GEOLOGICAL HISTORY OF CRATER LAKE

CRATER LAKE NATIONAL PARK

DEPARTMENT OF THE INTERIOR

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GEOLOGICAL HISTORY OF CRATER LAKE, OREGON.

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Of lakes in the United States there are many and in great variety, but of crater lakes there is but one of great importance. Crater lakes are lakes which occupy the craters of volcanoes or pits (calders) of volcanic origin. They are most abundant in Italy and Central America, regions in which volcanoes are still active; and they occur also in France, Germany, India, Hawaii, and other parts of the world where volcanism has played an important rôle in its geologic history.

The one in the United States belongs to the great volcanic field of the Northwest. Crater Lake of southern Oregon lies in the very heart of the Cascade Range, and, while it is especially attractive to the geologist on account of its remarkable geologic history, it is equally inviting to the tourist and others in search of health and pleasure by communion with the beautiful and sublime in nature. By the act of May 22, 1902, a tract around this lake having an area of 159,360 acres was set aside as a national park.

According to W. G. Steel [1] the lake was first seen by white men in 1853. It had long previously been known to the Indians, whose legends have contributed a name, Llao Rock, to one of the prominences of its rim. They regarded the lake with awe as an abode of the Great Spirit. Prospectors were the earliest explorers of the lake.[2] The first travelers of note who visited the lake were Lord Maxwell and Mr. Bentley, who in 1872, with Capt. O. C. Applegate, of Modoc war fame, and three others, made a boat trip along its borders and named several of the prominences on the rim after members of the party.[3] Mrs. F. F. Victor saw the lake in 1873, and briefly describes it in Atlantis Arisen.[4] The same year Mr. S. A. Clarke gave an interesting account of the lake in the December number of the Overland Monthly.

The first Geological Survey party visited the lake in 1883, when Everett Hayden and the writer, after spending several days in examining the rim, tumbled logs over the cliffs to the water's edge, lashed them together with ropes to make a raft, and paddled over to the island. In 1886,

[1] The Mountains of Oregon, by W. G. Steel, 1890, p. 13.

[2] The discovery and early history of Crater Lake, by M. W. Gorman, Mazama, Vol. I, No. 2, Crater Lake number, 1897, 159 pages. This number contains much valuable information concerning Crater Lake in addition to that referred to.

[3] The names Watchman, Glacier, Llao, and Vidae, which appear on the map of the lake, have been adopted by the United States Board on Geographic Names.

[4] Atlantis Arisen, by Mrs. Francis Fuller Victor, p. 179.

under the direction of Capt. C. E. Dutton, many soundings of the lake were made by W. G. Steel, and a topographic map of the vicinity was prepared by Mark B. Kerr and Eugene Ricksecker. Dutton was the first to discover the more novel and salient features in the geological history

