ART. XXIX.—*Notes on the Geology of the Hawaiian Islands;* by J. C. BRANNER. (With Plate XV.)

Introduction.—The few notes I was able to make during a recent visit to Hawaii are necessarily fragmentary, but our knowledge of the geology of these islands is so strictly confined to volcanic phenomena that I venture to publish these facts for what they are worth.

It is much to be hoped that the territory will make early provision for a geological study of the group. A modest territorial survey could be readily and cheaply carried on in connection with either the government survey or with the Bishop Museum at Honolulu. Such a survey could bring together illustrative material of the greatest scientific importance and educational value, and it would reflect great credit upon the intelligence of the people of the islands.

The canyons on the north side of Hawaii.—One of the most striking features of the island of Hawaii is the series of canyons on the northern coast of the island. These gorges are mentioned by Dutton,* but he says nothing further of them than that they are valleys of erosion.

One of the most striking things about them is that as one sails round the extreme north end of the island the coast bluffs are low—averaging less than a hundred feet—and the land but little broken and under cultivation. Suddenly there is an abrupt change in the coast topography: the bluffs facing the area have an elevation of a thousand feet, and enormous gorges extend inland with almost perpendicular walls, some of which it is said are as much as 2,000 feet in height. These gorges, great and small, continue for twelve miles along the coast, where they end as suddenly as they began, against comparatively smooth arable lands. The region of gorges is covered with forests, and, save in the flat valleys, is not cultivated. The gorges extend back inland for five or six miles, in the direction of the cluster of highlands near Waimea Village. The summit of this cluster is reported to be 5,505 feet high. One of the remarkable features of these valleys is the fact that they are nearly or quite as deep at or near their upper ends as they are at their lower ends. Another striking feature is that the largest of them have flat bottoms.

This deeply eroded part receives no more rain than the adjacent areas north and south of it, and the difference in topography is due, I believe, to the difference in age between

* Hawaiian Volcanoes. By C. E. Dutton. Fourth Ann. Report U. S. Geological Survey, 1882-83, pp. 75-219. Washington, 1884.

the different portions of the island. Lava flows from Mouna Kea have encroached upon this eroded region from the south,

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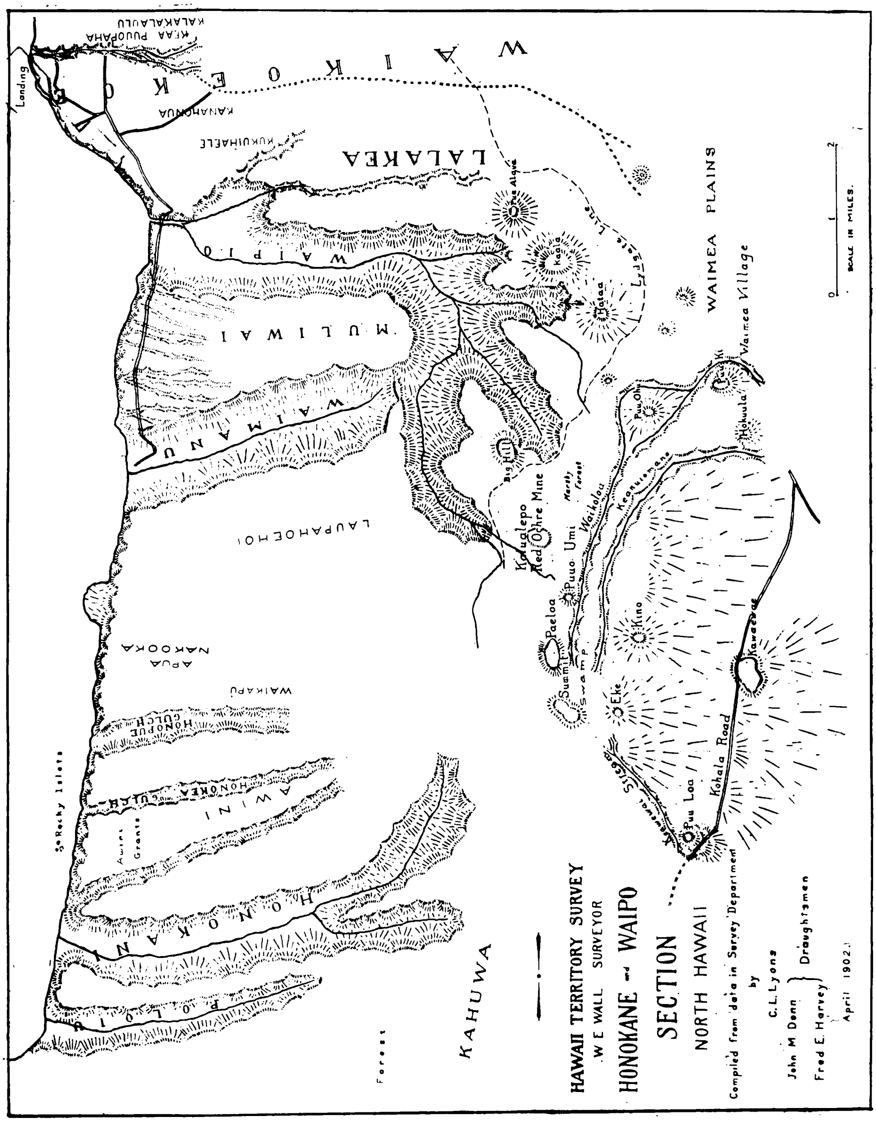


burying the lower and more eroded land surfaces, while on the north similar flows have likewise encroached upon that side.

