ART. II.—*Kilauea in* 1880; by WILLIAM T. BRIGHAM.

MAY 1, 1880, an outbreak from the summit crater of Mauna Loa, in the Hawaiian Islands was reported. Some persons made the ascent and found a fire fountain from the floor of the small crater adjoining Mokuaweoweo, but this soon ceased and no lava escaped from the crater or from any visible rent on the mountain side. This was unusual, and thinking the slight summit eruption was probably a prelude to a more extensive outbreak, I started in June for the Hawaiian Islands taking with me Mr. Charles Furneaux, a well-known artist, that I might be able to preserve for scientific study, should we be so fortunate as to see an eruption, those appearances that the camera does not retain and which are so difficult to describe.

As soon as possible after our arrival in Honolulu we sailed for Hilo and made the ascent to Kilauea. The road had certainly not improved during the fifteen years since I had last

* If c' be the rate of the index for perfectly elastic wires, then $\psi - c't$, and $2c't - \psi$ correspond respectively to the viscous motion and the strain intensity at the time t. The curves ψ will in general be circumflex, passing from an initial tangent c' to an asymptote which is the rate of rotation of the lower end of the wires.

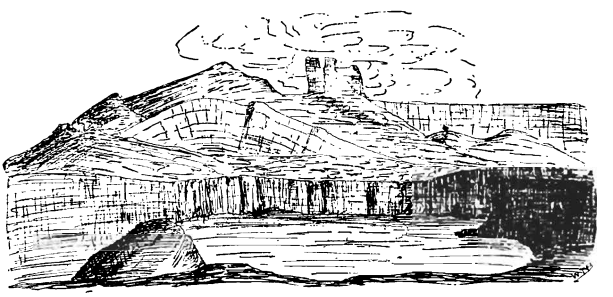
traveled over it, but on the evening of July 24th, 1880, with Mr. R. Forbes Carpenter and Mr. Furneaux, I arrived at the northeast bank of the crater, where we found a very comfortable hotel replacing the grass shanty I had occupied in 1865, while surveying Kilauea. The scene was familiar. Five times had I come to the crater at night on my way from Hilo, and almost as many times while journeying from Kau, but the wonder of the view never dulled, and to-night the fires far away to the southwest were very brilliant, brighter, perhaps, than I had seen them before.

On the morning of the 25th, we descended into the crater by the usual path leading under Waldron's Ledge. The temperature on the upper bank was 58° Fahr. and the steam from the many cracks parallel with the crater walls seemed more abundant than usual. These massive walls had been much broken, and huge fragments of ancient lava had been tumbled down in the path, making the descent much easier, and also indicating more clearly than I had ever seen before, the way in which this vast crater has attained its present proportions. The original walls may have been of small extent, but the jar of earthquake shocks cracks the not firmly united layers of lava which compose the bounding walls, and finally throws down to the floor blocks of lava in size proportioned to the strength or frequency of the shocks; then the next period of activity in the lava-supply sends over the floor streams of lava which float or melt these blocks, thus clearing away the talus. It is difficult to understand how the melted lava can raise and float the much more compact old lava, but I have seen it done more than once and the impression the sight conveyed was of a black hand gently passing under the heavy block and raising it or carrying it along. In the same way lava has insinuated itself beneath stone walls built to bar its progress and lifted and overthrown the futile barrier. So extensively has this process been at work in Kilauea that my survey of the crater, made with great care in 1865 and six years later adopted by the Trigonometrical Survey of the Hawaiian Government and republished on their official map, is already antiquated, except in a few points, ascertained by my monuments still standing; the whole boundary has perceptibly changed, and I consider Kilauea nearly five per cent larger than it was eighteen years ago.

The change visible on the bottom of the crater was even greater I was provided with an excellent barometer, by the kindness of my friend Mr. Carpenter, and found by it that while the bottom of the crater, at the base of the outer wall where first reached in our descent, was 650 feet below the Volcano House, the central portion was only 300 feet, or, in other words the floor was raised in the general shape of a flat dome

350 feet high. Nor was this hill of lava simply the overflow of the lakes whence the lava runs in frequent outbreaks; the mass was partly composed of these numberless little overflows, but the great mass was evidently elevated in the centre and the cracks every where indicated that this elevation was not a slow cumulative action but had been, at intervals, greatly and irregularly accelerated.

