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ART. XLIV.—*History of the Changes in the Mt. Loa Craters, on Hawaii*; by JAMES D. DANA. With Plate XII.

THE instructive papers of Messrs. Emerson, Van Slyke and Dodge (p. 87) are a good beginning for a future history of the Hawaiian volcanoes. The earlier history, for sixty-five years back, has a source of material in three scientific reports: that of Captain C. E. Dutton (1883),* the memoir of Mr. Wm. T. Brigham, who visited the region in 1864 and 1865,† and the report of the writer,‡ after an examination in 1840, each of which may be assumed to give the facts as they were observed, whatever the value of the explanations offered. In connection with these should be mentioned the descriptions and illustrations in the Narrative of the Exploring Expedition by Captain Wilkes.§ There are also accounts from various other sources which, although in many cases overdrawn, contain information of

* In the Fourth Annual Report of the Director of the U. S. Geol. Survey, 1882-'83, 140 pp. roy. 8vo, with maps and plates of Kilauea, the Mt. Loa crater, etc.

† Notes on the volcanoes of the Hawaiian Islands, with a history of their various eruptions, by Wm. T. Brigham, A.M., Mem. Boston Soc. Nat. Hist., vol. i, Part ii. 126 pp. 4to, with four plates (including a new map of Kilauea) and several woodcuts. 1868. Mr. Brigham's map is reproduced in Captain Dutton's Report, but without explanation or remark.

‡ Report Geol. Wilkes Expl. Exped., 756 pp., 4to, with folio atlas, 1849.

§ Narrative of the Expl. Exped., by Charles Wilkes, U. S. N., Commander of the Expedition, 1838-1842. 5 vols. roy. 8vo, with an atlas. 1845. The account of the volcanoes of Hawaii, is in vol. iv. Captain Wilkes required his officers to keep journals, and used them as a source for part of the material for his Narrative.

much importance. In my Geological Report I endeavored to bring the history in a brief way down to 1849, the time of its publication. Mr. Brigham reviewed the same to the date of his last examination in 1865.

Captain Dutton gives his own observations in 1882, and his conclusions, with a few citations from other accounts; but the condition of the crater at the time of the visit was not favorable for an appreciation of the phases of the volcano or for an understanding of all its phenomena; and he is led to doubt much that was well reported before him, very much more than appears, in the light of the facts presented beyond, to be reasonable.

The conclusions he gathers from the accounts, as stated on pp. 117, 118 of his Report, are the following:

"At the present time [1882] the liquid lava columns stand about 435 feet higher than they did forty years ago. No record has ever been kept of the progressive action by which these changes have been brought about. Nothing remains to show the successive steps in the accretion of lavas which gradually filled up the interior pit. The only guides we have are the fragmentary accounts of numberless visitors describing the condition of Kilauea from time to time. These are all so incoherent, and so grossly wanting in precision, that it is impossible to frame a connected account of the process.

"There are, however, a few general features of the process which appear, and these may be briefly summarized. All accounts go to show that the height of the liquid column oscillates in an irregular manner; and while most of these oscillations are small, usually not exceeding ten to fifteen feet, yet in exceptional cases they are very much greater. Whenever the liquid column rises there is a tendency to overflow the margin of the pool which surrounds it, and this frequently happens. The quantities of lava thus outflowing and spreading out over a considerable area vary extremely, being sufficient sometimes to cover no more than a few acres to the thickness of a very few feet, while on rare occasions a square mile or two may be overflowed with a considerable body. The duration of these overflows is also extremely variable. Sometimes it is a single belch or surge lasting but a few minutes. It is quite common for the lava to run in this way for a whole day, and in large outflows it may run for two or three weeks without interruption. Sooner or later the liquid column sinks and the overflow ceases. The eruptions are not by any means confined to the lakes, but break out at unexpected places. One of the most favored spots for this action is the former focus of the Old South Lake, which for several years has been completely frozen over. The cooling lava invariably takes the form of pahoehoe."

The above meagre summary, which Captain Dutton's facts, and his knowledge of the descriptions of earlier "visitors,"

have enabled him to present, contains little, it is true, that is important to the science of volcanoes. After a careful sifting of all the earlier accounts with reference to statements bearing on the progressive changes in the craters of Kilauea and Mt. Loa, I have found that very much more is taught. What, and of what significance, the following pages aim to show.

I. KILAUEA.

Besides the publications already mentioned, the following, relating to Kilauea prior to 1841, are cited from beyond, and referred to by means of the Roman numerals here prefixed. I add some descriptive and critical notes that the facts reported may be received with proper discrimination.

I. *a.* *Journal of a Tour around Hawaii* [in August, 1823] by a Deputation from the Mission of the Sandwich Islands. 264 pp. 8vo, with six plates. Boston, 1825 (Crocker & Brewster). "Drawn up by the Rev. Wm. Ellis," of England, one of the party, "from minutes kept by himself and by his associates on the tour, who subsequently gave it their approbation." Contains, facing p. 136, a night-view of "the south end of Kilauea," from a sketch taken by Mr. Ellis, looking southwestward,* engraved by S. S. Jocelyn, of New Haven, Ct. See also *Missionary Herald*, xxii, 25, 1826. *b.* London edition, "with large additions," 1826, under the title, "Narrative of a Tour through Hawaii;" 3d edit., March, 1827, 480 pp. 8vo. Contains, facing p. 226, a day-view of the "south-west end" of Kilauea, engraved, from the same sketch, in England; but a large cone stands where was the foot of a lava-stream descending the west wall; two cones are omitted; the active cones give out steam quietly. See p. 438.

II. *Polynesian Researches*, by Rev. Wm. Ellis, 2d edition, 4 vols. 12mo, London, 1831. The first edition, 2 vols. 8vo, published in 1829, contains nothing about Hawaii. In preparing for a second edition, the Narrative (*I b*) was added (as the fourth vol.); and, for a frontispiece to this volume, a new engraving of Kilauea (from a painting—a night-view) was introduced, having the subscript, "The volcano of Kilauea in Hawaii. Sketched by W. Ellis. Painted by E. Howard, Jr. . . . London, 1831." A copy of this plate, with the subscript, "Blowing Cones. Reproduced from Ellis' *Polynesian Research*, 1823," is contained in the Report of Captain Dutton. An outline copy is introduced beyond, on p. 441. The plate differs widely from those of 1825 and 1826;

* Leaving the north end of the crater, says the "Journal," p. 145 (and "Narrative," p. 247) "we passed along to the east side, where Mr. Ellis took a sketch of the southwest end of the crater." And then, in the next sentence, "As we travelled from this spot we unexpectedly came to another crater" nearly half as large as the former. The native name of it is Kirauea-iti [Kilauea-Iki, as now written]; "it is separated from the large crater by an isthmus nearly 100 yards wide." The position from which the view was taken was hence north of Byron's hut (p. 440), either on the isthmus referred to or farther north on the bluff adjacent.

and since the text (Polyn. Res., vol. iv, p. 266) gives the same statement as the Narrative as to where the sketch was taken, the artist's fancy is evidently the chief source of the differences. The cones are fewer, but they are as active; and one, placed out in the front, is a grand high shooter, far outdoing any of those on the other plates. Further, the features of the black ledge and the wall above are changed on both sides of the pit, and the Great South Lake is put in a *southeast* recess instead of to the southwest. Mr. Ellis was a second time at Kilauea, but this was before 1826. He then found the crater much more quiet, and "the fires in the south and west burning but feebly."