The great height of the sea bluffs is due to the long encroachment of the sea upon this old land margin. The flat bottoms of the largest of these canyons are due to the fact that the canyons were formed as V-shaped gorges on the land and have sunk until their lower ends were filled by the sea, forming deep fjords which were soon filled by the material cut by the waves from the headlands and thrown back into them, and by the debris brought down from the land by the streams. An approximate idea of the depression might be obtained by borings in the lower ends of these valleys. I am unable to learn of any deep wells having been put down in them. The accompanying photograph (fig. 2) gives some idea of the striking topography of the Waipio Valley, the largest of the group.

Professor W. T. Brigham, the able director of the Bishop Museum at Honolulu, tells me that there are precisely similar valleys on the north side of the island of Kauai. An assistant in the office of the government surveyor at Honolulu, who has lately visited the region, also states that the bluffs on that part of Kauai are from 1,000 to 1,500 feet high, and that some of these valleys are flat-bottomed while others are V-shaped and truncated above tide level.

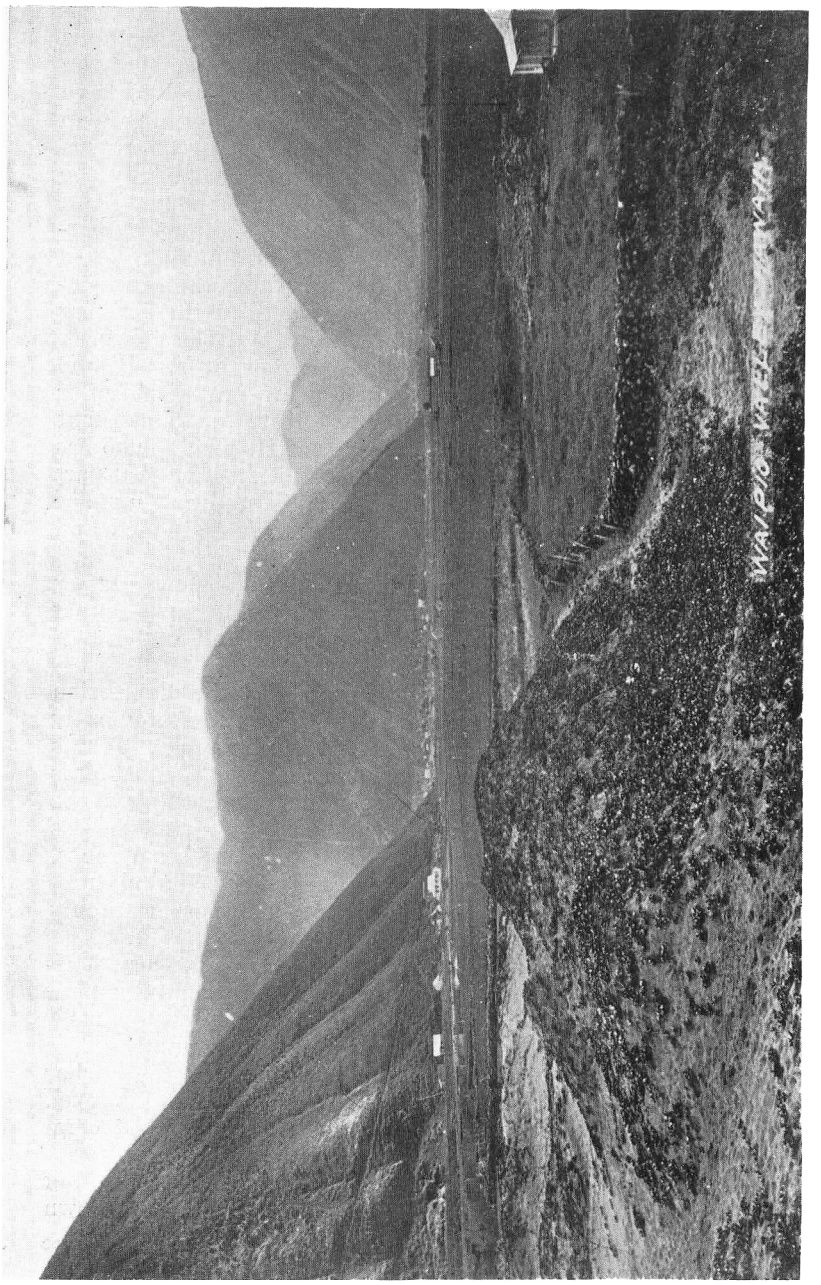
The origin of Pearl Harbor (Plate XV).*—The topography of Pearl Harbor is so different from that of most harbors that it is sometimes spoken of as being unusual and difficult of explanation.

