THE KEAIWA OR 1823 LAVA FLOW FROM KILAUEA VOLCANO, HAWAII[1]

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ABSTRACT

The Keaiwa lava on Kilauea is the oldest lava flow recorded by white men in the Hawaiian Islands. It is remarkable among the many flows from Kilauea because it welled out from a crack 6 miles long, spreading out seaward in a flow which is in places only a few inches thick. The absence of cinder or driblet cones along the crack indicates that the usual fire fountains of Hawaii did not play during this eruption. Attached to the walls of the crack in many places are lava balls that resemble bombs but do not owe their form to projection. Two phreatic explosions occurred along the crack immediately after the eruption.

INTRODUCTION

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 of which have erupted in historic time. The great dome of Mauna Loa rises 13,675 feet above sea-level and is crowned by the 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. In the southwest portion of this basin or caldera is the yawning pit of Halemaumau—"The House of Everlasting Fire."

Halemaumau is usually occupied by a lake of fiery lava which rises and falls according to the state of activity of the volcano. After long intervals of time the quiet lake of lava disappears and sometimes explosions result. Thus in 1790 and in 1924 explosions occurred which hurled huge blocks of rocks into the air and sent up

[1] Published by permission of the Director, United States Geological Survey. The writer is indebted to F. C. Calkins, of the Geological Survey, for constructive criticism of this article.

cauliflower clouds laden with ash and steam several miles into the air.[1] At times the subsidence of the lake has been followed by the opening of fissures on the flanks of the dome from which lava has poured out. These fissures on the slopes of Kilauea do not occur at random but are limited to two definite rift zones, one of which has a general trend to the east and the other to the southwest from Halemaumau.

The eastern slope of Kilauea is well watered by moisture precipitated from the northeast trade winds and hence is largely covered with a tropical jungle. As the winds pass over the top of the mountain they cease to drop their moisture. This meteorologic condition causes the Kau Desert on the leeward or southern and western slopes of the dome.

Flow after flow of lava from the high dome of Mauna Loa has buried the north slope of Kilauea so that it is possible that, within the next century, lava from Mauna Loa may flow into the crater of Kilauea. The great re-entrant in the south coast line of Kilauea is due to the downfaulting of that portion of the dome below the surface of the Pacific Ocean. For a distance of 6 miles, south of the caldera of Kilauea, the slope is about 250 feet to the mile, but in the remaining 3 miles to the coast, there are two fault escarpments over 1,000 feet high. Southwestward these escarpments die out and are veneered by the recent flows from the southwest rift zone.

This rift zone is a fissured shallow graben from 1 to 2 miles wide extending from Kilauea southwestward to the sea. It is from fissures in this zone that many great eruptions have occurred in recent times. For months during 1920 lava flowed in this region from the Maunaiki[2] (Hawaiian for Little Mountain). Maunaiki, the cone built by the 1920 eruption, is a low dome 70 feet high covering an area of about 1 square mile. The lava from this dome flowed to the margin of the flow through a set of ramifying tubes. Most of the lava, when it froze, formed the smooth billowy, *pahoehoe* type of lava which

[1] H. T. Stearns, "The Explosive Phase of Kilauea Volcano, Hawaii, in 1924," *Bull. Volcanologique, International Geophysical Union*, Naples, Vol. II, Nos. 5, 6 (1925), pp. 193–209. *Ibid.*, "The 1924 Eruption of the Hawaiian Volcano," *Scientific American*, Vol. CXXXII, No. 4 (April, 1925), pp. 242–43.

[2] See *Monthly Bulletin Hawaiian Volcano Observatory*, January to June, 1920.

changes at the extremities to the bristling and jagged *aa*[1] type. The flow of 1920 moved forward only a few feet a day so that people were able to witness it at close quarters.