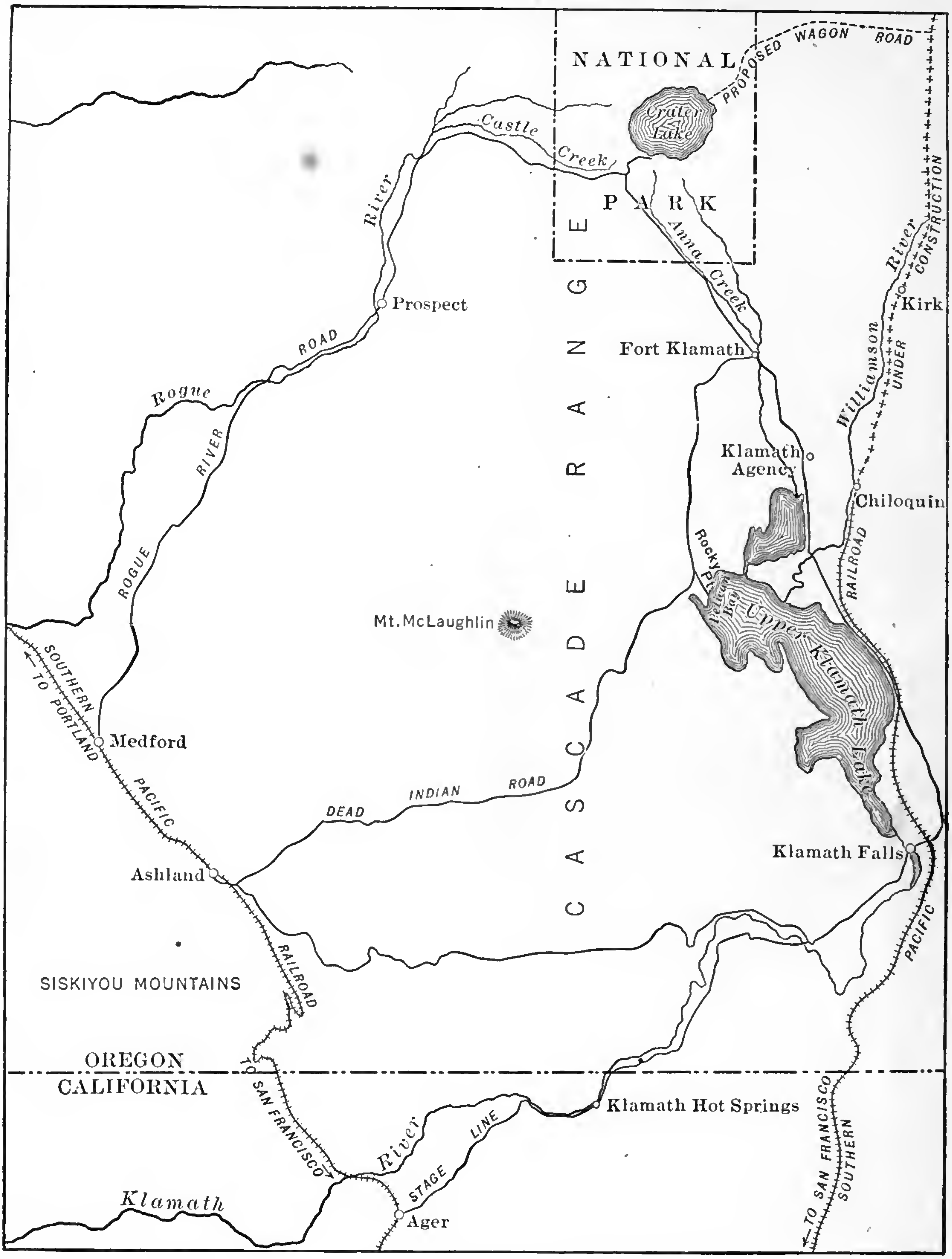


FIG. 1.—MAP SHOWING ROUTES TO CRATER LAKE.

of the lake, of which he has given for his entertaining pen an all too brief account.[1]

Under the inspiration of the "Mazamas," a society of mountain climbers at Portland, Oreg.,[2] a more extended study of the lake was made by

[1] Science, Vol. VII, 1886, p. 179–182, and Eighth Annual Report of the United States Geological Survey, p. 156–159.

[2] The National Geographic Magazine, Vol. VIII, 1897, page 58.

Government parties from the Department of Agriculture, the Fish Commission, and the Geological Survey.[1]

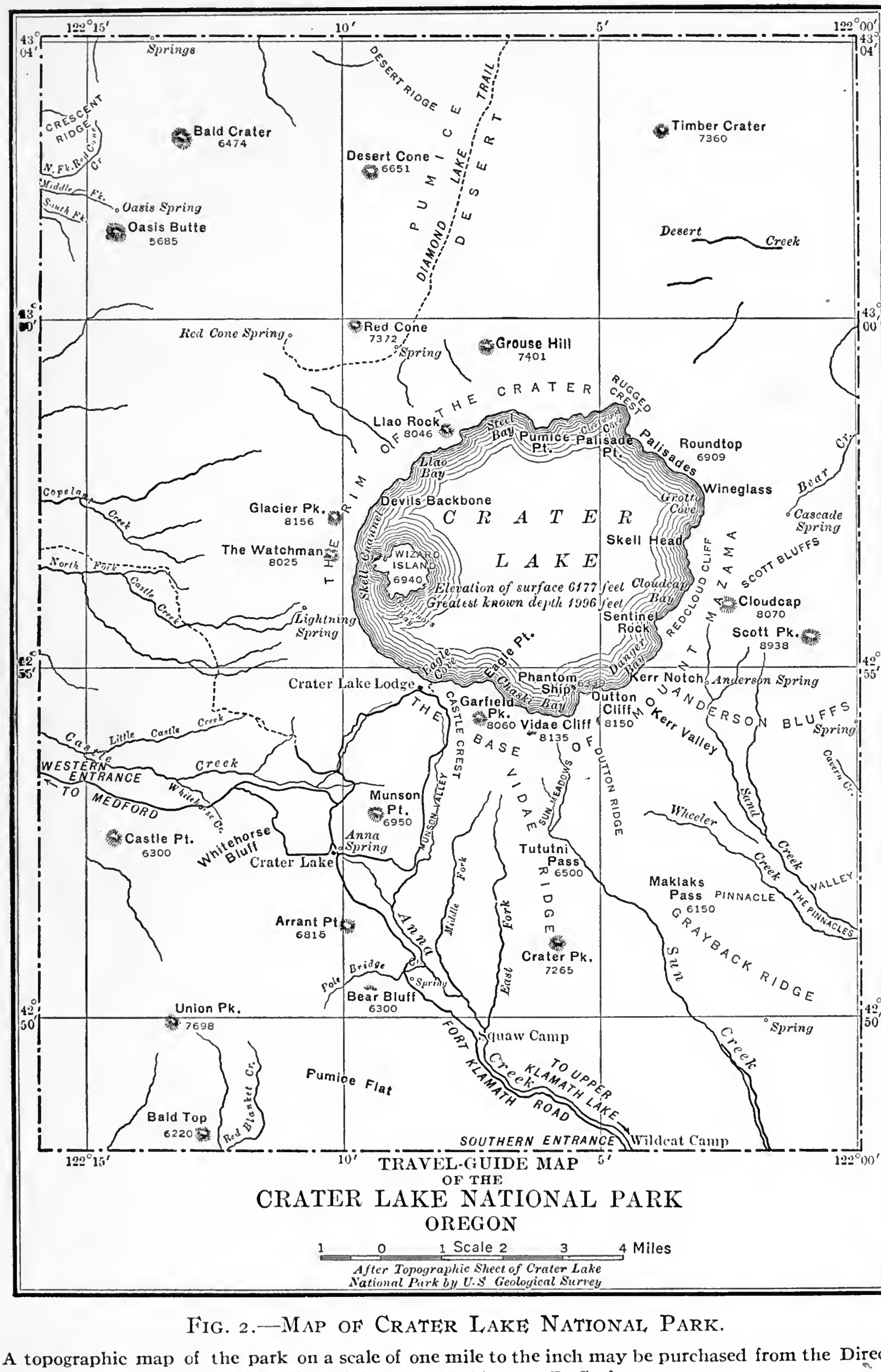


FIG. 2.—MAP OF CRATER LAKE NATIONAL PARK.