Briefly, this harbor has been formed by the depression beneath the sea of a small group of dendritic valleys previously carved by subaerial erosion in horizontal beds of rocks. If this explanation is not at once suggested by a glance at the map, it is made quite plain by a brief study of the rocks exposed about the harbor. The rocks are horizontal and consist of alternate beds of volcanic tuff and coral rocks. The so-called coral rocks, however, are not necessarily all of coral but are often mixtures of shells and other fragmental calcareous materials commonly found in and about coral reefs.

The low bluffs that surround the harbor are nearly all horizontal beds of tuff. Coral rocks are shown on the government map of the harbor at a few places. Those particular points I did not examine, but there is no reason for doubting this identification of the rock, for a few miles east of the harbor the coral rocks are exposed ten or more feet above tide level. In the wells put down in the vicinity of the harbor the coral rock is also found a very short distance below tide level.

The harbor is now quite shallow over most of its area, but this shallowness is due to the silts having been washed down

*The explanation here given was presented before the Social Science Association of Honolulu in March, 1903.



The Waipio Valley looking up the valley from near the sea shore.

from the surrounding land and deposited in the harbor's quiet waters. In the first edition of his work upon volcanoes Dana says (p. 282) that it would be necessary to cut a channel through the outer reef in order to make a harbor of this place. Later it has been found that there is a natural opening quite through the reef, and dredging is now going on to remove the bar of sand just outside of the narrow entrance. The shallowness of the water outside and its greater depth in the neck of the harbor is caused by tidal scour.

The depth of the silts in the harbor has probably been determined, but I have not been able thus far to get any information on this subject. The topography and geology offer no suggestion further than that the depth is likely to be approximately the same as that of the harbor at Honolulu, that is, about thirty feet. The depth of the silts can be readily determined by driving steel rods down into them.

We shall readily understand the process by which this topography was made if we imagine the whole island elevated fifty or seventy-five feet and the original rock-beds restored right across the present channels. We should then have the streams that now enter the upper parts of Pearl Harbor flowing across a table land of horizontal rocks, uniting at or near the point marked A on the map and entering the sea below the boat landing through a single channel. In the course of time these streams would all cut steep-sided gorges, and where the gorges, by bends of the streams, approached each other the watershed between the two streams would be lowered below the general land surface. Such a place would eventually be an isolated bit of high land and after depression would form an island, such as we have in Mokuumeume. A depression of the island would back the sea into the valleys; the cutting of the streams would then cease, and the land silts would settle in the quiet water of the submerged channels, forming shallows, later mud-flats, and then the swampy lands.

The map of the island (see Plate XV) shows that the entrance to Pearl Harbor through the coral reef is very like that opening into the harbor of Honolulu and like another similar one known as the Kalihi entrance about two miles east of the Honolulu harbor. It seems probable, therefore, that all three of these harbors and their passages through the coral reef have been formed in the same way.

Aside from the form of Pearl Harbor there is evidence of depression of Oahu and the other islands of this group. The evidence of depression on Oahu consists partly of the great depth at which coral rock has been found in deep wells; some of the evidence on the island of Hawaii is mentioned in the preceding note upon the Waipio and other canyons.

The east base of Diamond Head.—In an article published in vol. xi of the Bulletin of the Geological Society of America, pp. 57–60, Dr. Dall speaks of certain beds at the base of Diamond Head on the island of Oahu. It is possible that my own observations about the eastern base of that mountain were not made upon the same beds as those spoken of by Dr. Dall, but as nearly as I can make out from the text of his article, the beds are the same. If so I do not agree with some of his conclusions in regard to geologic structure. He says: "It (Diamond Head) is composed of horizontal layers of tuff, interstratified with thin layers of calcareous sand, the lime from which, leached out by the rain, is redeposited in a thin superficial crust of a brilliant white, giving the effect, among the

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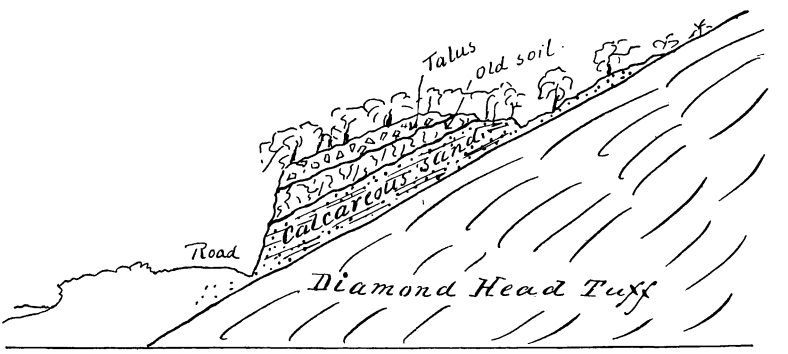

The section exposed beside the road at the southwest base of Diamond Head.

sparse arid vegetation, of a thin layer of snow. The strata of the head have not the 'onion peel' aspect of layers of successive subaerial eruptions, but are strictly horizontal and have every aspect of having been deposited in water. . . . . My observation was not carried to a point more than 100 feet above the sea-level, but it is evident that the sand layers occur, interstratified in the mass, clear to the top (700 feet). The upper limy layers appear, so far as observed, to be composed almost entirely of calcareous sand, and no shells or corals were observed in them in a recognizable state. At about 50 feet above the sea the heavy tuffs overlie the uppermost heavy layers of calcareous rock. The latter is nearly or quite horizontal, and consists of coral-sand grains more or less compactly consolidated, with occasional patches where marine fossil shells were abundant. There are hardly traces of coral larger than fine gravel and no coral masses."

