

THE VOLCANOES  
OF  
KILAUEA AND MAUNA LOA  
ON THE  
ISLAND OF HAWAII

THEIR VARIOUSLY RECORDED HISTORY  
TO THE PRESENT TIME

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This digression from the chronological record of the Kilauean eruptions seemed necessary to explain the geography of the emptyings of its great cauldron, and will save time later when our notes are more condensed. I have been through Puna many times, and have tried to trace from native tradition this or that eruption in the lava flows that, generally speaking, look all of an age, but I am not certain that any prior to that of 1840 can be correctly identified. I put no faith in the identification of that of 1823 on one of the government surveys, for Ellis closely questioned the natives and

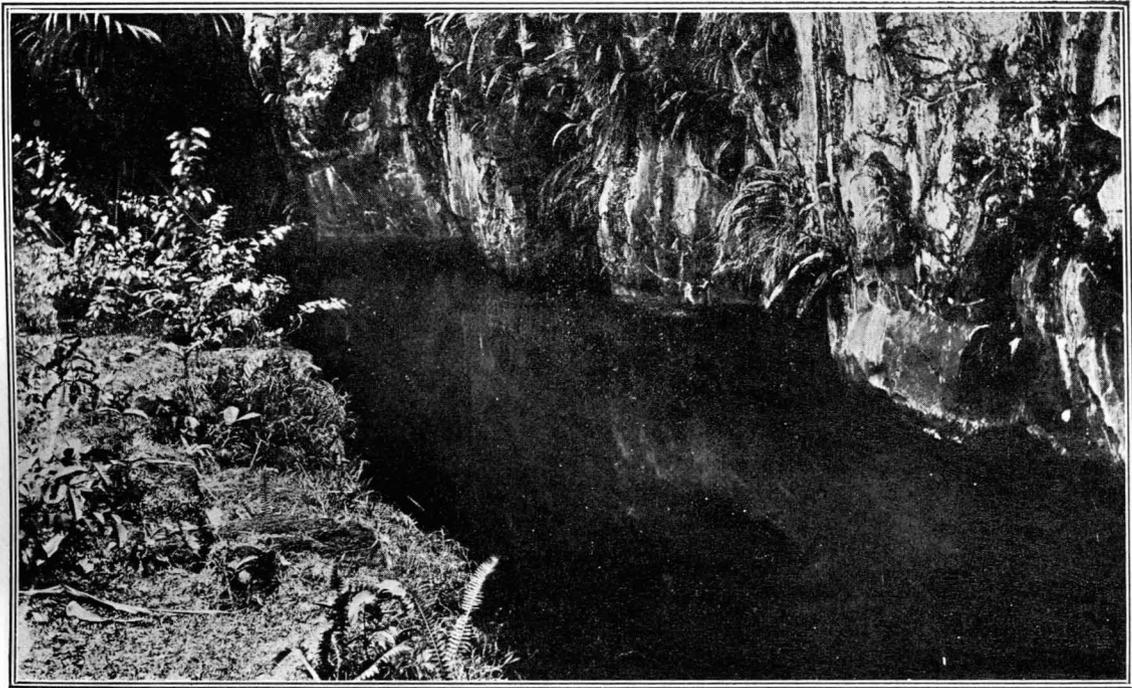


FIG. 67. BLUE POOL.

could not hear of any outbreak from the natives of Puna who met him both in Puna and Hilo. That or any other may be the flow of 1823 if that flow came to the surface on the Hilo side, which it probably did not, so far as the evidence goes.<sup>79</sup>

Since 1865 the great crater of Kilauea had been slowly filling up by the over-  
**1868** flow of the northern lakes of 1864, and of various cones between these and Halemaumau until the whole central portion was considerably elevated.<sup>80</sup> Mauna Loa had also been more or less active since visited by Mr. Horace Mann and myself in 1865. Then the great summit crater Mokuaweoweo was quite still, and apparently cold and extinct, exhibiting hardly any signs of recent action; only on one

<sup>79</sup>The evidence strongly favors the identification of the short flow on the other side of Kilauea as that of 1823, and I have so considered it on the map of Hawaii herewith.

<sup>80</sup>The following account was published in 1869 in the *Memoirs of the Boston Society of Natural History*, vol. i, 564. I have here united the eruptions of the two volcanoes, as the same cause seems to have effected both, and the subsidiary phenomena—earthquakes, landslide, and tidal wave, belong to either or both.

of the lower walls a little steam floated up from the cracks below. No one has ascended this mountain since our visit three years ago, but from the shores the glare of its crater has been distinctly seen more than once in the interval. As it was winter, and the snows and storms rendered the ascent dangerous, no one attempted it, and as no lava stream flowed down, little attention was paid to these distant and temporary volcanic displays.

During the past ninety years ten great eruptions have taken place on Hawaii, averaging one for every nine years, the last occurring in 1859, when a large stream of lava flowed from Mauna Loa some sixty miles into the sea. The lava had accumulated in the reservoirs which supply this mountain and was ready to break forth. To this brief statement of the condition of the Hawaiian volcanoes previous to the present outbreak, may be added the fact that the season had been exceedingly rainy, and the mountain streams were much higher than usual.

March 27, 1868, about half-past five in the morning, persons on the whale ships at anchor in the harbor of Kawaihae saw a dense cloud of smoke rise on the top of Mauna Loa, in one massive pillar, to the height of several miles, lighted up brilliantly by the glare from the crater Mokuaweoweo. In a few hours the smoke dispersed, and at night no light was visible.<sup>81</sup>

About ten o'clock A.M. on the 28th (Saturday), a series of earthquakes began, which has continued at intervals nearly eight months. The shocks commenced early in the morning; the first was followed at an interval of an hour by a second, and then by others at shorter intervals and with increasing violence, until at one o'clock P.M. a very severe shock was felt all through the southwest part of the island. From this time until the 10th of April the earth was in an almost constant tremor. In the district of Kona as many as fifty or sixty distinct shocks were counted in one day; in Kau over three hundred in the same time; while near Kilauea and about Kapapala it was difficult to count them. It is said that during the early part of April two thousand distinct shocks occurred in Kau, or an average of one hundred and forty or more each day. The culminating shock occurred on Thursday, April 2d, at twenty minutes before four in the afternoon. Every stone wall, almost every house, in Kau was overturned, and the whole was done in an instant. A gentleman riding found his horse lying flat under him before he could think of the cause, and persons were thrown to the ground in an equally unexpected manner. Mr. F. S. Lyman was at Keaiwa, near the point where the motion was greatest, between that and the centre of vibration,

<sup>81</sup> Rev. J. D. Paris writes from Kona, Hawaii, "In less than half an hour these columns of smoke had shot up along the slope of the great mountain southward to the distance of ten or fifteen miles. We thought it was from a stream of lava.....but the clouds soon shut in the whole mountain, and nothing more was seen during the day..... During the whole night no light nor smoke were to be seen. All was clear and still as death."

which was not very distant, as the angle of emergence was almost  $90^\circ$ , or nearly coincident with the seismic vertical, and he reported as follows:

First the earth swayed to and fro north and south, then east and west, round and round, then up and down and in every imaginable direction, for several minutes; everything crushing around us; the trees thrashing about as if torn by a mighty rushing wind. It was impossible to stand, we had to sit on the ground, bracing with hands and feet to keep from rolling over. In the midst of it we saw burst out from the pali [precipice] about a mile and a half to the north of us, what we supposed to be an immense river of molten lava (which afterwards proved to be red earth), which rushed down its headlong course and across the plain below, apparently bursting up from the ground, throwing rocks high in the air, and swallowing up everything in its way, trees, houses, cattle, horses, goats and men, all in an instant, as it were. It went three miles in not more than three minutes time, and then ceased. Some one pointed to the shore, and we ran to where we could see it. After the hard shaking had ceased, and all along the sea-shore, from directly below us to Punaluu, about three or four miles, the sea was boiling and foaming furiously, all red, for about an eighth of a mile from the shore, and the shore was covered by the sea. We went right over to Nahala's hill with the children and our natives, to where we could see both ways; expecting every moment to be swallowed up by the lava from beneath; for it sounded as if it was surging and rushing under our feet all the time, and there were frequent shakes. In places the ground was all cracked up, and every rock or pali that could fall had fallen. At Hilea we saw a small stream of black smoking lava, and outside of Punaluu a long black point of lava slowly pushed out to sea and soon disappeared.