A topographic map of the park on a scale of one mile to the inch may be purchased from the Director of the Geological Survey, Washington, D. C., for 5 cents.

Crater Lake is deeply set in the summit of the Cascade Range, about 65 miles north of the California line. It may be reached, as shown in figure 1,

[1] Crater Lake National Park, United States Geological Survey Professional Paper No. 3, 1902, 167 pages, 13 plates, by J. S. Diller, and H. B. Patton.

by two routes, one from the Southern Pacific Railroad at Medford or Ashland on the west, and the other from the Southern Pacific at Klamath Falls or Big Spring, just beyond the limit of the map (fig. 1) on the east. Ashland and Medford are in Rogue River Valley, which marks the line between the Klamath Mountains of the Coast Range on the west and the Cascade Range on the east. The journey from Medford by private conveyance 80 miles to Crater Lake affords a good opportunity to observe some of the most important features of this great pile of lavas. The Cascade Range in southern Oregon is a broad irregular platform, terminating rather abruptly in places upon its borders, especially to the westward,

FIG. 3.—CONES AND COULEES OF THE SUMMIT PLATFORM OF THE CASCADE RANGE. UNION PEAK ON THE RIGHT; MOUNT MCLAUGHLIN (PITT) IN THE DISTANCE.

where the underlying Cretaceous and Tertiary sediments come to the surface. It is surmounted by volcanic cones and coulees (fig. 3), which are generally smooth, but sometimes rough and rugged. The cones vary greatly in size and are distributed without regularity. Each has been an active volcano. The fragments blown out by violent eruption have fallen upon the volcanic orifice from which they issued and built up cinder cones. From their bases have spread streams of lava (coulees), raising the general level of the country between the cones. From some vents by many eruptions, both explosive and effusive, large cones, like McLoughlin, Shasta, and Hood, have been built up. Were we to examine their internal structure, exposed in the walls of the canyons carved in their slopes, we should find them composed of overlapping layers of lava and volcanic conglomerate, a structure which is well illustrated in the rim of Crater Lake.

The journey from Ashland by the Dead Indian road crosses the range where the average altitude is less than 5,000 feet. The road passes within a few miles of Mount McLoughlin and skirts Pelican Bay of Klamath Lake, famous for its fishing. After following northward for some 20