III. Journal of a voyage to the Pacific Ocean and residence at the Sandwich Islands, 1822–1825; by Rev. C. S. STEWART. 8vo. New York, 1828. Contains an account of a visit to Kilauea, made on July 2, 1825. *Am. J. Sci.*, xi, 363, 1826.

IV. Visit to the South Seas, by C. S. STEWART. 2 vols. 12mo. New York, 1831. In vol. ii, an account of Kilauea after a visit Oct. 9, 1829, not overdrawn like that in the preceding work. *Am. J. Sci.*, xx, 229, 1831.

V. Voyage of H. M. S. Blonde to the Sandwich Islands in the years 1824, 1825, by Right Hon. Lord BYRON, Commander. 260 pp. 4to, with plates. London, 1826. Contains an account of a visit to Kilauea on June 28, 29 (29, 30, American time), illustrated by a folded plate presenting a view of the volcano, by R. DAMPIER, in which the many cones give out vapors quietly, and a map of the crater by Lieut. MALDEN, R. N. (see p. 441 beyond).

VI. Letters of Rev. JOSEPH GOODRICH: *a*, *Am. J. Sci.*, xi, 2, 1826, letter of April 20, 1825; *b*, *ibid.*, xvi, 345, 1829, letter of Oct. 25, 1828; *c*, *ibid.*, xvi, 346, letter of June 12, 1828; *d*, *ibid.*, xxv, 199, 1834, letter of Nov. 17, 1832.

VII. Letter of Rev. A. BISHOP, *Missionary Herald*, xxiii, 53, 1827, after a visit to Kilauea, Jan. 3, 1826.

VIII. Note of Rev. L. CHAMBERLAIN, after a visit to Kilauea with J. Goodrich, Dec., 1824, *Missionary Herald*, xxii, 42, 1826; also in Ellis's *Pol. Res.*, iv, 253, and *Phil. Mag.*, Sept., 1826.

IX. *a*. Memoir of DAVID DOUGLAS, by Dr. W. J. Hooker, with portrait, letters and Journal, *Companion of the Bot. Mag.*, ii, 79–182, 1836; the part on Hawaii, pp. 158–177. The visit to Kilauea was on Jan. 23–25, 1834, and to top of Mauna Loa, on Jan. 29; the account of the latter in his Journal, p. 175, and that in a letter to Dr. Hooker, p. 158.—*b*. Letter to Capt. Sabine, dated Oahu, May 3, 1834, partly from his Journal, but with additional material on his barometric, hygrometric, thermometric and hypsometric observations, *Journal Royal Geogr. Soc.*, iv, 333–334, 1834.—*c*. Extracts from the Journal of Mr. Douglas, *Mag. Zool. and Bot.*, i, 582, 1837, and including the letter to Dr. Hooker which describes Mt. Loa.

Mr. Douglas spent a dozen years in travels over N. America (Oregon, California, Hudson's Bay region, etc.) as an exploring

naturalist, and twice visited the Sandwich Islands, making collections and observations in botany, zoology, etc., part of the time under the auspices of the Horticultural Society of London. His instruments included a barometer, chronometers, a reflecting circle, large dipping needle, etc. While on an excursion over Hawaii in July, 1834 (then 35 years old), he fell into a pit made to entrap wild cattle and was gored to death.

X. Account, by E. G. KELLEY, of observations made at Kilauea by Captains CHASE and PARKER, on the 8th of May, 1838, and published, after submission to Cpts. C. and P., in this Journal, xl, 117, 1841, with a map of the crater (see p. 448).

XI. Notes of Count Strzlecki, after a visit to Kilauea in 1838, in his "New South Wales and Van Diemens Land," 8vo, London, 1845, and cited in quotation marks from, he says, his "manuscript notes." Also a note in the Hawaiian Spectator, i, 436, but the facts differently stated—see note, p. 449.

XII. Account, by Captain JOHN SHEPHERD, R. N., after a visit, Sept. 16, 1839, contained in the London Athenæum of Nov. 14, 1840, p. 909.

XIII. Account, by Rev. TITUS COAN, dated September, 1840, Missionary Herald, xxxvii, 283.

XIV. Rev. H. Bingham's Residence of thirty-one years in the Sandwich Islands, 1847.

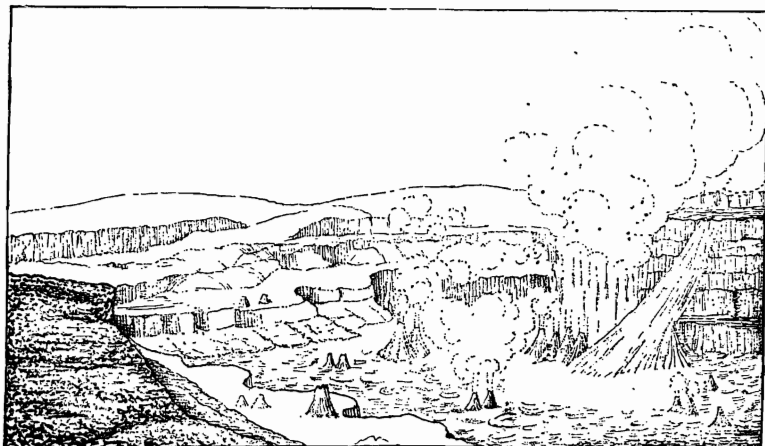
1. KILAUEA FROM JAN. 1823 TO JAN. 1841.

