from these bodies thrown out by the esplosions showed slight breadcrusting due to their sudden chilling.

Each rock shower accompanying an explosion was always confined to a certain sector, evidently due to the directed force of the explosion. For this reason some sectors around the pit received more debris than others. The impact of the rocks made pits of various sizes which gave the area adjacent to the pit the appearance of the bombed battle fields of France. The fine sand-like material also frequently fell in certain sectors but the dust was usually carried southwestward with the prevailing winds. Fortunately, the Observatory is situated on the windward side

of Halemaumau and 2 miles away, hence it received only a small amount of dust.

Volcanic dust fell over much of the Hilo, Puna, and Kau districts, and fell in small quantities many miles out at sea. Frequently, after a large explosion, the dust would be carried miles to the southwest in the upper atmosphere. The dust fell as a gray fluffy material and gave the vegetation a uniform and sickly appearance. After a rain this dust hardened into a gray compact coating like cement.

On the morning of May 25, from the side of Mauna Loa, a white steam cloud was seen by the writer rising from Kilauea indicating that the avalanching had ceased for a time. At Wood Valley, at an elevation of 1,900 feet and about 20 miles southwest of Kilauea crater, a dense cloud of dust from Kilauea, which had resulted from an explosion of about a half hour before, was encountered. It was evident that this was the center or the densest part of the explosion cloud. In the vicinity of the crater, the densest parts of the dust clouds usually drifted far overhead. Sharp sand, 1 millimeter in diameter, showered down, stinging hands and faces. It fell so rapidly that it slid down the wrinkles of clothing in continuous streams. It was impossible to see a building 150 feet away and some people passed by carrying lanterns. By riding crosswise to the shower, the thickest of the dust was left behind at an altitude of about 2,800 feet.

During the previous week the fall of dust had amounted to about 1 millimeter every 24 hours at Pahala.

Based upon an area of 60 square yards that was swept up and weighed by Mr. W. O. CLARK, there was approximately 400 pounds per acre falling every 24 hours at Pahala. The total fall in the vicinity of Pahala during the explosive phase of Kilauea must have been from 2 to 3 tons per acre. Some of this dust, however, was probably wind-blown from the Kau Desert.

The maximum depth of explosion debris was on the rim of Halemaumau. In July, the writer accompanied Dr. T. A. JAGGAR, Director of the Hawaiian Volcano Observatory, around Halemaumau and made measurements of the amount of explosions debris on the rim. It ranged in thickness from 6 to 17 inches, but the pit by this time had

increased considerably by peripheral collapse. Doubtless the debris on the rim during the explosions was over 2 feet thick in many places.

Pisolitic mud showers. — Pisolitic mud showers accompanied many of the explosion spasms. The rain in falling through the thick dust-laden air formed spheres of mud, or pisolites, some 3 millimeters in diameter. These pisolites fell in such abundance after the morning explosion spasm of May 18 that a layer an inch thick was formed on the south rim of Kilauea Crater, the direction in which most of the dust cloud had been blown by the wind.

The writer was 1½ miles southwest of Halemaumau two hours after the explosion of 8,10 a.m., May 22, when a shower of brown, dry, compact pisolites about 1 millimeter in diameter fell on him. It was evident from the conditions at Halemaumau that these pellets were formed by the condensation of steam and the accretion of dust particles as the drops of water fell through the dust laden air. Some of the moist pisolites when falling during a gust of wind would strike the fluffy dust and roll along increasing in size snowball fashion. This undoubtedly explains the origin of some of the larger pisolites. In some cases grains of sand would do likewise.

Gases. — Observations, in so far as it was possible to make them under the circustances, indicated that no asphyxiating or highly inflammable gases accompanied the explosions. Truman A. TAYLOR, who lay mortally injured from a shower of rocks less than 1,000 feet from Halemaumeu during the great explosion of May 18, was not troubled by poisonous or asphyxiating gases. He suffered sligtly from hot mud burns, but all facts indicate that the explosions were relatively low temperature explosions. No one positively identified any burning flames in the explosion clouds.

A white incrustation determined by O. H. EMERSON, of the Volcano Observatory, to consist chiefly of sulfates, formed on the floor of Kilauea crater in the vicinity of Halemaumau. This deposit indicated that there was either

small amounts of sulfurous gases present or sulfates in the ash.