In 1865 the floor of the crater was very irregular, full of caves and intersected by great cracks, but its general surface was nearly horizontal. A few years later the floor fell in over about a third of its area* and the caves and cracks were alike obliterated, a funnel-like depression remaining with but slight signs of fire at the bottom. The action however continued until the funnel was not only filled up but the overflow from it reached the outer walls of Kilauea, and then, for a while, the action decreased and the lava cooled. A renewal of activity floated this crust as is indicated by occasional outflows at the edges, and so the intermittent action had in 1880 formed a tolerably regular dome surmounted by four lakes† of an average diameter of a thousand feet each. The walls of these lakes of fire were much broken and changing daily. They were elevated in places far above the contour of the dome, and from the action of heated vapors, were decomposed until their layered structure was plainly visible at a distance by the bands of brilliant colors not unlike those of the clay cliffs at Gay Head on Martha's Vineyard. Emerald-green, vermilion, blue and indian-yellow, irregularly distributed, indicated either very little homogeneity of the masses or uncertain action of the sulphurous and acid vapors.



From South East Lake—toward North.

It was very easy to see what tumbled down these fantastic cliffs, for the molten mass within the lakes was most active near the edges and under the banks which were undermined horizon-

* See plan, Mem. Bost Soc. Nat. Hist., vol. i, p. 572.
† The latest (southeast) began to form May 15th, 1880.

tally to the extent of fifteen or twenty feet by the white-hot, restless waves. From the under surface of these over-hanging shelves depended long and flexible skeins of what seemed to be volcanic spun-glass, or Pele's hair, lapped by the white waves, and seeming, in the glare in which they swung, to be hot to transparency. These pendents were very numerous, often a foot in diameter and six to ten feet long, fibrous as asbestos, and very flexible. Although they were one of the most remarkable appearances at the southeast lake, it was nearly half an hour before I had any direct evidence of the process of their formation. Occasionally surface explosions took place and the viscous fragments, thrown violently against the roof above, spun out in falling back a glass thread, sometimes several from each lump, the fragment being sometimes as large as a man's head. An attraction, probably electrical, as the compass needle is strongly agitated in the vicinity of the currents from the lakes, drew together these isolated threads until the hank was formed which floated like seaweed in a falling tide. Although I watched several hours I did not see any of these hanks fall into the lake beneath.

The brittle nature of the banks which were formed by overflows and ejected matter loosely cemented by subsequent overflows or spatters, would admit of any amount of degradation, but how is the elevation to be explained? It was no paroxysmal force that raised these cliffs some two hundred feet. Leopold von Buch, that most determined advocate of the Elevation theory of Volcanic Mountains, would have been satisfied that his theory alone could explain the formation of these as well as of the dome in Kilauea of which these cliffs were the crown. A longer stay at the crater, however, gave a more satisfactory explanation. The action in these fire lakes or pools, as has often been mentioned is very irregular and intermittent, often apparently ceasing on one side until the crust there is cool and hard; it then breaks out again from beneath this new crust turning it back like the lid of a box against the bank to which it may be soldered by the molten spatters, or, as is more frequently the case, the crust is raised *en masse* and where it touches the superincumbent cliff, carries this up with it and sometimes topples it over on to the outer part of the wall. In this way I believe the cliffs seen in the sketch, and the whole bottom of Kilauea, nearly three miles in diameter, have been floated up by degrees. If the action was constant the lava would break out along the edges of the swelling plain, as indeed it does when the inflow of lava is long continued, and the surface would become a general level by the accumulation of running lava in the lowest places. But in fact, after a certain amount of lava has flowed up through the throats whose posi-

tion is marked by the surface lakes just mentioned, enough it may be to raise the cool but somewhat flexible crust a few feet in the middle, the supply ceases; the liquid which has permeated all the cracks and fissures in the overlying crust as the lava on a larger scale injects dikes in the earth's crust, cools and becomes solid, to be in turn raised by a new influx of lava from beneath. Each layer will be thicker near the source and will thin out as the distance therefrom increases, and this is what the cracks and chasms in the dome show so far as one can get into them. The successive layers are very irregular; one not far, perhaps two hundred feet from the outer lake, was six feet thick and contained on a rough estimate ten thousand cubic yards of vesicular lava; next to it was a layer not quite two feet thick and diminishing at a distance of two hundred yards to less than half a foot.