A type of eruption on Kilauea more common than the outbreak of 1920 is that of the 1921 eruption on the floor of the caldera. At that time a fissure opened and low fountains of lava played from it. The scoriaceous lava clots that piled up around the fountains form a line of driblet or spatter cones. Many lines of driblet cones 10–50 feet high can be seen in the southwest rift zone of Kilauea. Cones 50–150 feet high consisting of loose cinders formed by the extrusion of medium fluid lava highly charged with gas are found on Kilauea. The Kamakaia cones are of this type.

In general the lava eruptions of Kilauea build either low domes like Maunaiki, driblet cones such as were built in 1921, or cinder cones similar to the Kamakaia Hills. The flows from any one of these types of cones are usually less than 25 feet and more than 5 feet thick.[2]

LOCATION AND AREA

The Keaiwa or 1823 lava flow on Kilauea is unique among the hundreds of flows from this volcano because it is the first one recorded by white men. Although similar, perhaps, in texture and composition to some other flows, it is unusual because of its source, the manner of its extrusion, and its thinness. It covers an area of 5 or 6 square miles in the Kaalaala and Kapapala lands, in the Kau district, on the southwest slope of Kilauea, 12 miles from Halemaumau. (See Fig. 1.) The flow issued from the Great Crack, a fissure 6 miles long and 2–30 feet wide, one of the series of cracks that mark the southwest rift zone of Kilauea. It is known locally as the Keaiwa flow and covers a triangular area with the base at the sea and the apex 6 miles to the northeast, in the Kilauea section of the Hawaii National Park. It is accessible to hardy tourists, being crossed by the Kau-Puna trail 1¾ miles from the Volcano Road.

[1] The type of lava flow with a relatively smooth surface, often with a satiny or shiny crust that moves forward by projecting one tongue after another is called *pahoehoe*.

The *aa* type of lava flow consists of a field of bristling, jagged, and jumbled blocks that have been produced by the granulation of a stiff, overcooled fluid on the point of solidifying.

[2] The crater of Kilauea and its associated lava flows are well shown on the Kilauea, Pahala, and Puna contour maps of the Geological Survey.

DISPUTED IDENTITY AND EXTENT OF FLOW[1]

The location and extent of the Keaiwa flow have been shown on maps in many different ways, and there is every reason to believe that none of the old records regarding the eruptions were consulted in connection with the mapping. Moreover, the areas were not surveyed but merely hachured on the maps as incidental to the land surveying. A comparison of the Hawaiian Government land maps from 1885 to date shows some remarkable changes in dates and areas for the several flows, especially the flow of 1823. Thus the Keamoku flow from Mauna Loa is shown on one map as the flow of 1823 and represented as flowing down over Kilauea into the sea. Another map shows it separated into two flows, one originating on Mauna Loa and the other on the southwest slope of Kilauea, the latter called the Kamooalii, dated 1823, and shown as if it had flowed into the sea.

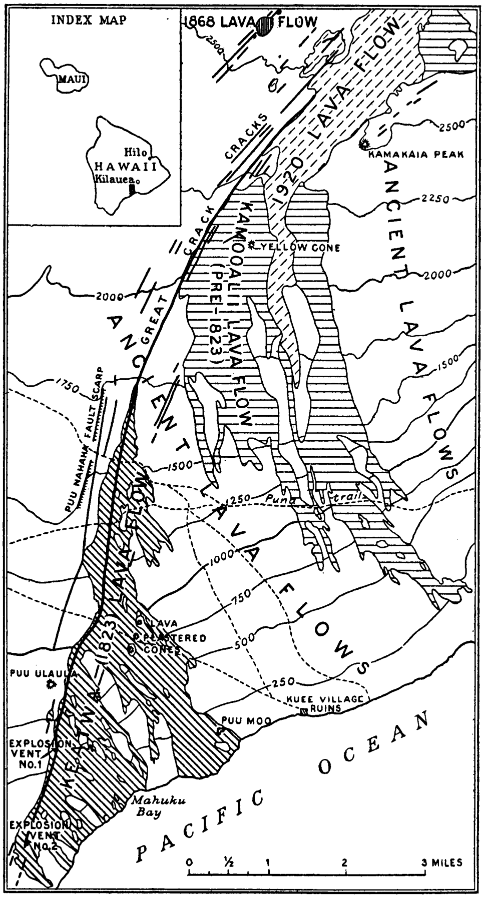

FIG. 1.—Map showing the Great Crack and the lava flow of 1823. Base map by U. S. Geological Survey.