Ten miles to the southwest of Keaiwa, at Waiohinu, the great stone church was levelled to the ground (Fig. 68), and nearly all the other buildings were destroyed. The earth opened all through the district, and often left dangerous fissures, although it usually closed. The meizoseismic curve (or that of maximum overthrow) seems to have been elliptical, with a major axis of about ten miles in a southwest and northeast direction, while the isoseismic curves were rather crescent-shaped, having their convexity towards Mauna Loa. In Kona the shocks were severe, but less so than in Kau; At Kohala they did very little damage, not even injuring the tall chimney of the Kohala sugar mill; while at Hilo, on the other side of the mountains, the violence of the vibrations was about the same as in Kona. The mountains seem to have deadened the shock, and simply transmitted it through their solid cones to the axes of the other islands of the group, where the shock of April 2nd was felt as a vibration from the central mountain to the sea. This was the case even in Kauai, nearly three hundred miles distant from the supposed seismic vertical. No damage was done except in these southern districts of Hawaii, where the undulations seemed to bend around the base of the mountain, forcing the isoseismic curves far from the meizoseismic curve in Kau.

At Hilo, although the shock was not so severe as at Waiohinu, more damage was done, for the houses were larger and more numerous. A correspondent writes: "I was coming from the tannery to my store, when I heard a loud, rumbling noise like a number of iron carriages drawn over a rough road by wild horses. Soon the shock came. The horses in the pasture took fright, and ran and snorted, the dogs howled, and the

pigeons flew about as if somebody had been shooting at them. The shock lasted a good while, how long I cannot say, but long enough to make me feel sea-sick, and it was with difficulty that I could stand. All the stone walls about the town were flat. Fissures opened, and the brooks ran mud; in one place a fissure opened about a foot, and when it closed the two sides were several inches from coincidence."

The land-slide referred to by Mr. Lyman, is well described by the Rev. T. Coan, whose letter will be given presently. The most destructive feature of the whole catastrophe, however, was the sea-wave which swept the shores of Hawaii from Kahuku to Kapoho and was felt at the most distant shores of the group. At Hilo the sea receded a hundred and fifty or two hundred feet, and when it returned rose about ten feet above

high-water mark. Along the shore between Kapoho and Kalaie, villages were swept away, and even heavy stone houses disappeared before the destroying waves.

The earth continued to vibrate, but the shocks were not very severe, until on Tuesday night, April 7th, lava broke out in Kahuku, and flowed some ten miles then into the sea. The exact locality of the flow was

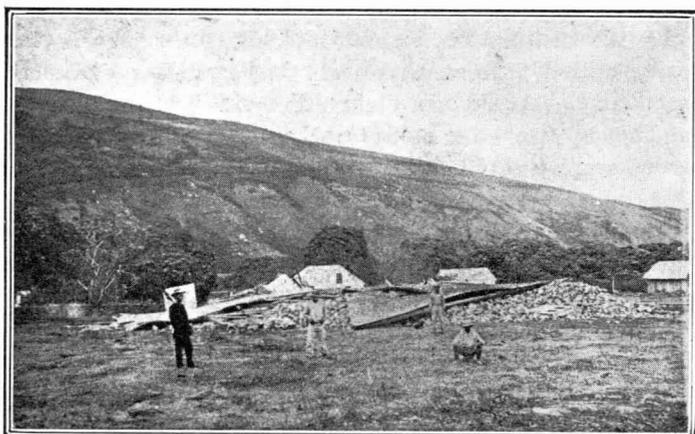


FIG. 68. CHURCH AT WAIOHINU WRECKED BY EARTHQUAKE.

afterwards determined by Mr. Coan. The schooner Oddfellow was cruising along the coast of Hilo, Puna and Kau, about the time of the sea-wave and the eruption, and from the report of a passenger the following notes are extracted. As she touched at many points, the information is of considerable interest.

*Saturday, March 28.*—Lakes in Kilauea active. Portion of the southwest cliff thrown down. *Sunday, 29.*—Shakes frequent but slight; one of them very peculiar in its motion commencing from northwest to southeast, shook a moment, and then shifted to northeast and southwest. North lake quite active. Shocks appear to have been stronger on the beach at Keauhou than they were at the volcano. *Thursday, April 2.*—Severe shock at Hilo. Keauhou and other villages in the neighborhood swept away. *Friday, 3.*—Shocks very violent in Kilauea. Fire in Kilauea iki, the south lake terribly active, and enlarging rapidly. *Saturday, 4.*—Saw fire on the hills at Kapoho; could not tell whether it was a lava-flow or not. *Sunday, 5.*—Made Kealakomo, Puna, at daylight. The houses nearest the beach gone; same at Kahue. All swept clean at Apua. Reached Keauhou, Kau, at seven A.M. and anchored. Found the anchorage and boat-landing all right. Every building, eleven in all, washed away; not a stick or stone of them left standing. Portions of the wreck washed inland over the flat about eight hundred feet; heavy ohia sticks and a large spar were carried that distance. In some places the ground appeared to have sunk, and the sea was flowing a fathom deep where

houses formerly stood. Men who were at work near the beach at the time of the shock (April 2), say that the walls of stone buildings were thrown outward by the shock, which was so severe that they were themselves thrown off their feet; then the sea came pouring over the rocks which lined the shore, and they escaped being overtaken by the hardest kind of running. No one was hurt. A messenger from Kilauea reports that hardly a sign of fire was to be seen in the crater. Got under way and ran down to Punaluu. *Monday, 6.*—Too rough to attempt a landing. The stone church and all the other buildings near the sea gone. At Ninole but three houses were left. Smoke or steam is issuing from the hills back of Hilea. Came to anchor at Kaalualu at noon. The houses, wharf, etc., all gone here, and the rocks inland strewn with the wreck for a distance of six or eight hundred feet. Dense clouds covered the summit of Mauna Loa, but no sign of fire, and no reflection from Kilauea. *Tuesday, 7.*—The deck covered this morning with very fine ashes. Procured animals, and rode along the beach to the south point. The sea had been inland in some places, a hundred and fifty yards, and the whole coast was lined with house timbers, lumber, broken canoes, dead animals that had drifted ashore. At Halii found the body of a native woman lying among the rocks, the right leg bitten off at the knee, and the body otherwise horribly mutilated by the sharks. The shock of the earthquake was evidently slight in this direction, for many of the stone pens were not much damaged, and at Kalae, the extreme southerly point, there was no sign of any disturbance. Weighed anchor at three P.M., and ran past Kalae. At six P.M., when the point was about ten miles astern, bearing E. by S., a volume of flame shot up from the mountain Loa, in what appeared to be the neighborhood of Kahuku. The heavens were lighted up at once, and the reflection extended rapidly in the direction of Waiohinu and Kaalualu. After the first outburst we saw the fire but once or twice, and then it appeared to be the grass burning on the edge of the cliff which extends inland from the south point. There was no flow of the lava over the cliff, nor toward Kona, and the stream probably ran down on the Kahuku flat or between there and Waiohinu to the neighborhood of the Kaalualu landing. It reached the sea somewhere in that direction at nine and a half P.M., when an immense body of steam at once arose, through which flashes resembling lightning were constantly darting as long as we were in sight. The top of the mountain was concealed by the dense clouds of smoke.

From a schooner at anchor off Lanai the light of this lava-stream was seen about midnight, over the mountain, while flashes like chain-lightning shot up into the clouds. From Lahaina the same light was seen, and the next day a column of smoke in the same direction. From Kona the light was first seen about eleven P.M. The Rev. S. E. Bishop, president of Lahainaluna Seminary on Maui, contributes the following observations:

During the night of April 7th a bright but varying crimson light over the volcano was visible from the Seminary at the distance of one hundred and twenty statute miles as measured on Wilkes' chart. This light was a reflection from a mass of cumulus cloud through which vivid lightning was constantly darting. After daylight and through the morning of the 8th, this stupendous column of cloud was visible pouring rapidly up to the ether, with ever varying shape. It was usually well defined on the westward side, where it, at times, presented a perpendicular wall of miles in height. On the east it was ill-defined. Above, it often spread out, especially toward the east, as if borne off by the southeast wind of the upper air. The base, so far as visible, appeared to be commingled with murky brown strata. The apparent altitude of this cumulus above the horizon, when at its highest was 3°30' which reduced for a base of 120 miles with 500 feet altitude of the point of observation, gives a height of 7.8 miles. This morning, the 9th, our atmosphere is charged with smoky haze, and a very distinct odor of sulphurous acid.