For convenient reference in describing the varying phases of the volcano, I introduce (see Plate XII) a view of the crater of Kilauea from its north side, as it appeared in December, 1840,* when it had, as a consequence of the eruption about six months before, a lower pit, and a "black ledge," besides the great southern lake of lavas, Halema'uma'u, all well defined. The artist of the expedition, Mr. J. Drayton, has, with the aid of his camera lucida, brought out well the features of the scene. The more distant wall is about 14,000 feet from the near side, and this is not far from the idea the view conveys, quite as nearly so as it appears to be in the actual scene. But one or two points of geological importance have been overlooked which should be mentioned to forestall wrong inferences; one is, the omission of the stratification of the wall, which is a marked feature; and another is the giving a slight concavity to the floor of the crater in the northern or near part, which was not a fact. The small jets of vapor over the bottom arise, with a single exception, from fissures or cavern-like openings; and such escapes of vapor are greatly multiplied by a rain. The exception was that of a lava-lake, about 200 feet in diameter, named Judd's Lake in the "Narrative," which was the

* Copied from the plate facing page 125, in the 4th volume of Wilkes's Narrative.

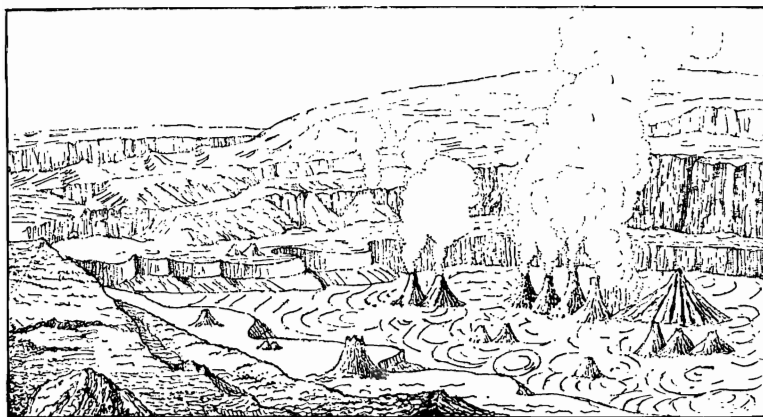
larger of two small lakes that were active in November, at the time of my visit.

1. BEFORE THE ERUPTION OF 1823.—The condition of Kilauea, prior to the eruption of 1823 is known only from statements in the "Journal of the Deputation of the Mission" (Ia), or the "Narrative" (Ib), and in a letter of Rev. Joseph



1. "The south end of Kilauea." Sketched by W. Ellis.

Goodrich (VIa), both made after the visit of August 23, and based on evidence, seen by each of the party, that a high-level



2. "The southwest end of Kilauea." W. Ellis, del.

mark existed in a "black ledge," as it was then called, running like a terrace-plain around the interior, some hundreds of feet above the bottom. "It was evident," says the Journal, "that

the crater had been recently filled with lavas up to the black ledge;" and Mr. Goodrich remarks that "the black ledge was made by the crater's being filled to that level" (VIa). This conclusion was evidently derived from the features of the ledge; for this was the first visit of foreigners. Still they may have had a hint from the islanders, one of whom in 1826, told the Rev. Mr. Bishop that "after rising a little higher the lava would discharge itself toward the sea as formerly by an underground way." I introduce here (fig. 1) an outline copy of the plate in the Journal (Ia), and also (fig. 2) of that in the Narrative (Ib), both reduced. They corroborate one another in all the main points, though having differences due either to corrections in England, or to changes suggested by Mr. Ellis. The black ledge borders the lower pit around, as in 1840, but is very narrow.

The eruption probably took place between the preceding months of March and June. At Ponahohoa in Kapapala, they saw (Ia, p. 117) a large sunken area, 50 feet deep, fissured in all directions, besides steaming chasms, and ejections of fresh lava, which they were told by the natives of the place were made by Pele two moons before; and by natives of Kearsakomo, five moons before (p. 151). It is added: "Perhaps the body of the lava that had filled Kilauea up to the black ledge" "had been drawn off by this subterranean channel."*

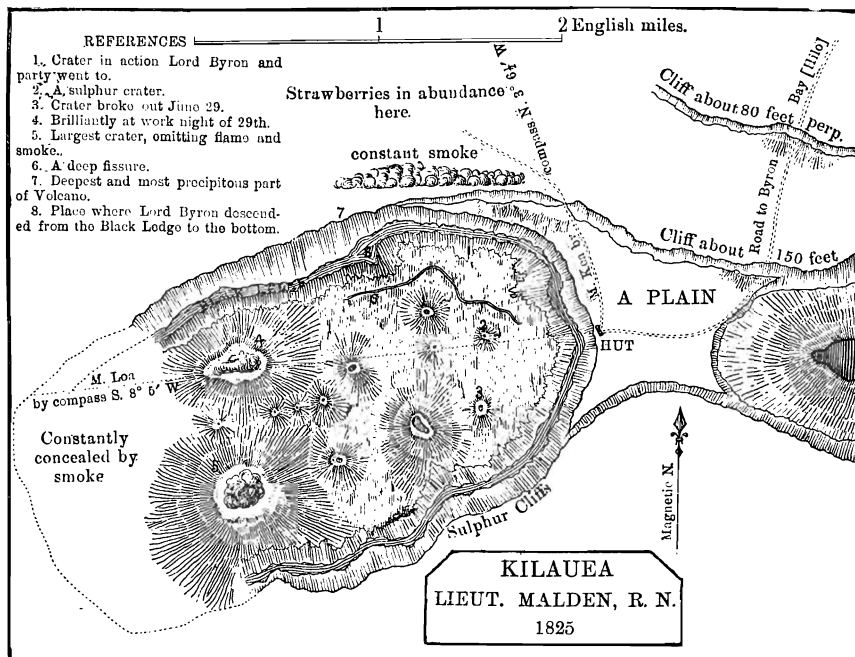
2. AFTER THE ERUPTION OF 1823. *a. Size of the Crater.*—The discharge, wherever it took place, was followed in the crater by a down-plunge of part of the floor, giving Kilauea its lower pit and "black ledge." The depth of the lower pit was estimated by the Mission party at 300 or 400 feet; and the total depth of the crater, 700 to 800, making the former nearly or quite half the latter. Mr. Goodrich, who was at the crater with the party, and three times afterward before April, 1825, estimated the whole depth at over 1000 feet, and that of the lower pit at 500 (VIa), the latter again half the former.