[1] W. O. Clark, of Pahala, Hawaii, first noticed the inconsistencies of maps and descriptions for the date of this flow and concluded that it was the flow of 1823 (oral communication to the author, May, 1924).

Hitchcock[1] disputes the areas and dates of the lava flows shown on one map but in the same publication accepts and reproduces another map without question. This map[2] shows the flow of 1823 as the flow of 1868, and the Kamooalii flow as the flow of 1823 and as reaching the sea. The map was originally prepared by E. D. Baldwin, a land surveyor, who surveyed the region in 1907. Baldwin, in a letter to Hitchcock,[3] gives no evidence to support the date he assigns to the flow marked "'68 crack" except his own opinion, based on the fact that it issued from a fissure and the record that the flow of 1868, some 6 miles to the north, issued from a fissure, and also the fact that both flows are black and fresh in appearance. A field examination of the flow marked by Baldwin "'68 crack" shows that on account of the topography the eastern lobe must have had two sources. Hitchcock himself recognized this dilemma.[4] A field examination shows also that the Kamooalii flow (assigned by Baldwin to 1823) is represented incorrectly as reaching the sea. Both W. O. Clark and the writer have ridden entirely around the Kamooalii flow and thus proved without doubt that it never reached the sea. (See Fig. 1 for correct boundaries of this flow.) The Kamooalii flow therefore cannot be the flow of 1823 because historic records, cited below, show that the flow in 1823 reached the sea and burned a canoe.

Ellis[5] describes the flow of 1823 as witnessed by the natives as follows:

> The people of Kearakomo also told us that no longer than five moons ago Pele [Hawaiian goddess of volcanoes] had issued from a subterranean cavern, and overflowed the lowland of Kearaara [Kaalaala] and the southern part of Kapapala. The inundation was sudden and violent, burnt one canoe, and carried four more into the sea. At Mahuku the deep torrent of lava bore into the sea a large rock, according to their own account near a hundred feet high, which, a short period before had been separated by an earthquake from the main pile

[1] C. H. Hitchcock, *Hawaii and Its Volcanoes*, Hawaiian Gazette Co., Honolulu, 1909; "Hawaiian Earthquakes of 1868," *Seismol. Soc. America Bull.*, Vol. II, No. 3 (September, 1912), pp. 181–92.

[2] C. H. Hitchcock, *Hawaii and Its Volcanoes*, 1909, pl. 26, p. 163.

[3] *Ibid.*, pp. 209–10.

[4] *Ibid.*, p. 208.

[5] William Ellis, *Journal*, Hawaiian Gazette Co., Honolulu, T. H., 1917 (reprint of 1827 edition, p. 200).

in the neighborhood. It now stands, they say, in the sea, nearly a mile from shore, its bottom surrounded by lava, its summit rising considerable above the water.

On Figure 1 is shown the location of Mahuku Bay, 4 miles from Kamooalii flow. It is surrounded, however, by the Keaiwa flow.

Ellis[1] further describes the flow of 1823 as follows:

> It was highly scoriaceous, of a different kind from the ancient bed of which the whole valley was composed, being of a jet-black color and bright variegated lusters, brittle, and porous; while the ancient lava was of a gray or reddish colour, compact, and broken with difficulty.

This is a very exact description of the flow of 1823 as mapped by the writer. The Kamooalii flow, on the other hand, is partly the massive blue *pahoehoe* of the dense type and partly the slow-moving type of *aa* 5–10 feet thick with a decided brown color due to decomposition. Its source is far above the Ponahoahoa Chasms, the place where Ellis visited the source of the flow of 1823. The Kamooalii flow is of the sluggish type which cools quickly and hence could not have reached the sea in time to burn a canoe. Additional evidence was gathered from an old Hawaiian named Pelelili, who resides at present in Wood Valley near Pahala, about 4 miles northwest of the Keaiwa flow. He said he crossed the Keaiwa flow (1823) in 1856, when he moved to Wood Valley from Puna.