At Kapapala, on the 7th, the ground was still in violent agitation, with a long undulatory motion. At night a very large flow of lava was seen running down the mountain to the sea. The next day smoke was seen issuing from cracks in this neighborhood. Mr. H. M. Whitney visited the scene of the eruption on the 10th, and from him we learn the following particulars:

As we approached the flow the rumbling noise became more and more distinct. The ground was covered with what appeared to be cinders, but on examining them we found they were fragments of [basaltic] pumice-stone which had been carried by the wind a distance of over ten miles. Mixed with these cinders was *Pele's hair*, which we found floating in the air, and when it was thick we had to hold our handkerchiefs to our nostrils to prevent inhaling it; our clothes were frequently covered with it. We hurried on and reached the flow shortly after noon, when from a ridge to the west of it the whole scene opened before us. Between us and the crater was a valley five hundred yards wide and ten miles long, which had recently been overflowed throughout its entire breadth and length from the mountain to the sea where it widened to two or three miles. The lava was of the smooth or pahoehoe variety, from ten to twenty feet deep, and partially cooled over, though flames, smoke and gas escaped from numerous crevices. On Tuesday afternoon, April 7th, at five o'clock, a new crater, several miles lower down than that referred to, and about two miles back of Captain Brown's residence, burst out. The lava stream commenced flowing down the beautiful grass-covered plateau, towards and around the farm-house, and the inmates had barely time to escape with the clothes they had on; the path by which they escaped was covered with lava ten minutes after they passed over it.

On ascending the ridge we found the eruption in full blast. Four enormous fountains, on a line a mile long, north and south, were continually spouting up from the opening. These jets were blood-red, and yet as fluid as water, ever varying in size, bulk and height. Sometimes two would join together, and again the whole four would be united, making one continuous fountain a mile in length. From the lower end of the crater, a stream of very liquid, boiling lava flowed out and down the plateau, a distance of two or three miles, then following the road ran down the precipice at an angle of about 30°, then along the foot of the pali or precipice, five miles to the sea, the stream being about eight or ten miles in length, and in some places half a mile wide. One peculiarity of the spouting was that the lava was ejected with a *rotary motion*, and as it ascended both lava and stones rotated always in one direction towards the south. This was the only stream which reached the sea, and flowed into it at Kailikii. It lasted only five days, the eruption ceasing entirely on the night of the 11th, or morning of the 12th. During its continuance, the atmosphere was filled with smoke so dense that the sun appeared like a ball of fire, and the whole island was shrouded in darkness. The smoke came from the rent or crater, and was highly charged with sulphur.

As the lava entered the sea, clouds of steam and smoke rose up, and flames of bluish fire were emitted, rising from the water to a height of from ten to twenty feet. During the night we were at the volcano, the air was highly charged with sulphurous gas and electricity, and frequent flashes of lightning were seen directly over the lava stream, accompanied with short claps of thunder. These flashes were also observed less frequently further up the mountain. About four thousand acres of good pasture land were destroyed, besides which the lava ran over an immense district of worthless land. On the night of the 6th of April, prior to the eruption, there was a shower of ashes and pumice-stone, which came from this crater, and covered the country to a distance of ten or fifteen miles each way. Generally the ashes were not more than one or two inches in depth, but in some places were found to be fifteen. The pumice-stone was very light, and appears to have been carried by the wind a great distance. Pieces two and three inches in diameter floated ashore at Kealakeakua, forty-five miles distant.

During the early part of April an observer in Kona kept a careful record of the principal shocks felt there, but in other places no observations were made. The only certain thing, among various and somewhat extravagant reports, is that the vibrations were very frequent and not very severe. In some places they were almost silent, but usually accompanied by subterranean detonations and rumblings, with a noise as of boiling, surging waves in the bowels of the earth. No observations were made on the gases said to have been emitted from some of the fissures.

When the eruption of lava was made known at Honolulu, many residents at once set out for Hawaii, and among them a gentleman of distinguished attainments in botany, Dr. William Hillebrand, who has given us so accurate and full an account of what he saw in passing through the disturbed region that it seems worthy of a more permanent record than would be its lot in the local newspaper in which it first appeared. He writes as follows:

I started from Hilo with a few friends for Kilauea April 17th; descended the crater on the 18th; examined the extensive fissures near the Puna road on the 20th; the so-called mud-flow on the 21st; and the lava streams in Kahuku on the 23rd. On the 24th we crossed the lava stream on the road to Kona, and reached Kealakeakua Bay on April 26th.

Of Hilo I have little to say, as your correspondents have communicated to you the most remarkable events from that place. I saw several fissures in the earth near Wahiawa River, of from eight inches to one foot in width, which were caused by the earthquake of April 2nd, and run in the direction of Mauna Loa. The earthquake waves all moved from southwest to northeast, and overturned movable objects standing at right angles with that line. A heavy book-case in the Rev. T. Coan's library, holding that relation to the wave, was overturned, while another heavy case, filled with shells and minerals, which stood parallel to the wave, remained standing.

*Kilauea.*—The ground around the crater, particularly on the eastern and western sides, is rent by a number of fissures, one near the Puna road more than twelve feet wide, and very deep; others of lesser size run parallel to and cross the Kau road, so as to render travel on it very dangerous. The lookout house is detached from the mainland by a very deep crevasse, and stands now on an isolated overhanging rock, which at the next severe concussion must tumble into the pit below. Many smaller fissures are hidden by grass and bushes, forming so many traps for the unwary. The Volcano House, however, has not suffered nor is the ground surrounding it broken in the least. From the walls of Kilauea large masses of rock have been detached and thrown down. On the west and northwest sides, where the fire had been most active before the great earthquake of April 2nd, the falling masses probably have been at once melted by the lava and carried off in its stream, for the walls there remain as perpendicular as they were before; but that this part of the wall has lost portions of its mass, is shown too evidently by the deep crevices along the western edge just spoken of, and the partial detachment in many places of large prisms of rock. But it is on the east and northeast wall particularly, that the character of the crater has undergone a change. Along the descent on the second ledge large masses of rock, many, more than one hundred tons in weight, obstruct the path and form abutments to the stone pillars—small buttress hills similar to those observed in front of the high basaltic wall of Koolau, Oahu. So also in the deep crater itself the eastern wall has lost much of its perpendicular dip, and has become shelving in part.

The crater itself was entirely devoid of liquid lava; no incandescence anywhere; pitchy darkness hovered over the abyss the first night. I say the first night, because during the second night of our stay between twelve M. and one A.M., detonations were heard again, and light reappeared for

a short time in the south lake Halemaumau. White vapors of steam issued from the floor in a hundred places, but of those stifling sulphurous and acid gases, formerly so overpowering in the neighborhood of the lakes and ovens, only the faintest trace was perceived here and there.

The heat was nowhere so great that we could not keep our footing for a minute or more, although in many places it would forbid the touch of the bare hand. The great south lake Halemaumau is transformed into a vast pit, more than five hundred feet deep, the solid eastern wall projecting far over the hollow below, while the remaining sides are falling off with a sharp inclination, and consist of a confused mass of rough aa. More than two-thirds of the old floor of Kilauea has caved in, and sunk from one hundred to three hundred feet below the level of the remaining floor.