Calcareous beds like those mentioned by Dr. Dall are exposed along the road leading from Waikiki beach past the lighthouse, and these beds appear to be horizontal. This appearance of horizontality, however, is deceptive and is due to the direction of the sections cut along the road. The beds are mostly calcareous sands dipping seaward an angle of from thirty to thirty-two degrees. (The highest angle of dry sand is thirty-five degrees.) The accompanying photograph shows the bedding fairly well. These beds are about fifteen feet thick at this place, and it is my opinion that they are old sand dunes that were blown up from the beach against the eastern flank of Diamond Head after the crater ceased to be active. In any case, these sands rest directly upon the Diamond Head tuffs, and are overlain by an old soil containing fossil plants, and by talus derived from the breaking up of the tuffs of the upper part of Diamond Head. The beach was farther north when these sands were blown up than it is now, for the waves have long been cutting away and encroaching upon the land.

The talus along this same road and near the lighthouse at the base of Diamond Head deserves a word. This talus for the most part has the same dip as the tuffs beneath them, but here and there they are horizontal for a short distance. Nearly all of them, however, appear to be horizontal owing to an angle at which they are cut by the road. This appearance of horizontality, therefore, is deceptive. The talus deposits are probably as much as thirty feet thick at and near the quarry south of the lighthouse. It is evident, however, that if they were really horizontal, as they were regarded by Dr. Dall, they would have a much greater thickness than they really have. The talus beds contain scattered throughout them a great many fossil shells. These shells are sometimes found in old soil layers, but they are found in almost every part of the materials, even among the loose, open angular rock fragments. These fossils are land shells. Whether they are living forms I did not ascertain. The animals have died, have fallen on the surface, and have eventually been buried by talus sliding down the steep slopes of Diamond Head. It is to these that Dr. Dall seems to refer when he says the tuffs, i. e. the talus beds, overlie the calcareous rock.

Since the above was written I have seen an article published (American Geologist, Jan., 1901) by Mr. S. E. Bishop of Honolulu in which he also disagrees with Dr. Dall in regard to the origin of the calcareous sand. He says that it is aeolian, and he accounts for the shells in the same way as the writer. I do not agree with either Mr. Dall or Mr. Bishop about the tuffs of Diamond Head having been deposited in shallow water. I think they are all land deposits; at least I

Aeolian sandstone at the east base of Diamond Head, Honolulu.

see no reason why they may not have been deposited on land, for in structure and contents they are similar to the other cinder cones on this and other islands of the Hawaiian group.

Cirques.—On the sides of Diamond Head near the top are many small cirques that throw light upon the origin of these topographic forms. The beds of tuff at the rim of the crater dipping outward, erosion has cut deep funnel-shaped pits—small cirques—in the outside of the crater. The back walls of these pits are very steep, even vertical or overhanging in the middle. In the development of these cirques or barriers separating two of them disappear and the cirques unite at the top but are separated below by symmetrical cones that form the spurs or ridges that radiate from the main mountain. Such cones are beautifully developed on the east face of Diamond Head. I have tried in vain to represent the cirques of Diamond Head by a diagram. The figure accompanying shows their relation to the edge of the crater on the right.

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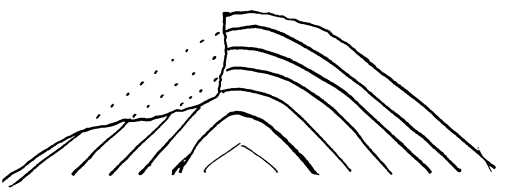

Section through a cirque on the outer rim of a crater.

On the island of Hawaii are several cirques of enormous size. The one shown on the next page and made from a photograph has walls said to be more than a thousand feet high. The upper ends of several of the deep valleys of northern Hawaii appear to have been cirques originally. It should be noted that the rocks both of Hawaii and of Diamond Head on Oahu in which the cirques are cut are of even texture throughout, and that they spall off rapidly in small angular lumps. Those who believe in the glacial origin of cirques find here good evidence that cirques both large and small may be and are formed without the aid of ice.