Moreover, in 1868 Dr. William Hillebrand and Rev. Titas Coan both searched for the flow of 1868, and Mr. Coan found and mapped it. It is scarcely possible that either of these men could have passed through the region without seeing or hearing about the Keaiwa flow had it occurred in that year. Moreover, Coan frequently made trips into the Kau district after 1868, hence it is exceedingly unlikely that the Keaiwa flow was extruded after his visit in 1868, or else he would have recorded it. Three important trails cross the Keaiwa flow, and the natives at Kuee would have had to cross it in order to reach Kapapala. Certainly, if it had been freshly poured out they would have told about it, and Coan or other whites who spoke Hawaiian fluently would have recorded it.

After a thorough investigation, the writer has concluded that both the areas and dates of the flows shown in Baldwin's map re-

[1] *Ibid.*, p. 165.

produced by Hitchcock are in error, that the Kamooalii flow is prehistoric, and that the Keaiwa flow should be dated 1823.

CHARACTERISTICS OF THE FLOW

Near its source the flow consists of black *pahoehoe* from 1 to 12 inches thick and extremely vesicular. A few hundred feet from the fissure the *pahoehoe* crust is broken and turned on end like slush ice in an ice jam. Farther seaward it becomes *aa*, bristling with jagged and formidable points. Nowhere does the flow average more than 5 feet in thickness, and for the first half mile from the fissure it is only a few inches to 2 feet thick, leaving many kipukas[1] on level ground. (See Fig. 1.) The large number of kipukas on the uniformly sloping plain indicates the extreme fluidity of the lava at the time it was poured out.

A microscopic examination[2] of a specimen from this flow shows that it has the usual microlitic texture of the recent lavas of Hawaii, with large amounts of unindividualized ferritic material and some glassy base. It contains some sharply defined olivine crystals and a few clusters of plagioclase and augite, some of them with associated olivine grains. It is unusually vesicular as compared with other lava flows on Kilauea and is similar to the frothy flows that have issued from fissures on the top of Mauna Loa. Only three other flows from Kilauea are comparable to it. Its rate of movement for a given gradient must have been considerably greater than that of ordinary types of *pahoehoe* or *aa*. It seems to have issued from the fissure as a sheet of lava rather than as a narrow stream, and Ellis' statement that it burned a native canoe upon reaching the ocean indicates that it must have moved very rapidly. The south end of the fissure is only half a mile from the shore; hence it is safe to assume that the flow quickly reached the sea.

In several places the flow was confined to channels, and it happened that a row of old driblet cones stood at right angles to the direction of one of the main channels. As a result these cones, called Lava Plastered Cones (see Fig. 1), formed a dam to the flowing lava, thereby causing it to pond. In a few places it seems as if the

[1] Hawaiian word for an island-like area not covered by a lava flow.

[2] Made by Whitman Cross, United States Geological Survey.

molten lava actually flowed up the slopes of the cones. The dam held long enough for the ponded lava to crust over, but the lava soon found an outlet and drained seaward. The shore lines of this pond are now preserved on the slopes of the cones 5–34 feet above the present surface of the flow. The large cone just south of the Kuee-Kau trail has a thin crust of Keaiwa lava smeared over its entire northern slope and 34 feet above the present level of the flow. In a few places the lava spilled over the rim into the old craters of the driblet cones, and some of these streams flowed on seaward through a breach where lava had formerly found an exit at the time when these craters were active. Because of the veneer of 1823 lava it might be thought that these ancient cones had been active in 1823. The pond of lava must have drained rapidly, because the shore lines are preserved only at high levels. In places blocks of crust from the upper shore line slid down on the sides of the Lava Plastered Cones to the present level of the flow while the lava was still viscous, as is indicated by the "shark teeth" slickensides developed on the sides of the cones by the sliding crusts.