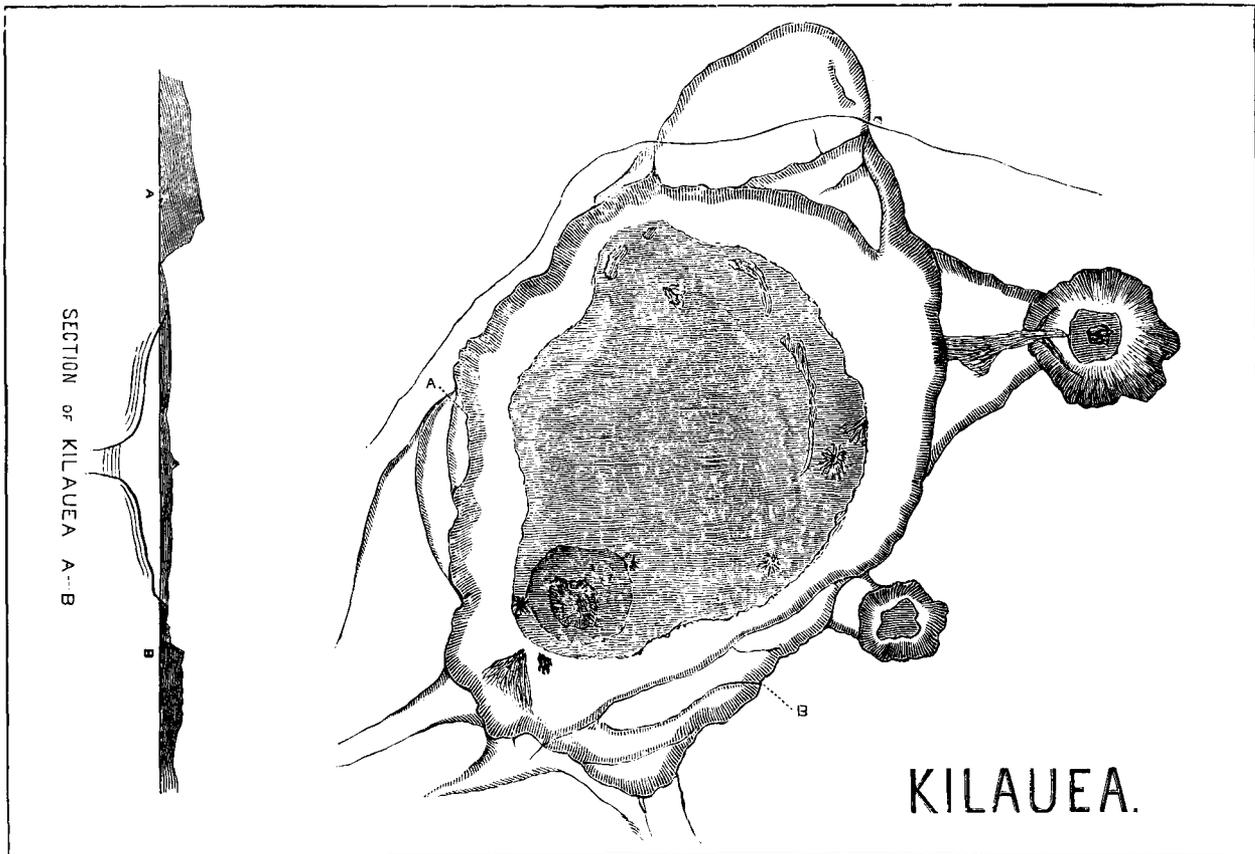


FIG. 69. KILAUEA AFTER THE ERUPTION OF 1868.

The depression embraces the whole western half, and infringes in a semicircular line on a considerable portion of the other half. This is greatest in the northern, and rather gradual and gentle in its southern portion. Entering on the depressed floor from the southern lake, it was some time before we became fully aware of its existence, and it was only on our return from the northwest corner, where it is deepest, that there presented itself through the mist in which we were enveloped, a high wall of three hundred feet, grotesque and fanciful in outline. At first we were quite bewildered, fancying that we beheld the great outer wall of the crater. On nearer approach we soon satisfied ourselves that this singular wall represented the line of demarcation of a great depression in the floor of the crater—a fact that surprised us the more, as a bird's eye view from above had altogether failed to apprise us of its existence. As we had been informed that the principal activity of the crater before the great earthquake had been in the northwest corner, we proceeded in that direction on

leaving the south lake. Having arrived at about the middle of the depression a considerable rise in the ground presented itself on our left—to the west. Having ascended this, we found ourselves at the brink of a fearful chasm, which fell off on our side with a beetling wall to the depth of several hundred feet and extended about half a mile from north to south. Very hot air rose from it. Around it, towards its northern extremity, the lava is thrown up into an indescribable confusion; pile upon pile of aa gorge and ridge by turns.

The caving in of the floor seemed to be still in progression, for twice during our exploration of the crater, our nerves were disturbed by a prolonged heavy rumbling and rattling noise, as from a distant platoon-fire of musketry, coming from the northwest corner.

Kilauea iki, which in 1865 was covered with shrubs on its side and partly on the bottom, was now overflowed with black, shining lava. It has been free from fire since 1832.

Thus far as to what we have seen. Now allow me to relate what I learned from Kaina [the District Judge, and a most intelligent Hawaiian], who has resided near the volcano without interruption for the last five months, and whose strong nerves sustained him during the fearful catastrophe introduced by the earthquake of April 2nd. He and the Chinaman who keeps the house, were the only persons who remained at Kilauea. He says that for two months preceding the first shock, namely, from January 20th to March 27th, the crater had been unusually active; eight lakes being in constant ebullition and frequently overflowing. During all this time (the date of its first appearance could not be ascertained exactly), there was in the northwest corner a blow-hole, from which at regular intervals of a minute or less, with a roaring noise, large masses of vapor were thrown off, as from a steam engine. This ceased about the 17th of March. At the same time the activity of the lakes became greatly increased, and Kaina anticipated mischief. March 27, the first shock was perceived. Two days later Mr. Abraham Fornander found the bottom of the crater overflowed with fresh lava, and incandescent.

Thursday, April 2nd, at a few minutes past four P.M., the big earthquake occurred, which caused the ground around Kilauea to rock like a ship at sea. At that moment there commenced fearful detonations in the crater; large quantities of lava were thrown up to a great height; portions of the wall tumbled in. This extraordinary commotion, accompanied with unearthly noise and swaying of the ground, continued from that day till Sunday night, April 5th, but *from the first the fire began to recede*. On Thursday night it was already confined to the regular lakes; on Saturday night it only remained in the great south lake, and on Sunday night there was none at all; Pele had left Kilauea. The noises now became weaker, and were separated by longer intervals. By Tuesday quiet reigned in Kilauea. On that afternoon the lava burst out at a distance of forty miles, southwest, in Kahuku.

April 2nd, from six to ten P.M., Kaina observed fire in the direction of Puna, which, at the time, caused him to believe that the lava had found a vent again in that direction, as it did in 1840; but he subsequently satisfied himself that it was only a reflection from lava in Kilauea iki. It was not seen afterward.

In Kapapala we are told that fire had been seen several nights in a southeast direction, and that natives had reported flowing lava there. We rode over in the morning of April 20th. At a distance of five miles from Mr. Reed's dwelling, where the Puna road turns off from the Kilauea road, heavy clouds of white vapor were seen to issue from the bush, which sparsely covered the pahoehoe, makai<sup>82</sup> of the road. Half an hour's ride brought us up to the place, but we were obliged to leave our horses some distance before reaching the spot, on account of fissures. After having crossed a number of them, heading for the heaviest cloud of vapor, we at last came to a deep crevasse in the pahoehoe, at least twenty-four feet in width, no bottom visible. It narrowed and widened out in places, but nowhere was less than eight feet wide. Its length we estimated at four hundred feet.

<sup>82</sup>Makai is the Hawaiian for "towards the sea". [486]

Parallel with this great crevasse, constituting a belt about six hundred feet in width, were a number of smaller ones on each side, diminishing in size with distance from it, from six feet to a few inches. From the larger openings in the former, heavy white columns of hot steam issued, which had a decidedly alkaline smell. Smaller jets of vapor to the number of thirty, rose from the smaller fissures. We could not discover fire in any place, but it is very probable that during dark nights the reflection of the underlying lava should be thrown up, for as the steam did not seem to contain combustible material, it is unlikely that the light seen should have been produced by it. The mean direction of all the fissures was N.E.  $9^{\circ}$  N., S.W.  $9^{\circ}$  S., or nearly the direction of a line connecting Kilauea with Waiohinu and Kahuku. The distance of these fissures from Kilauea is thirteen miles.