The craters near the Pali.—Dana mentions (Volcanoes, 2d ed.) the small crater at Pali as probably the last expiring effort of the volcanic phenomena of the island of Oahu. Mr. S. E. Bishop in his interesting paper upon the geology of Oahu, published in the Hawaiian Annual for 1901, also speaks of this crater. It occupies a striking position in relation to the topography of the island. The structural relation of its tuffs are shown by the accompanying sketch (fig. 7). It is clear that this crater

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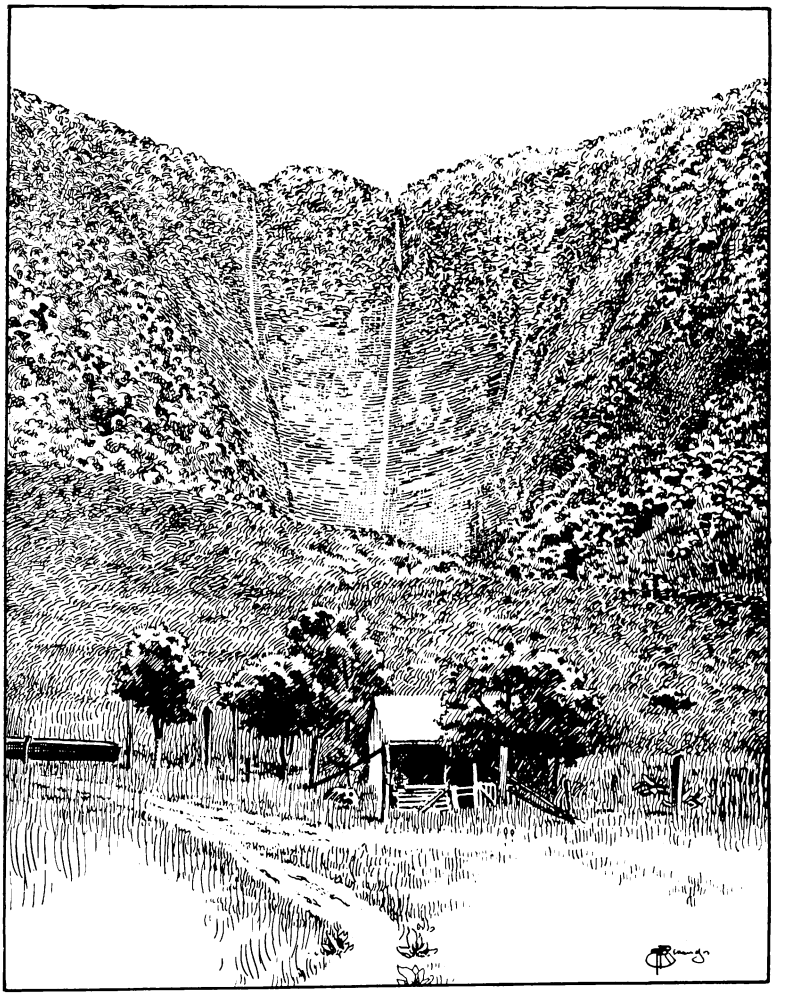

A cirque at the side of Waipio Valley, Island of Hawaii. The wall at the rear is more than a thousand feet high. From a photograph.

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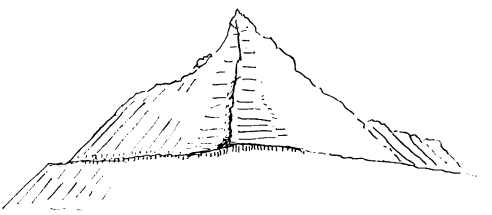
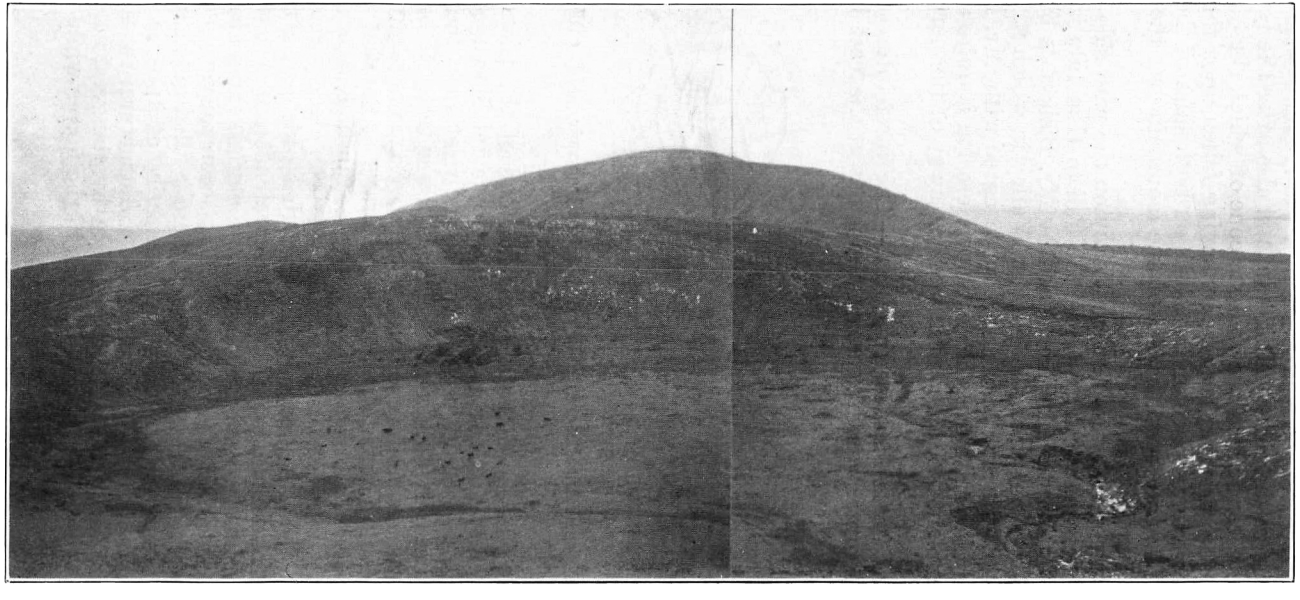


Section above the road at the Pali looking east. The horizontal beds are lavas; the sloping ones are tuffs deposited after the cutting of the steep north face of the Pali.