Tree molds 6 feet high are common on the upper part of the flow, which issued in a region previously covered with vegetation. These are thin shells of lava that cooled around trees. When the lava drained away the congealed lava molds remained standing. Some of the molds contain charcoal, and on some of them is preserved the impression of the tree bark, indicating that the lava chilled very quickly. Fragments of *ohio lahua* tree still occur on the surface of the flow near the molds, and most of them are only very slightly charred (see Fig. 2). On the edge of the flow, not more than 10 feet away, there are dead trees still standing that were killed by the heat. Ellis, who visited the flow a few days after its eruption, describes it as follows:

> The appearance of the tufts of long grass through which it had run; the scorched leaves still remaining on one side of a tree, while the other side was reduced to charcoal, and the strings of lava hanging from some of the branches like stalactites, together with the fresh appearance of the shrubs, partially overflowed and broken down, convinced us the lava had been thrown out only a few days before.[1]

[1] William Ellis, *Journal*, Hawaiian Gazette Co. (Ltd.), Honolulu, Hawaii, 1917 (reprint of 1827 edition, p. 165).

In places where thin streams of lava overflowed grassy areas the under surface of the lava is a mold of the grass and sticks on which it cooled (see Fig. 3).

A quarter of a mile south of Puu Ulaula and 500 feet west of the Great Crack there is a fissure 1,700 feet long which has been the source of a prehistoric flow and from which a small tongue of lava also has issued. The lava is black, fresh-looking *pahoehoe*, resembling in general the flow of 1823 with which, however, it is nowhere connected and cannot be definitely correlated. In all probability, however, this flow originated at the same time as the lava that issued in 1823 from the Great Crack, 500 feet away. (See Fig. 1.)

FIG. 2.—Tree mold in the 1823 lava flow with fragments of charred wood nearby. Photograph by Harold T. Stearns.

SOURCE OF THE FLOW—THE GREAT CRACK

The Great Crack is one of a number of open cracks that fissure the southwest rift zone, a belt 1–2 miles wide extending southwestward from Kilauea to the sea. Throughout most of its length (see Fig. 4) the Great Crack has the general appearance of a steep-sided trench 20 to 30 feet wide. A few yards north of the head of the Keaiwa flow the crack breaks up into many smaller ones. There are also graben areas which seem to have been produced by the separation of the fissure into two cracks for a short distance and the later collapse of the narrow slices thus formed, with the subsidence of the

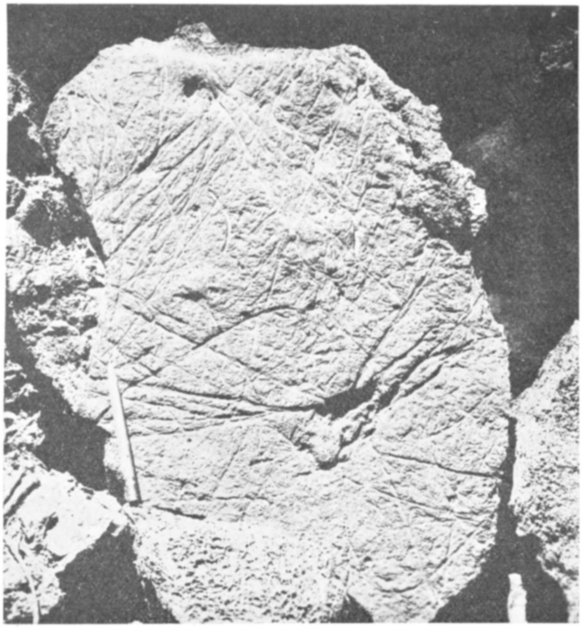

FIG. 3.—Grass impressions on the under surface of a cake of the lava of 1823 near the Great Crack. Pencil gives scale. Photo by O. H. Emerson. Courtesy of the Hawaiian Volcano Observatory.