Diagram of elevation.

After examining Kilauea by daylight, I procured lanterns and returned to the lakes about nightfall, traversing the bed of the crater while the daylight lasted. A guide (so-called) who was at the Volcano House, and who went with us that morning, refused to descend after dark, and the hotel keeper put every obstacle in our way; but I had often been there by night before, and my familiarity with the external action of this volcano made it quite safe to pass over any part of the terrible waste in the flickering, lurid light of the earth-fires, and it is only at night that the Halemaumau can be seen in all its splendor. In some respects also it is a safer journey by night than by day; for example, on our way down we crossed a low dome which gave no signs of fire except a clinking sound and a slight bluish vapor common enough in the vicinity of the lakes; the ground was so hot, however, that we crossed it rapidly to save our shoes; on our return about midnight we found that our path had led over a mound wholly injected with a network of molten lava filling the cracks not two inches from the surface, and which, now plainly visible in the darkness, was a startling as well as a beautiful sight. In the daylight the hot lava looks like black tar, and I have several times had to pull my companions from the spot where they might be standing unconscious of the silent black monster which was almost biting their feet, for it was almost invisible on the equally black floor.

In all of my previous visits the bank of the active pool had been at least twenty-five feet above the lava surface, but now we were able to approach the southeast lake nearly on a level and the effect was much grander than usual. I have spent at

various times as many as ten nights in the crater on the banks of this and other similar lakes, and have noticed blue and green flames playing over the cracks in the surface, but these seldom lasted longer than a few moments, and were not confined to any locality. Now, on the contrary, on the top of a huge hummock which seemed to have been broken from the bank, was a cluster of blow-holes from which escaped constantly a large volume of gas which burned with a bluish-green flame well shown in Mr. Furneaux's painting of the lake made on this visit. These jets were burning in the morning, and twelve hours after their volume was apparently unaltered. The pressure evidently varied but slightly, and any increase in pressure did not seem to correspond to greater activity in the molten lava. With suitable apparatus it would have been possible to have collected this gas before it was consumed. Its escape caused a noise similar to that of a steamboat blowing off steam. The mention of steam leads me to express a wish that those geologists who see in steam the prime cause of volcanic action, could have been here, and have studied an eruption of the Hawaiian volcanoes. A pailfull of water thrown into the southeast lake would have made more steam than was present all the time we stayed in the crater. It is difficult to mistake a steamy atmosphere for a very dry one, and then if steam was present in any quantity in the gaseous exhalations of Kilauea, the cold winds from Mauna Loa would soon precipitate it as rain, when in fact this is the dryest part of the island.

The ancient Halemaumau or Everlasting House, where fires have been seen, or whence vapors have escaped from time immemorial, was now replaced, I believe, by the four lakes which occupy the position of that single source. The guide and others insisted that the northeastern of the lakes was the Halemaumau, and without renewing my survey, for which I did not have with me the necessary instruments, I could not positively declare that they were wrong, but I sighted from two of my monuments left from 1865, and comparing with my notes of that survey on my return home, I found the Halemaumau of that day occupied a position nearly southwest of the present so-called Halemaumau, or in the midst of the present four lakes, so that no one of them is entitled exclusively to that name sacred to the ancient worshipers of Pele.

Among other changes the southern sulphur bank had wholly disappeared, having been consumed by a local outbreak of lava which occurred a few months before our visit. The other deposit of sulphur on the northern side near the hotel seemed smaller, and the impression conveyed was of a much smaller amount of sulphur in and around the crater than was found fifteen years before. None of the fine crystals so common then could be found now.

West of the crater on the Kau road, in the region called Umekahuna, are many small cracks which indicate plainly a general and extensive subsidence. Farther to the southwest was a long line of smoke or vapor extending, it may be, to Ponahohoa, where Rev. William Ellis found* marks of a recent outflow in 1823. I had no time to follow the evident line of fissure, and I am not informed that any one has been able to do so since. In March, 1881, an eruption took place in the lateral crater on the southeast side of Kilauea called on my survey Kilauea iki, and properly so called, although popular authority gives this name to Poli a Keawe, leaving this curious pit nameless. The overflow was slight and filled the deep crater about seventy-five feet from the bottom, leaving a glistening, level surface marked with cracks.