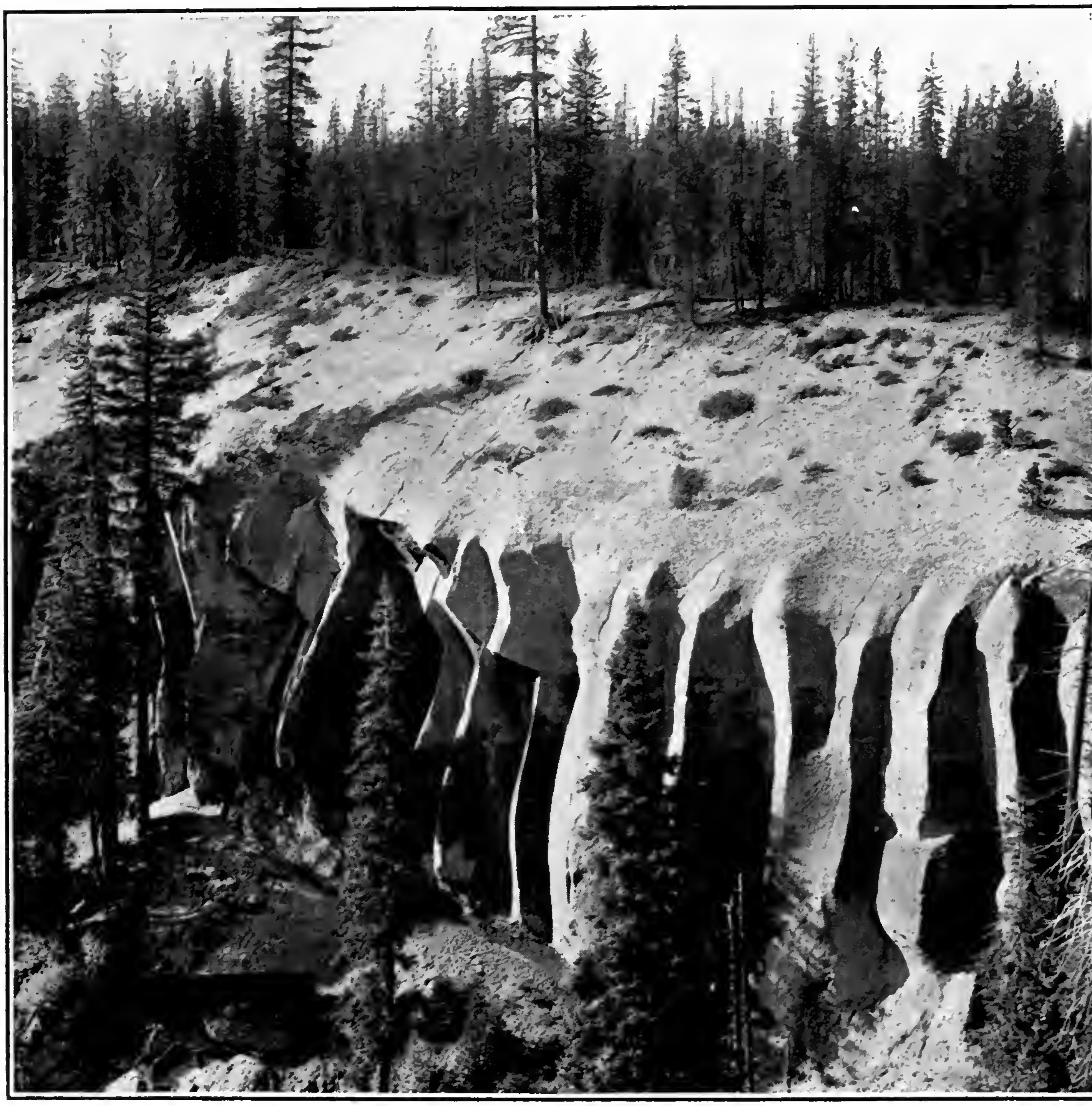


FIG. 4.—JOINTED TUFF OF ANNA CREEK CANYON.

miles along the eastern foot of the range, it ascends the eastern slope, along the castled canyon of Anna Creek to the rim of Crater Lake.

From Medford or Gold Hill the trip is a trifle shorter by the Rogue River road. It affords some fine views of the canyons and rapids of that turbulent stream and of the high falls, where it receives its affluents. Striking features along both roads, within 20 miles of the lake, are the plains developed upon a great mass of detritus filling the valleys. Across these plains Anna Creek and Rogue River have carved deep, narrow canyons with finely sculptured walls (fig. 4), which the roads follow for some distance.

With the completion of the railroad on the east the approach to the lake was greatly facilitated. Leaving the railroad near Klamath Falls, a small steamer crosses Upper Klamath Lake and connects with automobile stages to the lake.

Within the park, approaching the lake from any side, the observer sees, as in the distant part of figure 5, a broad cluster of gentle peaks rising about a thousand feet above the general crest of the range on which they stand, but not until after he has left the main road, 3 miles from the lake, does he begin to feel the steepness of the ascent. The way winds over a large moraine littered with lava bowlders and well studded

FIG. 5.—RIM OF CRATER LAKE AS SEEN FROM THE SOUTH ON ANNA CREEK.

with firs. Arriving at the crest, the lake in all its majestic beauty, as it appears in figure 6, comes suddenly upon the scene, and is profoundly impressive. Descending the wooded slope a short distance within the rim to Victor Rock, an excellent general view of the lake is obtained. Upon the left is the western border of the lake, and upon the right its southern border (fig. 7). The eye beholds 20 miles of unbroken cliffs ranging from over 500 to nearly 2,000 feet in height, encircling a deep blue sheet of placid water, in which the mirrored walls vie with the originals in brilliancy and greatly enhance the depth of the prospect.

The first point to fix our fascinated gaze is Wizard Island, lying nearly 2 miles away, near the western margin of the lake. Its irregular western edge and the steep but symmetrical truncated cone in the eastern portion are very suggestive of volcanic origin. We can not, however, in-

FIG. 6.—CRATER LAKE AS SEEN FROM NEAR VICTOR ROCK SHOWING THE WATCHMAN GLACIER PEAK, WIZARD ISLAND, THE DEVILS BACKBONE, LLAO ROCK, PUMICE POINT, AND MOUNT THIELSEN IN THE DISTANCE.

Photograph copyrighted by Kiser Photo. Co., Portland, Oreg.

FIG. 7.—THE SOUTHERN BORDER OF CRATER LAKE AS SEEN FROM CASTLE CREST.

dulge our first impulse to go at once to the island, for the various features of the rim are of greater importance in unraveling the earlier stages of its geological history.

The outer and inner slopes of the rim are in strong contrast; while the one is gentle, ranging in general from 10° to 15°, the other is abrupt and full of cliffs, as shown in figure 8. This difference is well expressed also by the contour map in figure 13. The vertical interval of the contours is 50 feet. Upon the inner slope the contours are crowded close together to show a slope so steep that one needs to travel but a little way to descend 50 feet, while upon the outer slope the contours are so far apart that to descend 50 feet one needs to travel a considerable portion of a mile. The outer slope at all points is away from the lake, and as the rim rises at least 1,000 feet above the general summit of the range, it is evidently the basal portion of a great hollow cone in which the lake is contained.

In addition to the strong contrast between the outer and inner slopes of the rim the map shows the occurrence of a number of small cones upon the outer slope of the great cone. These adnate cones are of peculiar significance when we come to consider the volcanic rocks of which the region is composed. The rim is ribbed by ridges and spurs radiating from the lake, and the head of each spur is marked by a prominence on the crest of the rim. The variation in the altitude of the rim crest is 1,456 feet (from about 6,700 at Kerr Notch to 8,156 feet at Glacier Peak) with seven points rising above 8,000 feet. The crest generally is passable, so that a pedestrian may follow it continuously around the lake, with the exception of short intervals about the notches in the southern side. At many points the best going is on the inner side of the crest, where the open slope, generally well marked with deer trails over beds of pumice, affords an unobstructed view of the lake.