As in this district the earthquake of April 2nd culminated to its greatest intensity, so as even to rend in twain the frame-work of a mountain-side, and hurl down on the plain a portion of its flank, it is necessary to give a short description of the country in order to insure a proper understanding of the disturbance. The locality in question is that comprised between the ranch stations of Messrs. Reed and Richardson, on the east, and Mr. F. S. Lyman on the west, a distance of five miles. The government road connecting these two places runs through a fine grassy plain, which has a very gentle fall towards the sea, its elevation being about 2000 feet. Into this plain project from the slope of Mauna Loa three parallel hills or spurs, each about one mile in length, and from 800 to 1800 feet in height. They include two broad valleys between them. The upper portions of these valleys rise with a steep incline towards a ridge which runs at right angles with the spurs, and is covered with a dense pulu forest, which extends far up the gentle slope of the dome of Mauna Loa. In the second one of these valleys—that next to Mr. Lyman's—the so-called mud-flow took place, but very extensive land-slides, confined simply to the loose earth and conglomerate, also occurred in the other valley.

The ground around Reed and Richardson's station is torn up into numerous small cracks and fissures, running in every direction. Some are large enough to engulf horse and rider, a fact which actually occurred a few days after the earthquake. A large cistern, built in solid masonry and covered with an arched stone roof, was rent to pieces, and the roof entirely broken away. Not a single stone fence is standing; their places are indicated by flat belts of stone on the ground. The dwelling house—a good wooden framed one—exhibits a wrench across its roof, so that the gutters empty themselves in the sitting room; the cook-house is thrown off its foundation; other out-buildings are completely overturned; and of the grass houses, some are smashed down, others greatly inclined. But all these signs of destruction are thrown in the shade by the grandeur of the force which shook off the side of the pali, burying in a minute thirty-one human beings, many hundred head of cattle, and entire flocks of goats, and ending four miles from its beginning in a mighty river of mud. Before reaching this mud-flow from Reed's house, we passed two considerable streams of muddy water, of a reddish-yellow color, emitting a strong odor of clay, such as may be perceived in potteries. Both streams have their origin in the land-slide of the first valley. When we passed them again, two days later, they had nearly disappeared; they evidently owed their origin to the drainage of the fallen mass. The mud-flow is met with three miles from Reed's. It projects itself from the spurs of the hills two miles down in the plain; begins at once with a thickness of six feet, which, towards the middle, where it forms a small hill, rises to thirty feet; averages about three-fourths of a mile in width, and contracts towards its end. From this end a long queue of boulders bears witness to the violent action of a torrent which shot out of the mud after it was deposited, and which has since perpetuated itself in a stream of some size, quite muddy, and emitting the above mentioned pottery odor when we saw it first, on April 20th, but perfectly clear and inodorous when we passed it three days later. A little higher up a koa grove gives still stronger evidence of the strength of the propelling force. The trees first seized are snapped off and prostrate, yet the mud in that place is only a few feet deep. The mass itself is nothing but the loose red soil of the mountain side, with a good

sprinkling of round boulders, with here and there stumps of trees, ferns, *hapuu* and *amaumau*, and entire lehua trunks. Near the lower end a vigorous, healthy taro-plant stood erect in the mud as if it had been planted there. From the sides of the mass protruded portions of the bodies of many cattle and goats, overwhelmed in their flight; a gain of one second of time might have saved them. The surface of the mud in this lower course was rather smooth, as if it had been forced down by the agency of water, and it was still so soft that the feet sank deep into it.

After we had flanked it for some distance along the side of the hill, the mud became solid enough to bear our weight, and we walked upon it to the head of the pali. The surface gradually became more rough; the boulders increased, and detached portions of earth and stone were scattered beyond its borders, which also flattened out gradually. The ascent soon became steep, and here, on a short spur, just in the middle of the mud, stands a native house on an island of grass and kalo, flanked by two trees. A poor woman who happened to be in it at the time of the outbreak, escaped the awful fate which doomed the remaining members of her family, and was removed from her perilous situation a few days after, when the crust had become solid enough to bear a man's weight.

As we went on the mass became more rough and hard, tree trunks and boulders increased, even angular rocks appeared, until at last the mud ceased entirely and gave place to a sea of huge rocks, all angular and exhibiting fresh fractures, large trunks of trees crushed between and under them, and streamlets of fresh, clear water meandering between them. This continued for the last three hundred feet of rise, and ended in a perpendicular wall of solid rock, some twenty feet high, after having climbed which, we reposed under the refreshing shade of tall fern trees, for we had entered at once the great pulu forest. Seated on the trunk of a prostrate tree, we could survey the whole scene of devastation we had just traversed. Immediately at our feet the rocky framework of the pali was torn up, and its contents turned topsy-turvy in dire confusion. The rocky wall we had just climbed, continued until it reached the sides of the two flanking hills. A perpendicular cut in the sides of the latter laid open some forty feet of red earth and conglomerate. On looking behind us we saw that the rock we were resting on was separated from the mountain by a deep crevasse, parallel to the wall, and only partly visible, as it extended under the dense trees. To our left a clear sparkling mountain stream leaped in a bounding cascade over the crag, and after losing its course amid the maze of rocks, gathered itself again, flowing over the solid bed-rock in a deep gorge cut in the mud. This stream had existed here before, but ere it reached half down the pali, became lost in the soil. It can easily be imagined what an amount of subsoil water must have been deposited here. Bearing this in mind, and the great depth of soil and conglomerate on this slope, as indicated by the cuts in the hill-sides, there seems to be no great difficulty in explaining how such enormous masses of earth, at first propelled horizontally through the air, hurled down the valley by the tremendous force which tore off the side of the mountain, should then have been seized by the propelling force of the now liberated subsoil water and carried in a mighty stream far beyond the place where at first they were deposited.

All this destruction was the work of the great earthquake of April 2nd. During the five days preceding it, over one thousand shocks had been counted. On that afternoon Mr. Harbottle, at Reed's, with his men, was driving cattle across the hill towards Hilo, when suddenly the earth shook violently and a great detonation was heard behind them. Horses and cattle turned round involuntarily. The whole atmosphere before them was red and black. In a very short time this subsided—some say in one minute, others in five minutes; but a black cloud continued to hover over the scene for some time. From that Thursday to Sunday the earth constantly rocked and swayed; the hills seemed to alternately approach and recede. Most people became seasick. Strange roaring and surging noises were heard under the ground. When the ear was applied to the earth it would often receive a distinct impression as if a subterranean wave struck against the earth's crust. The prevailing direction of the earthquake waves was said to have been from northeast to southwest.

Here follows a portion of Dr. Hillebrand's account that covers ground already trodden by Mr. Whitney. After he arrived at Kahuku his account gives us the appearance of the lava after the flow had ceased. He continues:

As the principal interest was the discovery of the main source of the stream, we at once went to that part of it, where, according to common report, the lava had issued. A very light, dark brown, glistening pumice stone lay scattered about long before the lava was seen. Near the flow it increased so much that the animals' feet sank deep into it at every step. We soon reached the ridge of a hill from which we surveyed the place where, according to our guide's account, the fountains of lava had been seen. The upper portion of the lava stream fills a broad valley or depression, between two parallel low hills of not more than three hundred feet in height, both running almost due north and south. From the western one of these hills Mr. Whitney had witnessed the eruption. From the eastern hill we in vain looked for a crater or cone. We did not make out any indication of an eruption until we had crossed nearly three-fourths of the stream, which here is not far from a mile wide. Then our attention was attracted by an accumulation of scoriæ. Nearing this we were struck by a current of hot air, and, a little farther on, found ourselves on the brink of a deep gap in the lava about twenty feet wide, but narrowing and continuing northward. We walked round the southern end of the gap, and followed it up on the western or lee side. Before long we came to another enlargement of the fissure, like the former, emitting hot air charged with acid gases which drove us back. Still continuing our march on the west side of the fissure as close as the hot gases would allow, we came in sight of a pretty miniature cone, built up most regularly of loose scoriæ to the height of twelve feet, and located right over the fissure. It encloses a chimney crater of about twelve feet diameter, with perpendicular sides, the depth of which could not be ascertained. Hot gases issued in abundance. On account of the exhalation of the latter we were obliged to cross the chasm, on the bridge formed by the side of the cone, to the windward side, along which we followed up steadily.