Lieut. Malden, R. N., of the *Blonde* (V, p. 184) made a map of the crater (of which the following is a copy reduced one-third),† and measured the height of the high northwest wall above the black ledge. He states, in a note to Lord Byron's work, that he obtained by triangulation, 8209 feet for the distance across from the "Hut," the place of encampment, to the

* It is a favoring fact that Mr. David Douglas in January, 1834, had information from the natives that in 1822 there was a great discharge in the Kapapala direction (IXb, p. 170). The same region was fissured and had its small ejections of lava at the eruption of Kilauea in 1868, and probably a large outflow off the coast.

† This copy has the lettering of the original, excepting the title, which is "A plan of the Volcano Peli, in the island of Owhyhee, by Lieut. Malden, R.N., 1825;" also the east half of Kilauea Iki is omitted.

highest part of the western wall, a point numbered 7 on his map, which is, in all probability, Kamohoalii of Mr. Dodge's map (Plate II of this volume), and $5^{\circ} 55'$ for the angle subtended by the wall between its summit and the black ledge; and that he thus made the height of the wall, 932 feet. There is here a slip, for the data give 851 in place of 932. The most recent survey makes that distance 8750 feet, using which

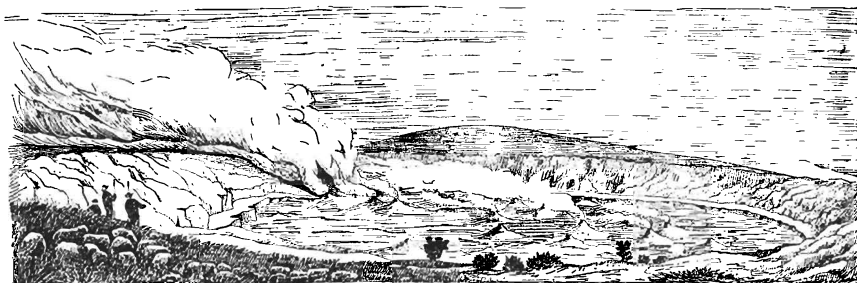


number in the calculation we get 907 for the height of the wall. It is therefore probable that 900 feet is not far from right.

Lieut. Malden *estimated* the depth of the lower pit at 400 feet (and Dampier's sketch beyond accords with this); but he saw it only from above (illness preventing his descent), and more than two years after the eruption. The observers of August, 1823, and Rev. Mr. Stewart in 1825, made it nearly or quite half of the total depth (giving for the total 1700 or 1800), and this is assumed by Mr. Goodrich in his later letters.

All accounts and pictures, together with Lieut. Malden's map, make the black ledge narrow. The plates from Ellis's sketch in the "Journal" and "Narrative" (p. 438) make the eastern side of it the broader; but the part shown is really the south-

eastern, toward the sulphur banks; and there Rev. E. Loomis, in June, 1824, found it by measurement to be "nearly fifteen rods" wide.* Lord Byron, on his descent into the pit, went from the northeast to the northwest side, and says: the width (referring probably to the north side) varies from four or five feet to upwards of twenty. The annexed sketch,

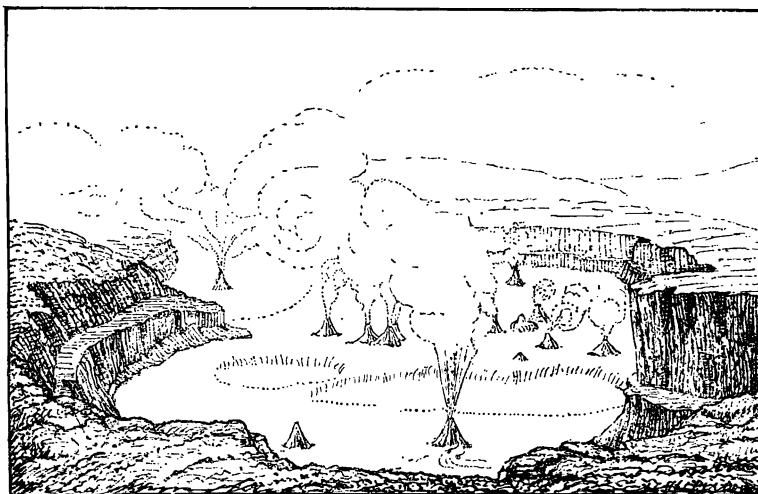


4. Kilauea. Drawn by R. Dampier.

which is a copy (reduced one-third) of the plate by R. Dampier, making the frontispiece to Lord Byron's "Voyage" (V), has the ledge very narrow.† It is not quite certain what part of the crater the view represents. Mts. Loa and Kea are in the

* Memoir of Wm. T. Brigham, p. 407.

† The plate in Ellis's Polynesian Researches makes the breadth about the same on the two sides, as the following outline copy (reduced a sixth) shows: but, as



Painted by E. Howard.

Sketched by W. Ellis.

5. The Volcano of Kilauea, in Hawaii.

has been explained (p. 436) it has little value as to details. In the relative depths, however, of the lower pit and upper portion it agrees better with the several descriptions than the other plates.

distance and the chief seat of fires is to the left, and by comparing with Lieut. Malden's map and Drayton's plates the position required for such a view can be ascertained. Rev. O. S. Stewart describes the ledge as in some places many rods, in others a few feet wide. Mr. Goodrich (VIa), after having measured the whole length of one side, remarks that "it is like a stair, although it is half a mile wide some part of the way"—which part he does not say.

On the 22d of December, 1824, Mr. Goodrich (VIa), with Mr. Chamberlain (VIII), measured the circumference of Kilauea at the top *with a line*, and made it $7\frac{1}{2}$ miles; which is the length it has on Mr. Dodge's map, the scale of which is 500 feet to the inch. They measured the crater also on the black ledge, going half way around it and estimating for the rest, and obtained, as the result, $5\frac{1}{2}$ miles for the circumference of the lower pit, which I find to be probably nearly right.

b. Condition of the crater after the eruption.—The "Journal" (Ia) says, on page 131, "the southwest and northern parts of the crater were one vast flood of liquid fire, in a state of terrific ebullition." "Fifty-one craters, of varied form and size, rose like so many conical islands, from the surface of the burning lake. Twenty-two constantly emitted columns of gray smoke or pyramids of brilliant flame [lava-jets?], and many of them at the same time vomited from their ignited mouths streams of florid lava which rolled in blazing torrents down their black, indented sides into the boiling mass below." In a night scene, p. 136, "the agitated mass of liquid lava, like a flood of metal, raged with tumultuous whirl," and "at frequent intervals shot up, with loudest detonations, spherical masses of fusing lava or bright ignited stones"*

Descending to the black ledge (Journal, p. 144) they "entered several small craters," "bearing marks of very recent fusion," "and many which from the top had appeared insignificant as mole-hills" proved to be "12 or 20 feet high." They also collected the "hair of Pele," and afterwards found it seven miles south of the crater, "where it had been wafted by the winds."