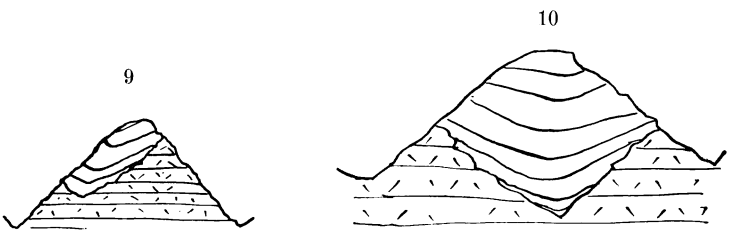


The Waipio Valley. In the foreground is the small crater just east of Kokohead. The whiteness of the beds is produced by coral fragments in the tuff. Hanauma Bay is just over the ridge and to the left of the highest hill.

became active after the excavation of the Nuuanu Valley that leads down to the city of Honolulu, and also after the removal of the northern half of the volcanic cone of which these mountains are the remnant, the cinders having fallen upon the steep —almost vertical—face of the bluffs on both sides of the Pali. The road down the north face of the mountain cuts these tuff beds at many places.

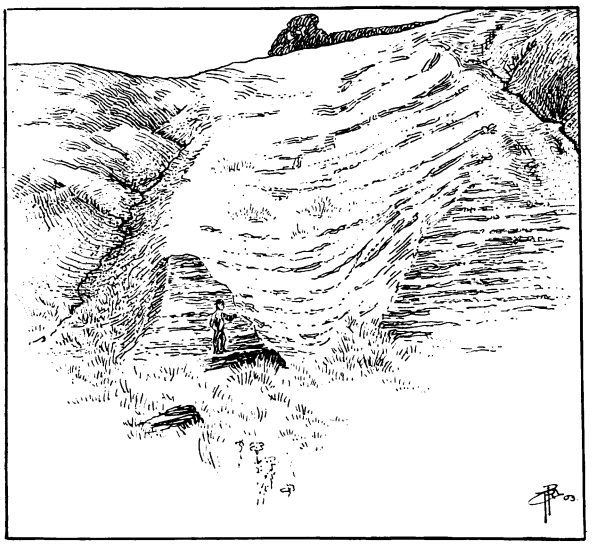
The eminence in the Nuuanu Valley on the west side of the road and less than half way from the Pali to Honolulu is also a crater. This crater, also mentioned by Mr. Bishop, is likewise necessarily newer than the Nuuanu Valley in which it is situated. I should add here that I quite agree with Mr. Bishop and with Major Dutton that subaerial erosion is quite competent to explain the more rapid wearing away of the north side of the Pali.

A small crater next to Kokohead.—The most interesting of the small craters examined on Oahu is one at the east base of



Sections exposed on the east side of Kokohead showing old gullies filled with tuff.

the great Kokohead crater at the east end of the island. Its chief interest is in the great quantity of coral blown out and now mingled with its tuffs, and in its age relation to the Kokohead crater. The Kokohead crater is newer than the basalt of the great mountain ranges, for its tuffs overlap the basalt at the west base of Kokohead. The small crater at the east base of Kokohead did not come into existence until Kokohead had ceased to be active and its sides had been deeply scored by erosion. This is shown by the fact that gulches on the east face of Kokohead were filled by the coral-laden materials blown from the smaller crater. These later materials extend half way up to the summit of Kokohead. The accompanying section is made from a photograph of one of these refilled gulches. This line of separation between the two series of tuffs is clearly visible at many places. Aside from the structural relations the two series are readily distinguishable by the great amount of coral and other calcareous materials in the newer while none is recognizable in the older series.

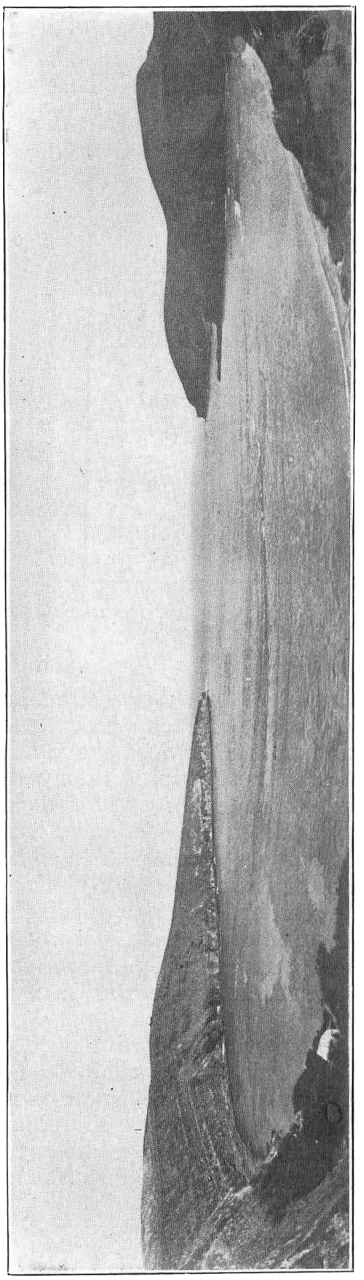


An old gully on the east side of Kokohead filled with tuff from the newer crater. From a photograph by F. E. Harvey.