FIG. 4.—The Great Crack from which the flow of 1823 issued. The trees grow in kipukas on older lava. Note the thinness of the flow. Photograph by Harold T. Stearns.

magma. In other places the graben is due to the collapse along the walls bordering the fissure when the region settled down after the extrusion of the lava. In a few places, especially near the sea, the Great Crack decreases in width to about 2 feet, and it finally dies out in échelon fashion at the coast. The cracks beyond the area of extravasation are only a few inches wide.

The Great Crack, which extends from 300 to 2,500 feet above sea-level, differs from the others only in its continuity; it can be traced continuously for about 8 miles, and before it was buried by the flow of 1920 it must have been traceable still farther toward Halemaumau. However, the mere fact that the Great Crack is continuous does not necessarily indicate that it was all opened at one time. There is ample evidence to show that it belongs to a system of fissures from which lava has poured out again and again. The Kamooalii flow and the flows of 1868 and 1920 issued from these fissures, and there is evidence that all the lava flows from the west side of Kilauea come from the same system.

The remarkable feature of the flow of 1823 is that it issued from the Great Crack along a continuous length of nearly 6 miles. This is unusual, because fissure eruptions in Hawaii tend to break out spasmodically from several parallel fissures at different altitudes. Evidence that lava issued from the entire length of the fissure is given by the occurrence of lava clots on both sides for the entire length. Furthermore, the topography of the area covered by the flow (see Fig. 1) makes it seem impossible that the flow should have originated in any one part of the crack. The walls of the fissure are plastered with a thin veneer of lava that froze on the walls as the lava subsided. The trickles and stalactites of lava that make up this veneer have been interpreted incorrectly by Powers[1] as proof that the fissure opened "as the flow was cooling." He also states that "the flow covers the country for one-fourth of a mile on either side of the opening." This is true in only one place along the entire length of the fissure. Everywhere else the flow is not more than a few yards wide, and in some places it extends only a few feet on the west side of the fissure, for the altitude of the surface prevented the lava from flowing farther in that direction.

[1] Sidney Powers, "Tectonic Lines in the Hawaiian Islands," *Geol. Soc. America Bull.*, Vol. XXVIII (September 21, 1917), p. 508.

LAVA FORMS IN AND NEAR THE GREAT CRACK

The walls of the Great Crack, in many places, show not only frozen trickles of lava but also large numbers of spherical lava balls imbedded in a matrix of 1823 lava. (See Fig. 5.) The writer has called these spherical masses "lava balls" to distinguish them from bombs. They are more or less spherical and range in diameter from a few inches to 3 feet. Some of them are perfect spheroids—for example, the one illustrated in Figure 6 which is 85 millimeters ($3\frac{1}{2}$ inches) in diameter and was collected from a wall of the Great

FIG. 5.—Lava balls imbedded in the lava of 1823 lining the wall of the Great Crack. Photograph by R. H. Finch, Hawaiian Volcano Observatory.

Crack. They have been seen also in the walls of other fissures from which frothy *pahoehoe* of the same type has poured out.

These balls are formed in three ways. The lava clots thrown into the air during the extravasation of the lava are scattered at distances as great as 200 feet from the fissure, indicating that the fountaining was violent and spasmodic. As no spatter cones exist on the fissure, it is probable that the eruption did not continue for a long time at any one place. During the eruption some of the clots must have fallen back into the crack filled with hot lava, and, being somewhat viscous and hence heavier than the rising gas-impregnated magma, they sank into it in the same manner as the blocks of crust founder in the fiery lake of Halemaumau. As they sank the clots grew by accretion into spherical masses, and when they floated up again were caught on the edge of the fissure, where they are exposed today. Others, doubtless, were carried away by the flowing lava. In Figure 7 is given a cross-section of the ball illustrated in Figure 6, showing its rind or skin and its core. The texture of the balls shows that the interior and skin are derived from the same