Reference has already been made to the glacial phenomena of the outer slope of the rim. There are scattered bowlders upon the surface, and also in piles of glacial moraine (fig. 9), which contain besides bowlders much gravel and sand. Such glacial drift is spread far and wide over the southern and western portion of the rim, extending down the watercourses in some cases for miles to broad plains, through which the present streams have carved the deep and picturesque canyons already observed on the ascent. At many points the lavas are well rounded, smoothed, and striated by glacial action. This is true of the ridges as well as of the valleys, and the distribution of these marks is coextensive with that of the glacial detritus.

A feature that is particularly impressive to the geologist making a trip around the lake on the rim crest is the general occurrence of polished and striated rocks, in place on the very brow of the cliff overlooking the lake. The best displays are along the crest for 3 miles northwest of Victor Rock (fig. 10), but they occur also on the slopes of Llao Rock, Roundtop, Kerr Notch, and Eagle Crags, thus completing the circuit of the lake. On the adjacent slope toward the lake the same rocks present rough fractured surfaces, showing no striæ. The glaciation of the rim is a

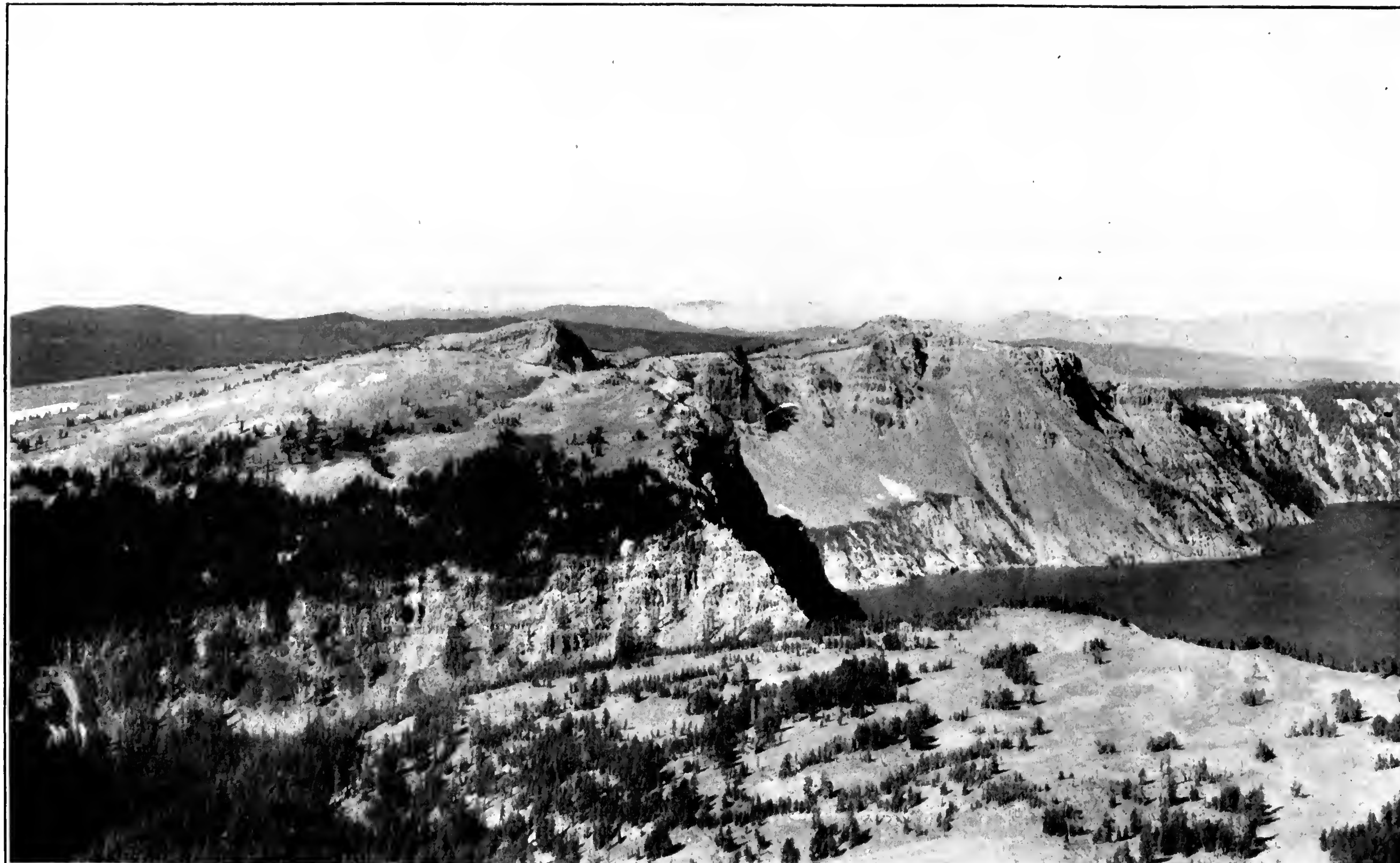


Fig. 8.—Contrast of outer and inner slope of rim of Crater Lake as seen from Mount Scott.

feature of its outer slope only, but, as shown in figure 10, it reaches up to the very crest. The glaciers armed with stones in their lower parts, that striated the crown of the rim, must have come down from above, and it is evident that the topographic conditions of to-day afford no such source of supply. The formation of glaciers requires an elevation extending above the snow line to afford a gathering ground for the snow that it may accumulate, and under the influence of gravity descend to develop glaciers lower down on the mountain slopes. During the glacial period Crater Lake did not exist. Its site must then have been occupied by a mountain to furnish the conditions necessary for the extensive glaciation of the rim, and the magnitude of the glacial phenomena indi-

FIG. 9.—GLACIAL MORAINE SOUTH OF VICTOR ROCK.

cates that the peak was a large one, rivaling, apparently, the highest peaks of the range.