The deepest part of the smaller crater is now being filled by debris washed down from the east slope of Kokohead. The west side of the small crater is now about 120 feet above the bottom of the pit. This entire wall is made up of tuffs with which are mingled corals, shells and other bits of reef rock. The lumps of coral are sometimes as much as a foot and a half in diameter, but for the most part they are smaller. These bits are usually well preserved and the life forms are readily recognizable. They are rather evenly scattered through the tuffs. The study of these fossils would be of much interest, as it would possibly show the age of the reef through which the crater broke and thus give us another clue to the ages of the various eruptions.

The beds from the smaller crater lap over and form the ridge that separates it from Hanauma Bay. This bay is not the site of a single crater as stated by Dutton,* but of several small ones. It is worthy of note also that the exposure on the sea shore that so closely resembles a section cut through to the middle of a crater is not such a section, but rather the encroachment of the sea upon this group of five or six craters.

* Fourth Ann. Rep. U. S. Geol. Survey, 218.



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Hanauma Bay, the site of several extinct craters.

Well borings on Oahu.—Several records of wells bored for water near Honolulu are given by Dana and Hitchcock.* In addition I have, with the aid of Mr. Fred E. Harvey of the Government Survey, been able to collect several others, and these records, about forty in all, have been plotted to scale for the purpose of attempting a correlation of the beds penetrated. It was found that the characters of the materials passed through as reported are not sufficient to warrant correlation. Herewith are given four of the sections that appear to resemble each other closely. They are all in the city of Honolulu. The enormous quantity of water flowing or being pumped from the wells on Oahu afford a valuable contribution to our knowledge of subterranean waters. It is to be noted that in every instance the wells penetrate beds of coral or other calcareous rocks. These rocks appear to be built round the volcanic core of the islands, but they are sometimes interbedded with lavas, tuffs, or water-worn bowlders. The chief rainfall is in the mountains, but the waters follow down the valleys, sink into porous beds that occupy the lower ends of the valleys and pass seaward as underground waters. It

*Geology of Oahu. Bul. Geol. Soc. Amer., xi, 15–17.

is said that several places are known about the islands where these fresh waters issue beneath the sea.