With respect to gases, the 1924 explosive phase of Kilauea was vastly different from the explosive phase of 1790. A short quotation from Rev. I. DIBBLE's " History of the Sandwich Islands, „ published in 1843, which was taken by him from the lips of the natives who were present at the scene, vividly illustrates the difference :

" The army of Keoua a Hawaiian chief , being pursued by Kamehameha, were at the time near Kilauea. For two preceding nights there had been eruptions, with ejections of stones and cinders. The army of Keoua set out on their way in three different companies. The company in advance had not proceeded far before the ground began to shake and rock beneath their feet, and it became quite impossible to stand. Soon a dense cloud of darkness was seen to rise out of the crater, and almost at the same instant, the thunder began to roar in the heavens and the lightning to flash. It continued to ascend and spread around till the whole region was enveloped, and the light of day was entirely excluded.

" The darkness was the more terrific, being made visible by an awful glare from streams of red and blue light variously combined through the action of the fires of the pit and the flashes of lightning above. Soon followed an immense volume of sand and cinders, which were thrown to a great height and came down in a destructive shower for many miles around. A few of the forward company were burned to death by sand, and all of them experienced a suffocating sensation.

" The rear company, which was nearest the volcano at the time, suffered little injury ; and after the earthquake and shower of sand had passed over, hastened on to greet their comrades ahead on their escape from so imminent peril. But what was their surprise and consternation to find the center company a collection of corpses. Some were lying down, and others were sitting upright, clasping with dying grasp their wives and children , and joining noses (the mode of expressing affection) as in the act of taking leave. So much like life they looked that at first they supposed them merely at rest, and it was not until they had

come up to them and handled them that they could detect their mistake. Mr. DIBBLE adds : A blast of sulphurous gas, a shower of heated embers, or a volume of heated steam would sufficiently account for this sudden death. Some of the narrators, who saw the corpses, affirm that though in no place deeply burnt, yet they were thoroughly scorched „.

It is evident from the preceding description that the explosive phase of Kilauea in 1790 was a juvenile explosion. Cinders, flames, bombs, and asphyxiating gases accompanied the explosion. The writer has found many of the lava bombs of the 1790 eruption and PERRET has described some in detail (1).

THE POSTLUDE

By May 26, the explosive force had spent itself sufficiently so that one could approach the rim of Halemaumau with some confidence. To reach the rim it was necessary, however, to step over cracks a foot wide upon portions of the rim which might avalanche at any moment. The bottom of the pit consisted of composite fans of talus through which steam rose in many places. (See Pl. XVI). Several intrusive bodies were visible in the walls of Halemaumau, some of which were still hot. No liquid lava was to be seen, however.

The pit remained quiet from May 29 until the return of the lava on July 19. On some days, especially during the first few weeks in June, there were occasional avalanches, gas rushes, and whirlwinds, but usually there was only a little steam escaping from the pit. During the middle part of the day, when the temperature was highest, the whole pit was frequently free of steam except for occasional little puffs.

Measurements of the pit on June 4 indicated that Halemaumau had increased in size to 3,400 feet long north-

---

(1) PERRET, F. A., *Some Kilauean ejectamenta:* Amer. Jour. Sci., vol. XXXV, June, 1913.

east-southwest, and 3,000 feet wide, northwest-southeast. The lowest part of the bottom was 1,335 feet below the rim (1).

About noon, July 19, the lava came back into the pit. It broke through the talus on the west side in a fountain over 100 feet high. The flow lasted for several days and formed a pool of lava in the bottom of the pit. There was no warning that the lava had returned other than an increase of the blue fumes rising from the pit. (Pl. XVII).

CAUSE OF THE EXPLOSIONS

In order to comprehend the mechanism of the explosions, it is necessary to understand fully the occurrence of ground water under the volcano of Kilauea. Detailed investigations of the water table under the volcano were made by the writer. Kilauea forms only a part of the great volcanic slag heap that is known as the island of Hawaii. The whole island consists of lava flows upon lava flows, porous and shattered, which at first were poured out under the ocean but now are largely poured out on land. Therefore, in the early development of the island, the salt water table doubtless passed through the island nearly at the same elevation as mean sea level. As the island increased in height, and obstructed the trade winds, precipitation on it increased and there formed above the salt water table a low dome of fresh water. With the increase in the size of the island and a proportionate increase in the precipitation, the dome of fresh water floating upon salt water must have increased also, and depressed the salt water level under the island.

At the present time a large portion of Kilauea, especially the east slope, receives a heavy rainfall. The mean average annual rainfall at the Observatory is nearly 80 inches (203 cm.), and at Olaa, 150 inches (381 cm.).

As there is practically no run-off from the cone of Kilauea, huge volumes of water annually percolate downward

---

(1) JAGGAR T. A., and FINCH, R. H., *The explosive eruption of Kilauea in Hawaii, 1924.* Amer. Jour. Sci., 5th ser., vol. VIII, No. 47, p. 374. November, 1924.

to the ground water reservoir. All along the coast of Kilauea there are springs where the ground water dissipates itself into the sea. A basaltic cone is extremely permeable, and large volumes of water can find their way with little difficulty through the various lava structures, such as tubes (canali) and *aa* (a blocchi) lava flows.