The Mazamas held a meeting in August, 1896, at Crater Lake in connection with the Crater Lake clubs of Medford, Ashland, and Klamath Falls, of the same State. Recognizing that the high mountain which once occupied the place of the lake was nameless, they christened it, with appropriate ceremonies, Mount Mazama. The rim of the lake is a remnant of Mount Mazama, but when the name is used in this paper reference is intended more especially to that part which has disappeared.

The inner slope of the rim, so well in view from Victor Rock, although precipitous, is not a continuous cliff. It is made up of many cliffs, whose horizontal extent is generally much greater than the vertical. The cliffs are in ledges, and sometimes the whole slope from crest to shore is one great cliff, not absolutely vertical, it is true, but yet at so high an angle as to make it far beyond the possibility of climbing. Dutton Cliff on the southern and Llao Rock on the northern borders of the lake are the greatest cliffs of the rim. Besides cliffs, the other elements of the inner slope are forests and talus, and these make it possible at a few points to approach the lake, not with great ease, but yet, care being taken, with little danger. Southwest of the lake the inner slope, clearly seen from

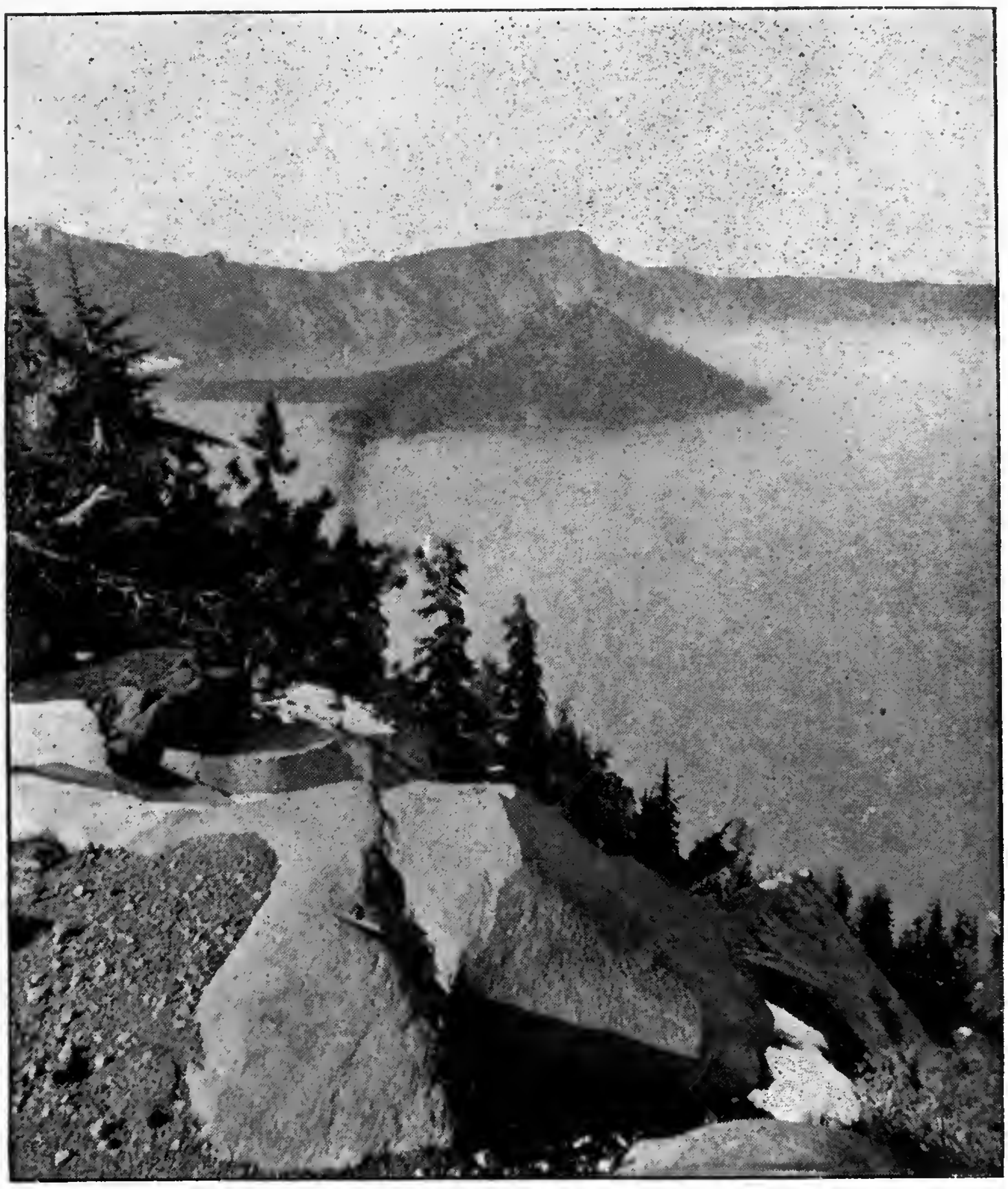


FIG. 10.—GLACIATED CREST OF RIM OF CRATER LAKE.
Photograph by M. M. Hazeltine, courtesy of Smithsonian Institution.