This crack or fissure tends south six degrees west to north six degrees east and is in the slope of the hill that forms the west boundary of the lava-stream. Its lava cover therefore is quite thin in many places, so that you can see how it sinks in the original rock of the hill. Its depth cannot be ascertained anywhere. More than four-fifths of the lava is on the eastern side, as it followed the declivity of the hill-slope to fill the trough of the valley, where it assumed a general downward course. It is from the entire length of this fissure that the lava has welled up simultaneously. The waves of lava for some distance from it are all parallel to its course, while in the middle of the stream they stand at a right angle to it. The edges are somewhat raised above the remainder of the stream, and scoriæ covers it in most parts, forming quite heavy layers where the stream has blowholes. Isolated flakes of brittle lava, resembling cow-dung, probably blown out at the end of the eruption, with fitful spouting of steam and gas, are seen all along its course. Nearing the upper end of the valley, where I expected to find the end of the fissure, I was surprised at the sudden appearance of a veritable cataract of lava coming down the precipitous side of the eastern hill, a height of at least three hundred feet. Having ascended it with considerable toil, I found myself again alongside the big crevasse, which in passing across the valley had deflected from its former course to a nearly N.E. direction, heading direct for the summit of Mauna Loa.

From here onward, the incline increasing considerably, the lava commenced to be very rugged and broken. As here it had passed over and destroyed a dense forest, a number of grotesque shapes met the eye. Wherever the lava had met a tree of some size, it had surrounded it with a perfect mould which either still held the smouldering remains of the trunk, or exhibited hollow cylinders bearing on the inside the markings of the bark of the tree. The leaf stalk scars of fern-trees were almost perfect. A few of the moulds contained still entire trunks with the unconsumed branches. In the bifurcations of these, heavy masses of lava had accumulated, hanging down in wavy points

like so many stalactites. Wherever there was a fern stump standing upright, it bore a cap of lava; everything indicated that the liquid mass had been thrown upwards by the violent rush of steam and gas. As I said before, this part of the flow was lined by a dense forest. It soon became apparent that the sides of the forest closed in upon each other, and from an eminence alongside the fissure I could see that the lava-stream contracted at some distance beyond to the apex of an isosceles triangle. The crevasse which ran straight up to the apex, was continuous, wider than below, and emitted in great profusion sulphurous and other acid gases. Its borders, which were of the color of red brick, commenced to be covered with the efflorescence of salts and sulphur, and in places they assumed altogether the appearance of sulphur banks. The heat of the lava increased so as to be unbearable in some places. Ashes and scorixæ covered every hollow in the floor, and the edge of the woods for some distance.

Having arrived at the apex of the triangle, I found that the crevasse, over which the trees almost closed from both sides, still extended a few hundred yards higher up in the woods, as indicated by a continuous line of white and yellow smoke. The choking nature of the latter forbade my marching along the edge of the fissure, while the impenetrable thicket, with the ground thickly covered by ashes, proved another effectual bar to my further progress. In fact, while hurrying out of an overpowering cloud of the smoke, I got one leg caught in a lateral fissure hidden under the ashes, where it received such a lively impression of heat that I made quick time to retire from that neighborhood. Just then I heard a deep, hollow, rumbling, prolonged sound, while the air and earth remained perfectly still. Subsequently I learned that it had been caused by the rolling down of large masses of pumice stone from the hill to the lower lava stream, but at the time being fearful of another catastrophe, I hurried back as fast as circumstances would permit, and felt a great relief in rejoining my friends who had remained behind, at the lower part of the stream. From the height above the cataract I saw two other lines of smoke running through the woods, taking their origin from the valley below, indicating two other fissures. Thus it appears that at the head of the valley the main fissure divided itself into three parts: the first and largest, running northeast; the middle one almost due north, and the third about north-northwest. The two latter did not seem to have thrown off much lava, if any, for there appeared no gap in the woods along their courses.<sup>83</sup>

From a letter addressed to me under date of August 27, 1868, by the Rev. T. Coan, I extract the following important facts and accurate descriptions:

I left Hilo on the fourth of August, on a missionary tour through Puna and Kau, and was absent eighteen days. During this tour I made careful observations with measurements and notes, on the remarkable volcanic phenomena of the past five months. The action of tellurial forces on our little island shell has been marvellous. The subsidence along the coast of Puna, from the east cape at Kapoho to Apua on the western line, is four to seven feet, varying in different localities. The great sand beach at Kaimu has been forced back into the young and beautiful coco-palm grove, and also into the groves of pandanus, so that trees now stand eight feet deep in sand, and many stand in the water. The plain of Kalapana has sunk about six feet, and water four to five feet deep now covers some twenty acres of what was once dry land. The old stone church is buried nearly to the eaves in sand, and the tide rises and falls within it.

This plain of Kalapana was doubtless at some former time buried much deeper beneath the sea. A coral reef of several yards thickness stretches half across the valley, and formed a barrier against further encroachments of the sea. It was three or four feet above high water mark, and formed a convenient site for the village. The church that Mr. Coan mentions was on this coral mound towards the shore. As the wall of rock

<sup>83</sup>Honolulu, May 4, 1868.

which bounds the plain on the southerly side shows clearly that some former subsidence resulted in a rupture of the crust forming the floor of the plain from this wall, it would have been well to note any change at this point. Mr. Coan observed none, and the loose rocks knocked down by the protracted earthquakes would perhaps obliterate any traces of so slight a dislocation as a fall of six feet would cause.<sup>84</sup>

At Kealakomo the salt-works are destroyed and the fountain on the shore sunk. Apua, the last village in Puna, was swept clear [by the tidal wave of April 2nd] and sunk. Its pretty sand beach and miniature bay rendering it a resort for fishermen, are no more; the sea stands some six feet deep where the houses once stood. The same is true of Keauhou, the first village in Kau, and an important pulu station; coconut trees stand seven feet in the water, and all the buildings were swept away by the tidal wave. Passing on to Punaluu, this wave rose twenty feet and swept all before it. The great sand barrier which protected the beautiful pond and the cold, limpid spring, was first swept into the sea and then brought back and deposited in the pond, filling it up and changing the shore line. I got the height of this wave by measurement on a palm tree, and also upon the surrounding ridge of scoriform lava, making the rise above common high water about twenty feet.

From Punaluu onward to Honuapo, all houses were swept away except two standing on high lava ridges. The road was strown with boulders and fragments of rocks, and in some places it has sunk, so that it is with great difficulty, and not without a guide, that the traveler threads his zigzag way along this coast for five miles. Not a house remains in the considerable village of Honuapo: the sea occupies the site of former dwellings. The wave here corresponded with that at Punaluu, as shown by measurements on coconut trees. There were points where the influx of the sea was greater than at other places, and this seems to have been caused by the approach of the wave from the southwest, or at an angle of 45° to the shore, and by striking headlands and projecting points causing the waters to heap up within the points of tangency, while the current swept on at a lower mark where the coast presented no lateral obstructions.<sup>85</sup>

In crossing over the great lava fields from Puna to Kau, I passed about nine miles to the south and leeward of Kilauea, the great volcano flanking us on the right. The country through which we passed was terribly rent by the earthquake of April 2nd, and in some places we were obliged to deflect widely from the old track to avoid fissures. For several miles the cracks were so numerous and so wide, that a stranger would be utterly unable to find his way through this mural network of fractures. Our guide zigzagged us everywhere, our animals often demurring, trembling, and refusing to go. The whole atmosphere was filled with sulphurous smoke, through which the sun shone with sanguine rays. After passing most of these fissures, I requested my guide to turn to the left and follow the line of fissure seaward, hoping to find the locality of a disputed eruption which it was affirmed by some and denied by others had taken place in that wide and wild field of ancient lavas. After an hour of hard search amidst hills and ridges of aa and fields of pahoehoe, we found a veritable eruption. . . . The fused lavas had been thrown out of the fissures at five different points, on a line of less than a mile in length. The largest batch was one thousand feet long and six hundred feet wide, with an average depth of ten feet, and with a steaming and tumulated surface. This series of small eruptions is about eleven miles southwest of Kilauea, and it shows distinctly the subterranean path taken by the igneous flood which left that seething cauldron on the night after the rending earthquake of April 2nd. That shock doubtless opened a pathway for the struggling fires, and they went off in a southwestern course under the highlands of Kau, uniting with the subterranean

<sup>84</sup> In crossing this plain twenty-five years later I found my surmise correct and the former wall had been covered by the confused fragments.