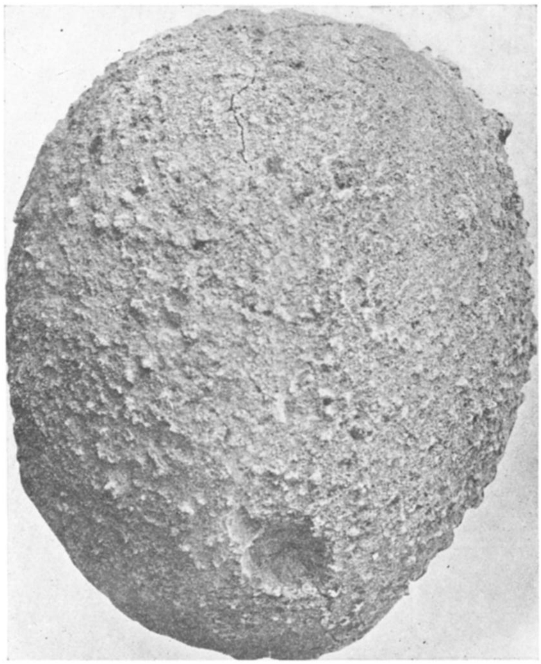

FIG. 6.—A lava ball from the Great Crack. Natural size

magma. The core, however, is more vesicular and has larger phenocrysts. This hypothesis for their origin seems to be the most tenable as no true bombs occur among the lava clots in or near the crack, and none of these balls are found free of the matrix.

Associated with these lava balls, and in outward appearance similar to them, are balls which, when broken open, reveal bits of foreign *aa* that have fallen into the magma from the walls of the fissure. While floating up to the surface these bits of *aa* acquired a skin of lava. Many of these balls measure 30 centimeters (1 foot) or more in diameter, and when broken open they are usually found to contain several separate pieces of *aa* held together by a skin of the lava of 1823. The included fragments show no sign of fusion. About 20 feet below the brink of the crack there is exposed in some places a bed of red *aa* 5–8 feet thick made up of the typical loose fragments. Beds like this undoubtedly supplied the material for the cores of the balls of this type.

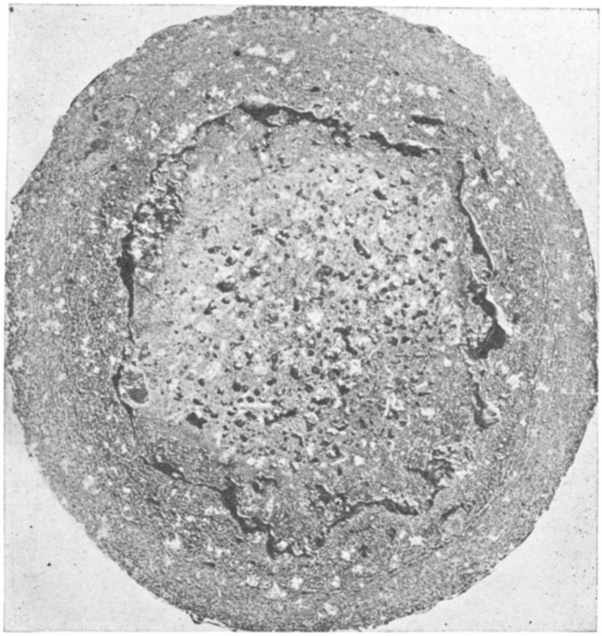

Fig. 7.—Cross-section of the lava ball shown in Figure 6. Natural size

Other balls contained angular blocks of dense, weathered *pahoehoe* that had fallen from the wall, received a coating of lava, and floated up in the same manner. Examination of the balls at ancient fissures somewhat similar to the Great Crack shows that they also originated in this way. The formation of the balls probably requires a magma of a specific consistency and temperature. Projecting portions of the walls of the fissure were coated over and formed parts of spheroids. As no fusion effects were found on the walls of the fissure or on the inclusions, it is concluded that the country rock chilled the magma rather rapidly.