As the moon rose about midnight we started for the upper bank and the Volcano House. The brilliant moonlight of the tropics glittered on the metallic lava in cold contrast to the hot fire-light we had just left, and as the shadow of the high ledge fell across our path we had to walk warily and in single file to avoid the cracks our feeble lantern hardly indicated. Once on the path up the wall, we separated, and the most active got home half an hour before the last of the party.

On the 29th of July, having in the meantime made the ascent of Mauna Loa, I returned to Kilauea. In the afternoon I went to the Kau bank, and while Mr. Furneaux sketched Kilauea from the West, I photographed the cliffs of Halemaumau, and then descending two of the gravelly terraces which form the border of the crater on this side, found myself on the brink of

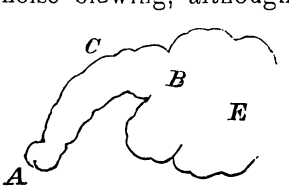
From Kau Bank—toward the East.

a perpendicular cliff beneath which the lava was escaping from several openings situated on the lower edge of the dome. The action was curious, and although the heat was very great at this height of nearly one hundred feet, I managed to watch and sketch it for an hour. The noise here was peculiar; for in addition to the clinking as of shivering glass, usually heard when this black and glassy lava cools, and the puffing or blowing common enough in the lava pools, there was a dull subterranean rumbling as of heavy machinery moving beneath the crater. It was the same noise I had heard during an earth-

* A Tour through Hawaii. London, 1827, p. 203.

quake two days before at Stone's Ranch many miles from Kilauea, and it was not unlike the sound of many looms in a cotton factory. Here there was no earthquake tremor although there is always in and about Kilauea a vibration of the ground very clearly seen when using a compass needle, but seldom noticed otherwise.

The cliff where I watched was not over the lowest part of the crater, but was where the active pools approached nearest to the outer walls, for the dome has a very eccentric apex. The fluidity of the lava as it came to the surface was about that of cream. There is so far as I know no definite scale to which we may refer various degrees of viscidity, and I am compelled to use homely comparisons which have the further disadvantage of being a variable standard. It was white-hot cream when it came out from under the crust, but in the distance of perhaps a foot had changed to a cherry red molasses, while a few feet more transformed the stream into dull red tar. By daylight the color ranges from that of arterial to venous blood, and thence to a slaty blue marking the loss of temperature by chromatic changes. At night all the moving portion is a bright red. A single outlet of small dimensions made much noise blowing, although the gas expelled was invisible. The



lava (A in the diagram) issued white-hot, ran a few feet rapidly, then crusted over, retaining its red glow along the edges of the narrow conduit C. At B there was a contraction and the flow stopped for a while; then the fountain at A renewed the supply and the lava ran rapidly from the narrow outlet B, spreading in a broad, thin sheet which did not lose its color until it reached the point E, while the original narrower and thicker stream had formed a crust and become black in less than a quarter of the distance. In places the lava met upward inclines, then the cooling but still flexible crust made a dam and carried the fluid part up and over a rise of some feet. The little lava spring was an epitome of a full lava flow and was more instructive than the immense fiery floods that from time to time break out from these volcanoes and flow for many miles. Later in the evening this insignificant flow became more active, covering twenty acres and giving more light than the lakes themselves.

Over one of the steam cracks near the Volcano House on the northeastern bank, and in close proximity to what remained of the sulphur bank, had been built a very rude steam bath. A hut of ample dimensions, a box with a stool in it, and loose boards to fit around the neck of the bather, with a wooden sluice from the steam crack to the box and a slide to regulate

the admission of steam, constitute the entire apparatus. Seated in the box late that evening, in utter darkness, while the attendant had gone outside with the lantern to get a pail of cold water, I heard, in the stillness, sounds deep down in the steam crack, rumbling and hard noises totally unlike the soft hissing or sputtering of the steam. Fearing that my imagination lent strength if not being to these sounds, I went to a crack outside and, at the risk of pitching in head-first, listened carefully. The same noise was heard distinctly, not unlike that of an earthquake, but feebler.