*The plate in the "Journal" of the "south end" represents "one" continuous area of lavas in "tumultuous whirl," in accord with the text, and that in the "Narrative" is similar, but with more extravagant whirls, for they are hundreds of feet in diameter, and even the black ledge is covered by them. The engraver has apparently tried to conform to the description. In the plate of the Polynesian Researches, the liquid surface is confined to the great South Lake, and a separate large area (or two of them), and nothing of the "tumultuous whirl" is represented, although the expression remains in the text (p. 245). It seems probable from the description that the party saw only "one" great lake, that of the South end, and that great overflows sent streams far northward. The height of the throw of stones (see plates) is evidently an exaggeration, as it is inconsistent with the condition of "ebullition" at the time, and with all that has been said of Kilauea since. The text says "shot up," but does not say how high.

Mr. Ellis argues from the "conical islands" (Ib, p. 226, and II, iv, p. 237) that the boiling caldron of melted lava "was comparatively shallow," implying that the cones stood on the solid bottom of the lake. He also noticed that the walls of Kilauea were "composed of different strata of ancient lava."

On page 144, the Journal (Ia), after describing long, covered, tunnel-like chambers occupying the emptied interiors of lava streams, the upper surface rippled, the roof "hung with red and brown stalactitic lava," and "the bottom one continued glassy stream," says that they followed one such covered way "to the edge of the precipice that bounds the great crater, and looked over the fearful steep down which the fiery cascade had rushed, the fall "several hundred feet." The plate in the "Journal" (p. 438) represents rudely such a stream descending the *west* wall (like that of 1832, on the opposite side of the crater); but it is strangely (perhaps because badly drawn) omitted from the plate in the "Narrative."

Mr. Goodrich's letter on April, 1825 (VIa), does not distinguish the events of his first four visits. He observes that in February, 1825, he counted twelve places where the lava was red hot, and three or four where it was "spouting up lava 30 or 40 feet"; and mentions the escape of vapors in many places, making "a tremendous roaring." On December 22, 1824, a crater opened in the bottom where the lavas boiled like a fountain, with jets 40 to 50 feet high, and flowed off 50 or 60 rods.

Lord Byron's "Voyage" states (p. 184) that on June 30th, 1825, "fifty cones of various height appeared below," at least "one-half of these in activity"; and Mr. R. Dampier's sketch represents such a scene. Lieut. Malden's map makes the cones fewer and very broad, unlike the descriptions; crater No. 5 (p. 440) is probably Halema'uma'u, for the distance from the hut is right for it, and if so the part "concealed by smoke" was of much less extent than was supposed by the party.

Rev. C. S. Stewart, who was with the party from the Blonde, makes the same statement (III) as to the number of "conical craters," and the position of the great seat of action in the southwest. He describes (p. 298) the black ledge as covered with tortuous streams of shining lava bearing "incontestible evidence of once having been the level of the fiery flood," and adds that "a subduction of lava" had "sunk the abyss many hundreds of feet to its present depth." A cone on the bottom, visited by the party, spoken of as "one of the largest," "whose laborious action" had attracted attention during the night (p. 304 and No. 1 on the map), was judged to be 150 feet high "a huge, irregularly shapen, inverted funnel of lava, covered with clefts and orifices, from which bodies of steam escaped with deafen-

ing explosions, while pale flames, ashes, stones and lava were propelled with equal force and noise from its ragged yawning mouth." The following night, crater No. 3 (Malden's map) became suddenly eruptive, and a lake of fire (No. 4?), perhaps two miles in circumference, opened in the more distant part.

Mr. Bishop, after a visit, Jan. 3, 1826, reported (VII) a similar condition of the crater; and also the filling up of the lower pit since August, 1823, of 400 feet—probably on the view that the original depth was 900 feet.

It will be observed that the above citations from Mr. Ellis and other early writers on Kilauea contain no mention of "blowing cones," except what is implied in the general descriptions. This is true of other later reports, including that of Captain Wilkes, who saw no cone in action. Further, it appears that the blowing described was done partly by the small cones, and partly by openings or oven-shaped places over the floor of the crater, as implied in the statement of Mr. Goodrich (p. 443), just as was true in 1886. They blow violently because they are small, or have relatively small apertures, so that the imprisoned vapors, on bursting the envelope of liquid or semi-liquid lava, go out with a rush and a roar. The only heights of ejections of lava mentioned are 30 to 40 and 50 feet; and the heights of cones 12, 20, and, for "one of the largest cones," 150 feet; which are common facts of later time down to the present.*

The close correspondence between the heights and character of ejections given in the earlier accounts, and those of recent years, is interesting as proving long-continued uniformity as to kind and quality of work even to the blowholes. The activity was however greater and more general than has been witnessed for many years. There are exaggerations, but they are mostly confined to the pictures, and to some of the general descriptions. The *estimates* made were usually below the truth, from honest caution.

Further, Mr. Ellis guards the reader, as has been shown, against the inference, from the island-like position of the cones in the region of liquid lavas, that they were floating-cones.†

* It is obvious that the high-shooting cone in the plate of Ellis's *Polynesian Researches* (II), blowing to a height of 700 or 800 feet (measuring it by the height of the upper wall), is the artist's fancy sketch, as suggested on page 436. It is wholly un-Kilauean and fundamentally out of place. The earlier plate from Mr. Ellis's sketch in the 'Journal' (I), also exaggerates, but only a third as much except over the South Lake.

† On page 111 of Captain Dutton's Report, the author presents the case differently, as follows.—"The earlier visitors to Kilauea whose accounts of it are now accessible speak of a phenomenon which did not exist at the time of my visit. I refer here to what has been termed 'blowing cones' within the lake. Ellis, in his account of Kilauea in 1823, described them as 'conical inverted funnels' rising to heights varying from twenty to forty, or even fifty feet above the surface

c. *Progress in the filling of the lower pit.*—As early as February, 1825, Mr. Goodrich stated, in view of the overflows he had observed, and the making of a "mound" over 60 feet high in six weeks, that the pit had begun to fill up (VIa); and in his letter of October 25, 1828, (VIb) he made the pit to have diminished in depth since August, 1823, by 300 or 400 feet. A year later, Oct. 25, 1829, Mr. Stewart (VI) described the lavas as still 200 feet below the level of the black ledge—which implies a filling of 400 feet, if the depth in 1823 was 600 feet, and of 600 if 800 feet deep. He states that although the crater was comparatively quiet, the bottom was crossed by a chain of lava-lakes, one of them a mile wide, throwing up masses of lava 15 to 20 feet; and that there were also six cones in action in the lower pit and one on the black ledge. Here again the height of the ejections mentioned is small. In October, 1830, the black ledge was still distinct (XIV, p. 387.)