Scattered along the Great Crack and at various distances from it up to about 200 feet are large thin pancake-like clots of lava which resemble large cow dungs in appearance, especially as many of them are stained yellow from chemical action. They are about 30 centimeters (1 foot) in diameter and 1–3 centimeters ($\frac{1}{2}$–1 inch) in thickness. When removed from the *aa* their under surfaces are found to be perfect molds of the underlying rock with its irregularities. The fact that they do not form a continuous coating on the surface near the Great Crack indicates that they resulted from spasmodic eruption in the fissure.

PHREATIC EXPLOSIONS[1]

The eruption of 1823 was unusual because of the two phreatic explosions that occurred at two different places on the Great Crack immediately after the extravasation of lava. The explosion at vent No. 1 (see Fig. 1) was small, for it threw out accessory ejecta[2] most of which are less than 4 inches in diameter, and the area covered by the explosion débris lies within a radius of only 50 feet from the vent. The explosion at vent No. 2 was more violent, for it hurled blocks as large as 1 foot in diameter 200 feet from the vent. The large blocks all occur within 50 feet of the fissure, and the débris is more abundant on the southeast side. The average depth of the débris near the vent is only 3 inches. The blocks from this explosion fell on the lava of 1823, and practically all of them smashed through the frothy crust of the flow after it had cooled. In one place, however, a block was found frozen in the crust, indicating that some of the lava was still viscous at the time of the explosion, which therefore probably took place not more than an hour after the last lava was extruded.

[1] This term is used according to Suess's original definition to indicate explosions not accompanied by the ejection of fluid or incandescent materials.

[2] In his terminology of ejecta the writer follows J. H. Johnston-Lavis ("On the Fragmentary Ejecta of Volcanoes," *Geol. Assoc. Proc.*, Vol. IX [1887], pp. 421–32). He defines them as follows: (1) Essential ejecta are those materials that issue in a fluid state and consist either of the volatile constituents or the magma in which these are contained, that produced the particular emission in question. (2) Accessory ejecta consist of the older volcanic materials of the same vent, torn away, expelled, and mixed with the essential ejecta of an eruption. (3) Accidental ejecta consist of either volcanic materials from other centers, or sedimentary or other rocks of the subvolcanic platform, also torn out, expelled, and mixed with the two before-mentioned ejecta.

A detailed study of the gray, brown, red, and black ejecta torn from the walls of vent No. 2 leads to some interesting conclusions. None of the blocks showed any secondary fusion such as bread-crusting or glazing of their surfaces. A field examination of them showed an absence of essential ejecta. However, among the accessory ejecta were found a few fragments of limestone consisting of brecciated shells and coral. These are the first accidental ejecta ever found on Kilauea. The vent (see Fig. 1) is 280 feet above and only a little over half a mile from the sea. The presence of limestone among the ejecta demonstrates that there is a buried coral reef under this area. The area, therefore, must have been reclaimed from the sea by lava flows. As such reclamation is a common event on Kilauea and Mauna Loa, these ejecta should not necessarily be interpreted as part of a limestone platform extending under the island, as has been suggested by some earlier writers.

As no essential ejecta were found among the débris at the two vents, the explosions were undoubtedly phreatic. The source of the water that caused the explosions were probably the main water table of the island, which is at about sea-level under the vents.

SUMMARY

The Keaiwa flow of 1823 from Kilauea welled up in the Great Crack and spread out seaward as a thin flow, in places only a few inches thick. The absence of cinders or driblet cones in or along the crack indicates that the usual fire fountains of Hawaii did not play during this eruption. Lining the Great Crack in many places are lava balls that appear to be bombs, but that do not owe their form to projection.

After a field examination of the areas and sources of the various flows and a careful investigation of the maps and records regarding the flows dated 1823, it is concluded that the Kamooalii and Keamoku flows are both prehistoric and that the Keaiwa flow is the one that issued in 1823. Its extent and location are shown on the accompanying map (Fig. 1).