<sup>85</sup> To the casual traveler no signs of this shore catastrophe remain. Wharves and villages replace those destroyed, and even a sugar-mill and its surrounding hamlet occupies one of the points where the ravages were greatest.

fires of Mauna Loa, and finding a fuller vent at Kahuku on the seventh of April. This is the theory, and it is rendered probable by the great and constant trembling of the earth along that whole line, by subterranean noises heard by the people of Kapapala, Keaiwa, Waiohinu, and other places, and by the issuing of steam at several points from fissures along that line.

When it was found that Kilauea had discharged its contents, the first supposition was that the course of the eruption of 1840, or towards the southeast, had been followed, and this was strengthened by the report of fire seen at the bottom of some of the numerous pit craters on that line; but while it is possible that lava may have been injected in earthquake fissures opened in this direction even so far as the pit craters (see map, p. 51), the probable path was that indicated by Mr. Coan, which is apparently the same as that of the eruption 1823. When the Rev. William Ellis went over the ground the next year he found deep fissures extending in a southwest direction, some of them ten or twelve feet across, and emitting sulphurous vapors at a high temperature.<sup>86</sup> In one place where the chasm was about three feet wide, a large quantity of lava had been recently vomited. I do not agree with Mr. Coan that the lava from Kilauea and that from Mauna Loa effected a juncture before reaching the surface. It seems more probable that the former passed into the sea near Punaluu, as did that of 1823, not appearing above ground except at Kapapala. The fact that the openings on the side of Mauna Loa above Kahuku were much higher than those mentioned at Kapapala, seems to indicate conclusively that the lava of Kilauea did not flow out in the stream that deluged the height above Ka Lae. The lava of both these volcanic vents is so similar that nothing can be inferred from that of its individual source.

**Landslide.**—Between Kapapala and Keaiwa in Kau, I examined what has incorrectly been called the Mud Flow. I went entirely around it, and crossed it at its head and center, measuring its length and breadth which I found were severally three miles long and half a mile wide. The breadth at the head is about a mile, and the ground on the side-hill, where the cleavage took place, is now a bold precipice sixty feet high. Below this line of fracture the superstrata of the earth, consisting of soil, rocks, lavas, boulders, trees, roots, ferns and all tropical jungle, and water, slid and rolled down an incline of some 20°, until the immense masses came to the brow of a precipice near a thousand feet high, and here all plunged down an incline of 40° to 70° to the cultivated and inhabited plains below. The momentum acquired by this terrific slide was so great that the mass was forced over the plain, and even up an angle of 1° 30', at the rate of more than a mile a minute. In its course it swept along enormous trees, and rocks from the size of a pebble to those weighing many tons. Immense blocks of lava, some fresh as of yesterday, and others in all stages of decomposition, were uncovered by the slide. The depth of the deposit on the grass plains may average six feet: in depressions at the foot of the precipice it may be thirty or even forty feet.<sup>87</sup>

**Eruption in Kahuku.**—From the land-slide I went on to the igneous eruption in western Kau. Rents, tiltings, and other disturbances of the strata were seen along the shore, while the wooded and grassy hills on the right were scalped, scarred, cracked and striated, some of the once

<sup>86</sup> Ellis's *Polynesian Researches*, London, 1859, vol. iv, p. 220. See also quotation on p. 39 of the present work.

<sup>87</sup> I have a map of the landslide constructed for me by the late Latimer Coan, son of Rev. T. Coan, but it seemed unnecessary to reproduce it here, the descriptions are so definite.

green hills looked as if a gigantic cultivator had been driven down their sides, tearing off the sward and exposing the soil in wide parallel grooves, and leaving broad belts of vegetation resembling rows of sugar cane. In passing from Waiohinu to Kahuku, we started a little after sunrise and rode westward. About three miles from Waiohinu we crossed a lateral arm of the eruption, about one-sixteenth of a mile wide, and some two miles long, from where it left the parent stream. It was a high ridge of aa, say twenty-five feet deep, and running in a southeasterly direction. Crossing this and riding half a mile over verdant and beautiful fields, we come to another lateral outgush of similar character, and dimensions. Then came a third, which flowed some four miles and threatened to fill the harbor of Kaalualu. This was longer and broader than the other two, but of the same general character. After another half mile we crossed a fourth rugged stream of aa, and then moving southwest we rode rapidly over a fine surface of soil down a slope of about  $3^{\circ}$  to the ends of the two large parallel streams that entered the sea at Kailikii. Over all this wide field of pasturage, cinder and pumice had been scattered, and the grass had been consumed as by a prairie fire.

This portion of the eruption went into the sea about one mile northwest of Ka Lae, the south cape of the island. On the left flank of the stream is a high and very steep ridge (four hundred to five hundred feet high), extending from the cape up the southern slope of Mauna Loa. The outburst of April 7th commenced about ten miles from the sea by the opening of a horrid fissure in the forest on the upper side of this precipice. For about three miles the burning river flowed down partly above and partly below this precipice. The area above was rich and beautiful land for cultivation and pasturage; that below was simply pahoehoe. The four lateral streams before mentioned all ran off upon the beautiful highlands, covering several thousand acres, but without reaching the sea. Some three miles from the head the main stream went altogether over the precipice, and pursued its rapid course over the pahoehoe some seven miles to the sea which it reached in two hours. There it formed, as is usual when lava streams enter the sea, two cones of lava sand, or lava shivered into millions of particles by coming in contact with water while in an intensely heated state. There is no island there and there is nothing but what is common under similar circumstances. This stream is about half a mile wide, and it entered the sea some three-fourths of a mile from the high pali before spoken of. After running a day or two, in this channel, partial obstructions occurred, by cooling masses, when the shell of the stream was tapped some five miles from the sea, and a torrent of white-hot lava pushed out on the east side, running off to the great precipice and following its base in a breadth of half a mile down to the sea, and thus forming an island five miles long and a quarter of a mile wide, surrounded on three sides by fire. Three houses stand unscathed on this islet, and about thirty head of cattle were inclosed by the igneous flood.

The route taken by this lava flow was substantially that of a stream of unknown date, but whose smooth surface of hard pahoehoe looks fresh and undecomposed. Where this ancient stream originated is not known, for no one has ever taken the trouble to trace up the various flows that radiate like the spokes of a wheel from the cone of Mauna Loa.<sup>88</sup> The pali referred to was probably formed by the subsidence of the ground over which the successive streams of lava have flowed, and it forms the boundary of a fine pasture land, which appears to have been exempt from these lava inundations for many ages; the outcropping ledges of lava are weathered and lichen-covered until they resemble the gneiss and granite rocks of New England, at least from a distance.

<sup>88</sup> It will be seen from the map of this island that the government survey has done much in tracing the flows of known date, but much remains to be done, although it is probably impossible to fully trace other than the superficial flows.

The flow of 1840 which reached the sea at Nanawale, formed conical hills which lasted many years although composed of the loose gravelly rapilli resulting from the sudden shivering of the lava, and the same form of cinder piles is seen at the junction of lava and sea-water in this flow of 1868. It is not universally the case, however, that lava is broken up in this way when passing into the sea. Sometimes the heat has been so intense as to induce the spheroidal state preventing the actual contact of the water, and the melted rock has run on under the water, forming submarine ledges of pahoehoe.

From the shore we rode up on the elevated plateau with the two parallel streams of cooled lava on our left, some five hundred feet below, with nothing to obstruct a full bird's eye view of the scene. At length we came to the great trunk at Kahuku, from which all the lateral branches had been sent off. At our right on one of these branches were the ruins of the large stone church of Kahuku. The great earthquake had shaken down the walls, and the roof was lowered and standing over the ruins, around which the sea of molten lava had flowed, leaving them upon a small island unconsumed and uncovered. One-eighth of a mile above this, and on the same stream, we saw three small thatched houses, where four natives had been surrounded by the burning sea and confined for ten days in this fiery prison. The whole inclosed island contained about an acre, and before the people were aware of it, no avenue of escape was left. The hot clinkers came rolling along in a great stream within twenty-five feet of one of the houses, and cooled in a ridge as high as the top of the house. We climbed over this rough mass and visited the people who still live in this awful but now romantic inclosure. They seemed cheerful and were right glad to see us. On inquiring how they felt and how they spent their time during those days of fiery trial, they replied that in expectation of certain death they were calm and resigned, looking up to God and spending most of their time in prayer.