Victor Rock, is pretty well wooded, and from near the end of the road, just east of Victor Rock, a steep trail descends to the water. Where fresh talus slopes prevail there are no trees, and the loose material maintains the steepest slope possible without sliding. Such slopes are well displayed along the western shore opposite the island and near the northeast corner of the lake under the Palisades, illustrated in figure 11. At this point the rim is only 575 feet high, and a long slide, called from its shape the Wineglass, reaches from crest to shore.

The best views of the rim are obtained from a boat on the lake, which affords an opportunity to examine in detail the position and structure of

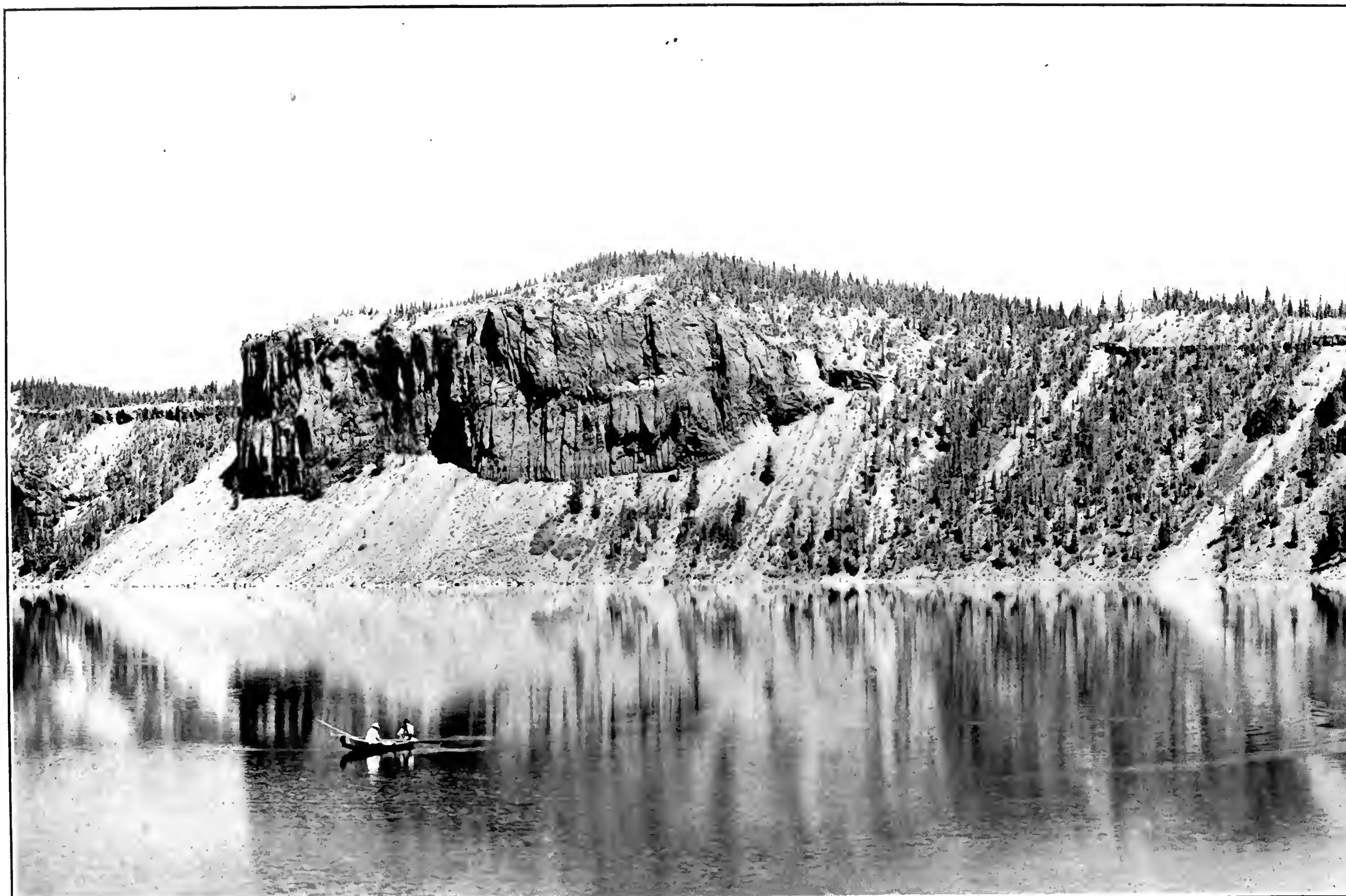


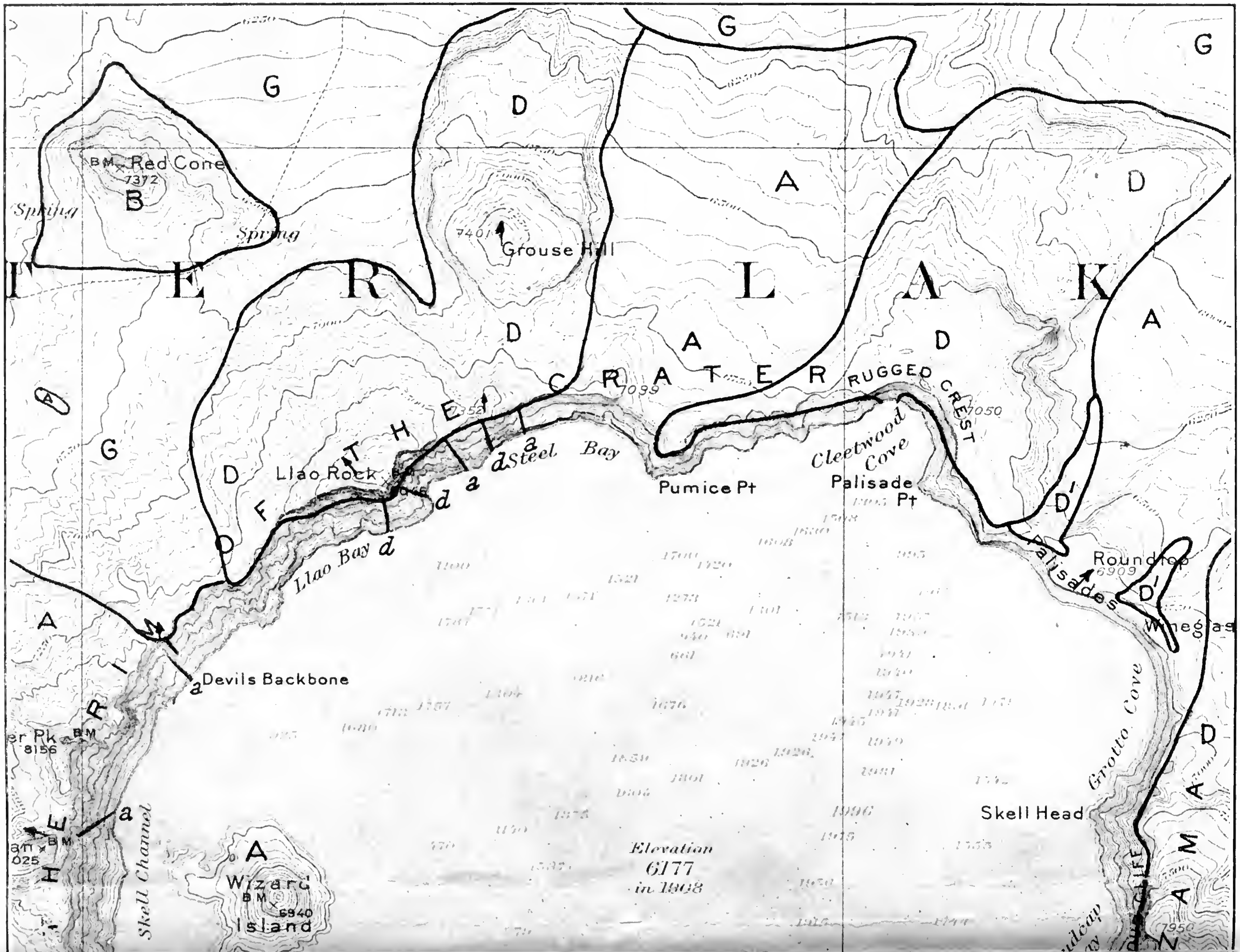
Fig. 11.—Talus slope under the Palisades under Roundtop. Wineglass on the right and a thin layer of tuffaceous dacite near crest on both sides of Roundtop.

the cliffs. They are composed wholly of volcanic conglomerate and streams of lava arranged in layers, as shown in figure 12, that dip into the rim and away from the lake on all sides. Both forms of volcanic material are well exposed on the trail descending the inner slope, and, although most of the cliffs are of lava, many are of conglomerate.