3. BEFORE THE ERUPTION OF 1832.—Before the eruption of 1832, as Mr. Goodrich states, after a visit to Kilauea "about the 1st of September" of that year (VIc), "the crater had been filled up to the black ledge and about fifty feet above, about 900 feet in the whole since I first visited it, and it had now again sunk down to nearly the same depth as at first (in 1823), leaving as usual a boiling caldron at the south end." The precise time of the discharge and down-plunge is not stated. He adds, "The earthquake of January last had rent in twain the walls of the crater on the east side, from the top to the bottom, producing seams from a few inches to several yards in width, from which the region around was deluged with lava." "The chasms passed within a few yards of where Mr. Stewart, Lord Byron, myself and others had slept," "so that the very spot where I have lain quietly many times is entirely overrun with lava." (See map, p. 440). This outflow is stated by Mr. David Douglas (IXb) to have occurred in June, 1832. We may conclude, therefore, that the time of eruption was probably in January, but perhaps in June of 1832; certainly before September 1832, the time of Mr. Goodrich's visit.

4. AFTER THE ERUPTION.—a. *Size of the crater after the eruption.*—As to the new depth of the lower pit, we have first Mr.

of the lake, with openings at the top from which jets of vapor and sometimes spouts of lava were thrown out. As many as fifty were seen at one time within the great lava lake then existing, and most of them were simultaneously active. The same phenomenon was described in 1825 by parties from H. B. M. frigate *Blonde*. They were also observed by Wilkes in 1841, and have frequently been seen within the last ten or fifteen years by many other visitors. They appear to have been composed of solidified but very hot lava. None of them were permanent, but after a short period of activity they were either melted down, or shifted their positions. Ultimately, no doubt, they were remelted. That they shifted their positions is fully attested by many observers. Most probably they were masses of solidified lava floating like bergs in the lake."

Goodrich's statement above cited, "the same depth as at first," and the additional remark that the filling amounted to "about 900 feet," which statement would make the depth of the lower pit after the eruption of 1832 nearly 900 feet, and of the crater from top to bottom 1750 feet. This estimate of the original depth accords with his view in 1825 that the upper and lower walls were of nearly equal height, and that Lieut. Malden's measurement was therefore good for both. There is no published account furnishing data for correcting this estimate.

By letter from Mr. W. D. Alexander, Surveyor General of the Hawaiian Islands, dated March 2, 1887, I learn that his father, Rev. Wm. C. Alexander (who arrived at the Sandwich Islands in 1832) visited the crater on the 12th of January, 1833, four months after Mr. Goodrich's visit, and in his private diary gives the depth of the crater as 2000 feet. This tends to confirm Mr. Goodrich's numbers, although only a rough estimate. He says nothing of any black ledge, except of that at the bottom of the 2,000 feet; and this leads to the inference that the ledge was quite narrow, as in 1823.

On the 22nd of January, 1834, Mr. David Douglas, of Scotland (XI), made careful barometric measurements of the crater, (all the details of which, with the calculation, are given in his letter to Captain Sabine, IX*b*). He obtained for the depth to the black ledge, on the highest northwest side, 715 feet; and to the bottom of the lower pit, 1,077 feet, (mean of two calculations). This makes the depth of the lower pit at that date 362 feet; in addition to which he says that there were 43 feet more to the surface of the liquid lavas.

We thus know that the down-plunge was a fact; and using as evidence only the measurements of Mr. Douglas, and noting that they were made at least a year and a half after the eruption, it was larger both as to depth and breadth than that of 1840. Hence the eruption of 1832—instead of being "a very small one, only remarkable from the fact that the fissure from which it emanated opens at a level of more than 400 feet above the present lava-lakes" with, "so far as known," "no sympathy" "within the lavas of Kilauea"—*—was one of Kilauea's greatest, although not registered, so far as known, in any outside stream of lava.

b. Condition after the eruption.—Mr. Goodrich describes the Great Lake at the south end as "60 or 80 rods long, and 20 or 30 rods wide," about 20 feet below the brim; "the whole mass of liquid and semi-fluid lava was boiling, foaming and dashing its fiery bellows against the rocky shore; the mass was in motion, running from north to south, at the rate of two or

* Report of Captain Dutton, p. 124, referring to the eruption near Lord Byron's Hut.

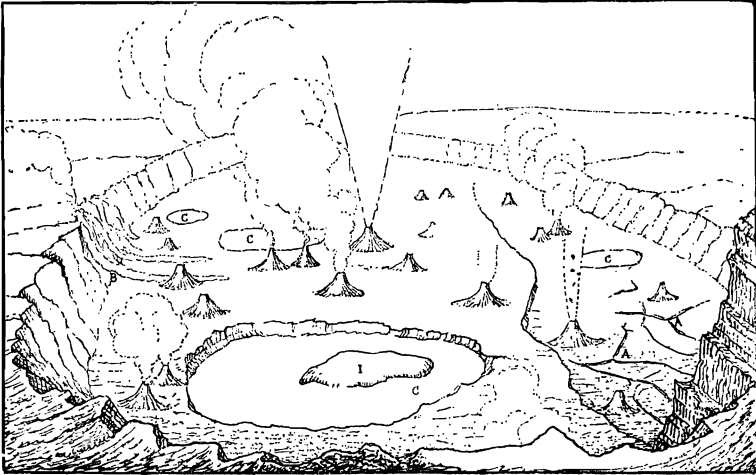
three miles an hour, boiling up as a spring at one end and running to the other." Mr. Alexander, while in the crater four months later, found this lake, "the principal furnace, not in lively action," and ascended, much disappointed; but by the time he had reached the summit, "the grand crater commenced furious action, spouting with a roaring sound, streams of melted lava far into the air." The next day he went again to the bottom, and direct to the great boiling caldron two and a half miles distant," and found it "3000 feet long and 1000 feet wide, tossing its fiery surges 40 or 50 feet into the air." He went to the brink of the lake, but left it on account of the fumes, and three minutes afterward the spot was covered with the lavas of an overflow, "which," he says, "seemed to pursue us as we hastened away." It is important to observe that uniformly the "far into the air" and similar expressions in the general descriptions of travelers become, when put in figures, not far from 30, 40 or 50 feet of actual height.