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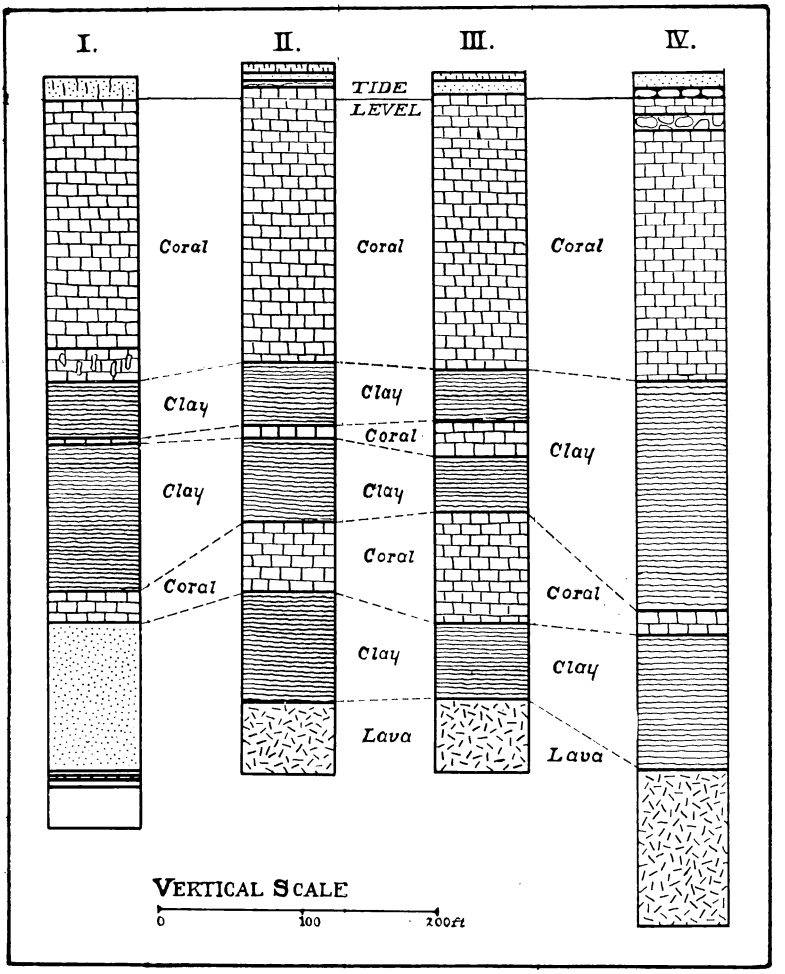
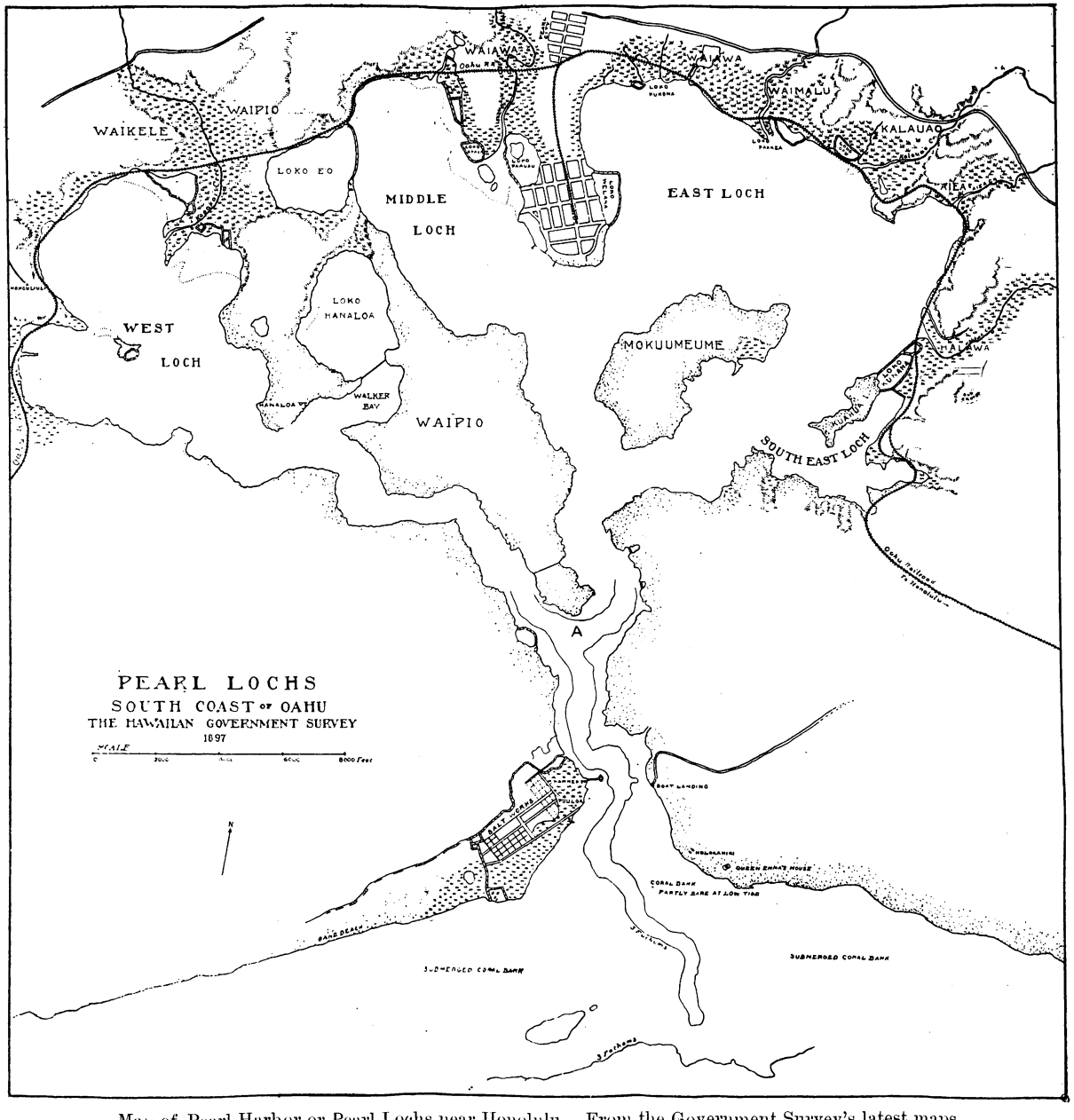


A GROUP OF WELL RECORDS IN HONOLULU.

I. Mrs. Ward's well at Kukuluaeo below King st.
II. Thomas Square well near corner of Beretania and Kapiolani sts.
III. Mr. Sass' well in Kukaokahua ice works.
IV. Pumping Station, corner of Alafai and Beretania sts.

Buried soils.—The tuffs in the vicinity of Salt Lake (west of Honolulu) in many instances fell upon a region covered with forests. This is shown by the tuffs resting directly upon

the old soil surfaces. These soils still retain many root impressions, while at the base of the tuffs are abundant plant fragments preserved as petrifactions. In many places by roadsides and in quarries one may see vertical holes left in the tuffs where the plants have decayed out after being buried. Examples are visible in the new cut opposite Coral Island and in the old cuts near the railway just west of Mr. Dimon's place in Moanalua. In some instances the tree trunks have been petrified and preserved. They often show branches of the plants. The largest trunks seen were about four inches in diameter.



Map of Pearl Harbor or Pearl Lochs near Honolulu. From the Government Survey's latest maps.