The explosions of Kilauea in May, 1924, were phreatic (1). The eruptions were primarily low temperature steam explosions, and these necessitate water derived either from the magma or from the ground-water reservoir. There is no evidence to support the hypothesis that a large portion of the steam was obtained as juvenile steam from the Kilauea magma. The low temperature, duration, and characteristics of the explosions exclude the possibility that they could have been caused by the combination of magmatic hydrogen and oxygen. It remains, therefore, to explain them on the basis of the remaining supply, — groundwater.

The tremendous collapse following the subsidence of the lava column is unprecedented in the records of the Observatory. If the interpretation of the faulting in the Kapoho region is correct, then even the magma in the rifts of Kilauea was drained downward. A marked subsidence of the lava column of Halemaumau can be explained by deep intrusion, by a submarine lava flow, or by several other causes. However, no conclusive data are available to indicate where the magma went. Regardless of what became of the magma there was a great engulfment at Halemaumau in the two weeks preceding the explosions. The peripheral faulting accompanying the collapse caused thousands of tons of rock to avalanche into the bottom of the pit.

If we assume that the lava column of Halemaumau subsided some 3,600 feet or below sea level, then it would be possible for the water table to close in above the lava column. During normal times the fissure-shaft which feeds Halemaumau must be completely surrounded by ground water below the water table. Normally, therefore, the water is unable to find its way into the shaft because of the shell

---

(1) i. e., According to SUESS, original definition: an explosion not accompanied by fluid or magnatic ejectamenta.

of solidified lava and the back pressure of the gas cushion surrounding the magma fissure-shaft. However, when the magma subsides below sea level, it leaves above it a fissured, shattered shaft of hot rock practically free from liquid lava. With an abundant supply of ground water, such as occupies the crevices and interstices below Kilauea, and an extremely permeable formation, it would take only a few days for the ground water to chill the rock walls of the fissure-shaft of Halemaumau and to close in above the magma column. This chilled shaft would then become a depression in the water tables and, like a funnel, would cause the ground water to flow down into it. Once this movement of the ground water had been established, all the water in the surrounding area would migrate toward the depression in order to reach an hydrostatic equilibrium. Because of the high permeability of fractured and jointed basalt, and its high porosity, large volumes of ground water could find its way into the shattered shaft.

Liberal gas effervescence from the lava column or a slight upward movement would reheat the fissure-shaft above it and convert the ground water into steam. The steam formed in this manner would naturally move upward through the fissure-shaft and blow out through the safety valve of Halemaumau. However, the great collapse following the subsidence of the lava caused thousands of tons of debris to collect in the bottom of the pit. It is very probable that this debris plugged the fissure-shaft and acted like a stopper. Steam or superheated water collected in the fissures below until critical temperatures and pressures developed to blow out the stopper. Many facts associated with the explosions indicate that the explosions occurred at shallow depths beneath the bottom of the pit. Some of the large blocks were hurled out during the explosions at low angles with the rim as though discharged from a rifle barrel. This indicates a tight plugging of the vent. Mud may have also helped to seal the vent.

Following each explosion, tons of debris fell back into the pit and peripheral avalanches added more material, so that the plug was immediately replaced for another explosion. Ground water would again enter the fissure-shaft, and when the steam generated reached a critical pressure, another

explosion spasm would result. Thus, Kilauea became a magnificent gigantic geyser. With this geyser mechanism it is not difficult to understand the regular intervals which frequently occurred between explosions. In fact, in the mechanism, in the material thrown out, in the gases present, and in the periodicity, the explosion parallels, except for size, the history of many geysers in Yellowstone Park, U. S. A., or in the Rotorua District, New Zealand.

The writer found after exploring Mauna Loa and Kilauea that explosions of the phreatic type, doubtless due in large part to ground water, had occurred at several extinct craters. In 1925, when in Java, the writer found Papandajan Volcano in a similar explosive phase which could also be best explained on the basis of ground water.

The fact that the lava returned to the pit on July 19 in the usual way doubtless indicates that at no time did the lava contain such amounts of gas as were discharged during these explosions. The conception of the large part played by ground water in a volcanic explosion opens a new field of thought and research. It seems to be the only tangible way to explain such a phenomenon as occurred at Kilauea in May, 1924 (1).

---

(1) See *Bulletin Hawaiian Volcano Observatory*, May and June, 1925.