Mr. Douglas, whose visit was in 1834, reports (XI) that he found two great boiling lakes in the crater, a northern 319 yards in diameter, and a southern 1190 by 700 yards in area, heart-shaped in form. The great southern lake was "at times calm and level, the numerous fiery-red streaks on its surface alone attesting its state of ebullition, when again the red hot lavas would dart upwards and boil with terrific grandeur, spouting to a height which from the distance at which I stood (on the west wall) I calculated to be from 20 to 70 feet. Close by stood a chimney above 40 feet high which occasionally discharged its steam as if all the steam engines in the world were concentrated in it." There were other chimneys over the bottom, some active and others comparatively quiet. In each of the large lakes the lavas had an apparent movement southward, the velocity of which Mr. Douglas measured (by throwing on a block of lava and seeing how long it took to go 100 yards) making it nearly $3\frac{1}{4}$ miles an hour.*

c. Filling of the pit after the eruption of 1832.—On the 8th of

* Mr. Douglas's testimony with regard to the Hawaiian volcanoes has been doubted because of his incredible account of what he saw at the summit crater in a letter to the eminent botanist, Dr. Hooker. But I find that injustice has been done him. His *Journal* of his visit to the summit (IXa), evidently written by him at the time of his observations, represents the crater as having been long quiet. While at Honolulu, over three months later (May 3), he wrote Capt. Sabine on his various physical investigations and barometric measurements, and gave him the same facts as to the summit crater that he has in his *Journal*, and partly in the same words. Only three days later (May 6) he wrote his letter to Dr. Hooker—a reasonable letter in all parts excepting its description of the terrific activity and immense size of the Mt. Loa crater. His words indicate a mixing up and magnifying of what he had seen at the Kilauea and summit craters, which can be explained only on the ground of temporary hallucination. Mr. Douglas was an excellent Scotchman, and all the rest of his writings are beyond questioning.

May, 1838, about six years after the eruption, Captains Chase and Parker were at Kilauea. An account of what they saw was written by Mr. E. G. Kelley from their statements, submitted to them for approval, and afterward published in this Journal (X), with a plate from their sketches, but redrawn unfortunately by a New Haven artist who evidently had Vesuvius in his thoughts. An outline copy is here introduced. It was taken at the south end looking northeastward, and has the Great South Lake in the foreground. There is no black ledge on the



Kilauea, from the south end.

west or north side; and to the left instead of a black ledge there is a depressed plain, 40 feet below the general level; the part of it AA was flooded by lavas after having been passed over by the party. The crater was unusually active; there were 26 volcanic cones, 20 to 60 feet high, eight of them throwing out cinders, red hot lava and steam, and six lakes of lava (c), including the Great Lake "occupying more space than all the rest."

Not far from the center of the Great Lake there was an island, I, of black solid lava which "heaved up and down in the liquid mass" and "rocked like a ship on a stormy sea." This is the first mention of a "floating island." The descending streams at B are described as streams of sulphur, but as this is not possible they were probably lava-streams in part colored yellow.

The same year, in August or September, Count Strzelecki (who later visited New South Wales), was at the crater (XI). He made some barometric measurements over the region, and

determined the height of the north-northeast wall down to the "boiling surface of igneous matter" to be 600 feet, and makes no mention of a black ledge. He describes six craters with boiling lavas, four of which were only 3 or 4 feet high, a fifth, 40 feet, the sixth 150; the first five as containing 12,000 square feet each, while the sixth—which he says is called "Hau-mau-mau"—contained nearly a million. He alludes plainly to the ebullition over this great lake in the expression "ceaseless impetuosity and fury." He states that the lava sank and rose in all the lakes simultaneously; which is not always true.*

On the 16th of September, 1839, Captain John Shepherd, R. N., visited Kilauea (XII). He speaks of the black ledge as "obliterated;" of cones 20 to 30 feet high, whence issued vapors and lava with loud detonations; of a lake of lava toward the *east* side one mile long and half a mile wide within a cone 100 feet high, from the summit of which he saw the expanse of liquid lava in violent ebullition. He also mentions that the lavas had an apparent flow from south to north, and adds, "caused by the escape of elastic fluids, throwing up the spray in many parts 30 to 40 feet."

5. BEFORE THE ERUPTION OF 1840.—Mr. Coan states (XIII) "on the testimony of many natives" that in the latter part of May, for a week previous to the eruption, the interior of Kilauea was "one great sea of liquid lavas;" which signifies the existence of many active cones and boiling lakes over the bottom and extensive outflows from the lakes and from opened fissures. He remarks, further, that the ground about Kilauea so trembled from the action below that the islanders avoided the path along the verge of the crater.

There was indubitable evidence at the time of my visit, in November, five months after the eruption, of a recent flooding of the black ledge with lavas, in the tortuous scoria-covered streams of cooled lava that covered it.

6. THE ERUPTION OF 1840.—No intelligent observer was present at the eruption. Mr. Coan, then a resident of Hilo, returned home from Oahu in July, and his first account of it appeared in September of that year. He found that, through

* Count Strzelecki's note in the *Hawaiian Spectator* occurs in the number for October, 1838, which number also states that he was visiting various portions of the Pacific in H. B. M. S. Fly. It differs widely from the report in his own work, in making the area of the largest lake 300,000 square yards, and those of the smaller "about 5,700 square yards each." His volume is the later publication, and should set aside the newspaper note. Count Strzelecki, in this volume, describes the terraces around the Kilauea crater as vast platforms; makes the height above the sea-level of the north-northeast side of Kilauea two paces from the edge of the precipice, 4,109 feet and 600 feet above the fires below; and observes that this is 950 below the brim of the *ancient* crater, the highest point of which he made 5,054 feet, and its circuit 24 miles. He thought he saw evidence that this greater crater was formerly brimfull of molten lava.

the discharge of lavas and a consequent down-plunge in the crater, there was again a lower pit with a black ledge. He gathered facts showing that the eruption began on the 30th of May, made itself apparent at intervals down the eastern slopes of the mountain, finally broke out as a stream twelve miles from the coast and flowed into the sea just south of Nanawale; and that the flowing continued for three weeks. The condition of the crater in November, the time of my visit, agrees well with the view in the accompanying Plate, (Pl. XII) which was taken two months later. The route to the seashore was surveyed by the officers of the Expedition in January, and less perfectly by myself in November.