Passing up the main stream, we came to the place where Captain Brown's houses once stood; just in the rear of this was an awful vent from which fiery jets were thrown hundreds of feet high, with fearful hissings and belchings. Beyond this we saw numbers of green islets, of two to five acres in extent, formed by the surging sea of fire as it seethed and boiled and swept around these reserved places. On some of these islands cattle were feeding, and twenty head were taken from one islet of less than two acres, after the lavas were partly cooled. They were terribly heated and frantic, and some of them died. Still pursuing our course upward, we veered to the right, and once more took the soil on the uplands which bordered the stream. Here the great trunk of the stream was in its full breadth and I hired two men to measure across, while we rode through a charred forest and deep cinders more than one hundred feet above the shining lava fields which lay on our left. At length we descended again to the stream of fresh and warm pahoehoe, and rode nearly a mile upon its crackling surface. We soon came to a region of fissures and blow-holes, and where the evidences of Plutonic fury were unmistakable. From these infernal orifices amazing jets had been thrown hundreds of feet heavenwards, forming ridges, hills and jagged cones of every contour, and leaving the products of raging seas and rivers of fire, such as must have been appalling to near witnesses of these fiery dynamics. Here we left our horses, and with great effort struggled over the sharp and confused masses which were heaped wildly around. Climbing a rough hillside some two hundred feet high, and on an angle of forty-five degrees, we came upon the great head fissure from which the first lavas were disgorged. We followed this to the terminal point in the woods, over ridges and heaps of cinder, pumice and scoria. From this high terrace we could overlook the stream below for about three miles. The great vent or fissure extended longitudinally and in an irregular line for two and a half miles or more, and at many points along this line the steam and smoke were still rising with no little heat. No fire was, however, seen; it all disappeared in less than four days after the commencement of the eruption. The fissure opened from two to twenty feet wide, and there are places where it is interrupted or so narrow that it can be crossed. [494]

Near the head of this fissure a small quantity of sulphur is found, as also alum, gypsum, Glauber's and other salts; none of these are abundant, and the products of this eruption are identical with those of all former eruptions on this island. Returning to the point whence I had sent the men to line across the stream, I regretted to find that they had measured until they came to the great fissure, and seeing no way of crossing it, had returned. They had measured half a mile, and thought they were half way across, but from sight I judged they were only one-third across, giving a mile and a half as the estimated width at this point, which was about the widest place of the undivided or trunk stream. I would say that the average width of the flow by uniting all the branches would be one and a half miles, the length ten miles, and the average depth fifteen feet. Where it entered deep basins and gorges it is fifty to a hundred feet deep, but where it spread over grass fields and unbroken surfaces, we find it from two to fifteen feet deep. The course of the main stream, the one that entered the sea, is due south. The flow upon the surface was short and energetic, some say three and some five days,—we give it as four days. The scene was brilliant and awe-inspiring; obstructions along the line of flow often opened vents through which fiery jets were thrown up to the height of five hundred to seven hundred feet, with amazing brilliancy and a force which made the earth tremble. All the southern coast of Hawaii was illuminated with the dazzling glare; but the amount of matter discharged is small compared with the eruption of 1855.

**Kilauea.**—In going to Kau my route was along the shore road through Puna; my return was via Kilauea. At this place I spent a day and a night, and examined the changes. Previous to the great earthquake, the fiery abysses of Kilauea had been in a raging condition as if seeking vent. The molten sea had broken up vertically in the bottom of Little Kilauea, and had left a burning stratum upon the old deposits of 1832. The terrible rendings of April 2nd tore up the earth, opened great fissures everywhere around Kilauea, sent down thundering avalanches of rocks from the high surrounding walls, and probably opened a subterranean passage for the igneous flood to the southwest. That night Pele decamped in this underground passage, and the central area of the great crater subsided about three hundred feet, leaving or rather forming a new Black Ledge of unequal width, all around the crater. In some parts the central depression left the ledge a perpendicular or beetling wall with a serrated line, but in most parts the centre sagged away gently forming a large concave basin with an angle of 20° to 70°. The surface of this concave was once the crowning or convex central portion of the crater, where ferns and ohelos have been growing for nearly twenty years. This superincumbent plateau has been depressed so quietly that the surface is very little disturbed, and the ferns and bushes are still growing in the basin three hundred feet below their position on the first of April. Some parts, however, of this great area have been covered with fresh lava, and some ferns have been killed by heat and gases.

From the black ledge I passed down and across this depression (about a mile), and then up the ascent on the other side for half a mile to the rim of Halemaumau. This is all changed; it has gone down some five hundred feet below the highest point on the black ledge, and about two hundred feet below the depression in the basin before mentioned. The walls have fallen on all sides, and the pit resembles a vast funnel, half a mile in diameter at the top and about fifteen hundred feet across the bottom. There are two places where visitors can descend into this great pit, with some difficulty and risk. Much of the time this pit is filled with smoke and sulphurous gases, with little visible fire; occasionally explosions, detonations, and fiery demonstrations occur in this awful pit.

On the fourteenth, fifteenth and sixteenth of this month (August), the sea was agitated around our entire group, rising and falling from two to four feet above and below the ordinary marks, once in ten, fifteen and twenty-five minutes; the accounts of rise and time vary as noted in different places by different observers, and I give the range.

The sea-waves of which Mr. Coan speaks were doubtless caused by the terrible earthquake which on the thirteenth of August shook the whole western coast of South

America, and drove an oceanic wave to the shores of New Zealand and these islands. But although this was decidedly a foreign volcanic or seismic demonstration, the vibrations of the land of Hawaii have not ceased, and it is not at all improbable that the reservoirs of lava are emptying themselves beneath the sea; certainly the lava is in motion. The destruction of life and property on Hawaii was comparatively small, owing to the nature of the district affected. The losses in Kau were as follows :

Houses destroyed by land-slide.....	10	Deaths, 31
Houses destroyed by sea-wave .....	108	Deaths, 46
Houses destroyed by earthquake .....	46	Deaths, 0
Houses destroyed by lava-stream .....	37	Deaths, 0
Totals .....	201	77

One life was lost in Puna by the sea-wave, and one in Hilo by a falling cliff. A shock of no greater violence in the city of Boston would probably have killed fifty thousand people, and laid most of the city in ruins.

The data for determining the direction and force of the vibrations are quite different from those used by Mallet in his remarkable investigation of the Calabrian earthquake of 1857. The houses are mostly of wood and grass, and stone walls are built of angular blocks of lava, often without any cement; a brick wall or wall of hewn stone, is not to be found in Kau. On the other hand the rocks which form the upper crust are of uniform composition, the direction of the strata is well known, and there are no strata of sedimentary rock to mislead by reflection of earth waves. On the whole, Hawaii offers many advantages for the study of seismic as well as volcanic phenomena. (Published March, 1869.)

Forty years have passed and I have little to add to the careful record of these observers, nearly all of whom have passed from earth. Neither have I much to correct in my own observations on the record. Many times I have passed through the country so terribly shaken, and every time I have cause to wonder, not at the rapidity of the destructive force of the earthquakes and lava streams, but at the rapid healing in the skin of Mother Earth in this climate. The great cones, the wide chasms are there, but how changed! Quiet and peaceful, they add so much to the grandeur if not to the beauty of the scene. The avalanche of earth, stone and water that was so much more fatal to life than the volcanic outbreak, has now disappeared beneath vegetation, and while I could trace it easily in 1880, when I passed that way a few months ago I could not point it out to my companions.

The seismic studies are not much advanced here, although the island of Oahu boasts a seismometer. No scientific body has built an observatory on the brink of Kilauea, and no competent observer has established himself in our midst.<sup>89</sup>

<sup>89</sup> Since the above was written two of the Professors of the Massachusetts Institute of Technology, Messrs. Jagger and Daly have visited Kilauea with a view to determine the desirability of establishing an observatory there under the control of that institution.