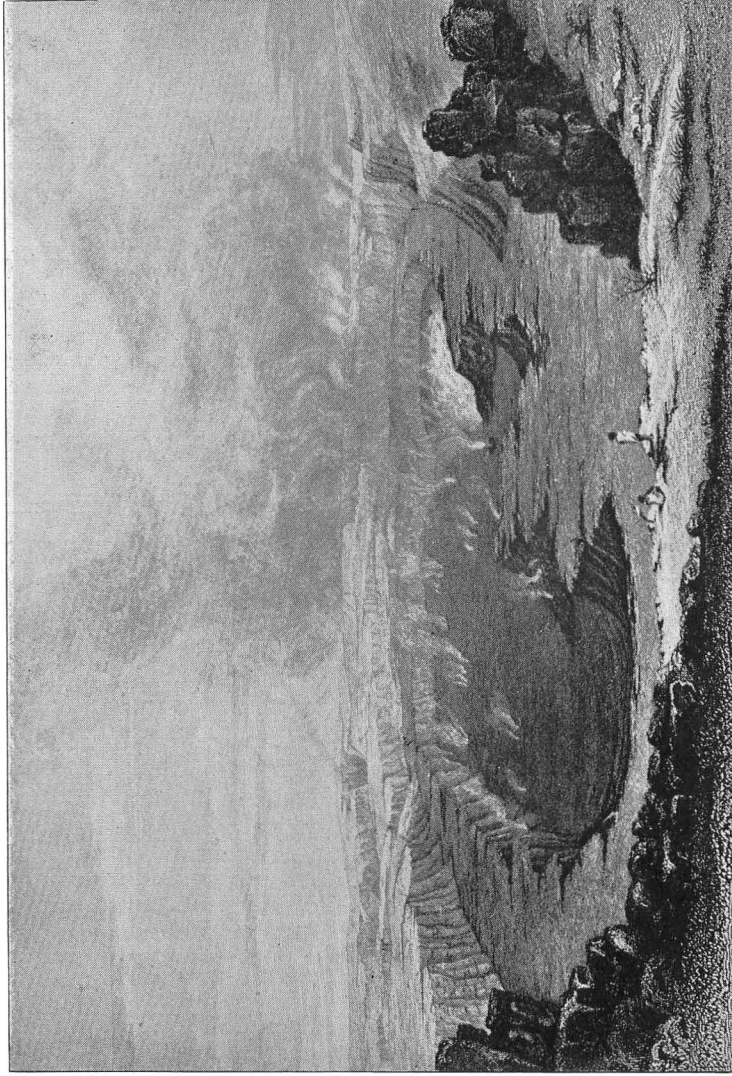
My failure to survey the whole route of the lavas to the seacoast and investigate other parts of Hawaii was in obedience to orders. The vessel of the Expedition to which I was attached—the sloop-of-war “Peacock”—was at the time already under sailing orders for hydrographic work in the equatorial regions of the Pacific; and, although the geologist of the Expedition, I was required to go off with her, away from the most important field of geological investigation in the ocean. Only a week was allowed me for Hawaii. I left the region of volcanoes with a silent protest—the only safe kind—but found compensation through work in another field; and though an old field to me, it was one of unexhausted delight and instruction—the coral islands of the central Pacific. I was enabled to add much to the knowledge of reefs, corals and crustaceans which I had gathered during the preceding season in the Paumotu, Society, Samoan, Friendly and Feejee Islands, by excursions and studies in the Union Group of atolls, the Phoenix Group, the Kingsmill or Gilbert islands, and others. Captain Wilkes had once (while we were off Patagonia) sent me word, when I was seeking information from the log-book of his vessel as to the winds of a Cape Horn gale, that he had that department in charge. At the Hawaiian Islands it was made to appear that at his pleasure, he had the geological department also in charge, although he knew nothing of the subject. The “Narrative,” however, was intended to include all departments; and the energetic commander was never conscious of incapacity in any direction.

7. AFTER THE ERUPTION OF 1840.—*Size of the Crater.*—Capt. Wilkes states, on page 123 of the 4th volume of the Narrative, that the “black ledge surrounds it [the crater] at the depth of 660 feet, and thence to the bottom is 384 feet;” and four pages beyond: “the black ledge is of various widths, from 600 to 2,000 feet.” The black ledge “was found [to be] 660 feet below the rim.” The floor of the crater “was afterwards found to be 384 feet below the black ledge, making the whole depth 987 [1,044?] feet below the northern rim.”

The observations here reported were made in December, 1840, the party leaving on the 18th for the top of Mt. Loa. Other observations on Kilauea were made by Capt. Wilkes and his officers just a month later, in January; and these include a topographic survey of the crater by Capt. Wilkes, who says: "I measured my base and visited all the stations around the crater in their turn." On page 175 it is stated that the observations of one of the officers of the expedition, Lieut. Budd, made the depth to the black ledge 650 feet, and thence to the bottom 342 feet, whence "the total depth 992 feet." On page 179, we learn that Lieut. Eld was instructed to make the measurement of the depth, "as I was desirous of proving *my own* as well as Lieut. Budd's observations;" and then follows the remark, "The measurements coincided within a few feet of each other." Had the precise numbers obtained by Lieut. Eld been reported we might be able to remove the doubts left by the varying statements. But the fact that Lieut. Budd's results are inserted by Capt. Wilkes on his own map of the crater is a strong reason for believing that the coincidence was between the results obtained by the two Lieutenants.

I add here a few words from my own report, on the surface about Kilauea, on the stratification and rock of the walls and the absence from them of scoria, and on the escaping vapors of the Great Lake. "The country around [Kilauea] is slightly raised above the general level, as if by former eruptions over the surface." The walls "consist of naked rock in successive layers" "and look in the distance like cliffs of stratified limestone." The rock is a heavy compact dark gray to grayish black lava [basalt] containing usually fine grains of chrysolite; and no layers of scoria like that making a crust of two to four inches over the solidified lavas from the lava-lakes, intervene even in the walls of the lower pit, each new stream having apparently melted the scoria-crust of the layer it flowed over. While the cooled lava-streams over the bottom were of the smooth-surfaced kind [and would be called pahoehoe] there was the important distinction into streams having the scoria-crust just mentioned, and those having a solid exterior and no separable crust, pointing to some marked difference in conditions of origin. "The vapors rising from the surface of the Great Lake were quite invisible until reaching an elevation where part became condensed by heat" (p. 179); here began "a column of wreaths and curling heaps" and upon this column "the broad canopy of clouds above the pit seemed to rest" (p. 172).

[To be continued.]



CRATER OF KILAUEA. J. Drayton, U. S. Expl. Exped., 1840.