On arriving at the water's edge the observer is struck with the fact that there is no beach. (See fig. 14.) The steep slopes above the surface of the lake continue beneath its waters to great depths. Here and there upon the shore, where a rill descends from a melting snow bank near the crest, a small delta deposit makes a little shallow, turning the deep-blue water to pale green.

FIG. 12.—SOUTHERN RIM OF CRATER LAKE FROM VIDAE CLIFF TO GARFIELD PEAK, SHOWING SHEETS OF LAVA DIPPING AWAY FROM THE LAKE.

As the boat skirts the western shore and passes toward Llao Rock the layered structure of the rim is evident, although it is fairly well illustrated on all sides. On the whole the lava streams predominate, although there is much conglomerate. Of all the flows exposed upon the inner slope that of Llao Rock is most prominent and interesting. In the middle it is over 1,200 feet thick, and fills an ancient valley down the outer slope of the rim. (See fig. 15.) Upon either side it tapers to a thin edge against the upper slope of the valley. To the lake it presents a sheer cliff—that is, it is abruptly cut off—and one wonders how much farther it may have extended in that direction. Beneath the rock the outline of the valley in cross section is evident. It rests upon pumice and many layers of older lavas, forming the rim down to the water's edge. The direction of flow in this great lava stream



Red Cone
7372
Spring
Spring
Grouse Hill
7401
Llao Rock
Llao Bay
Steel Bay
Pumice Pt
Cleetwood Cove
Palisade Pt
RUGGED CREST
7050
7099
Palisades
Roundtop
6909
Devils Backbone
Skell Head
Grotto Cove
Skell Channel
Wizard Island
6940
Elevation
6177
in 1908
8156

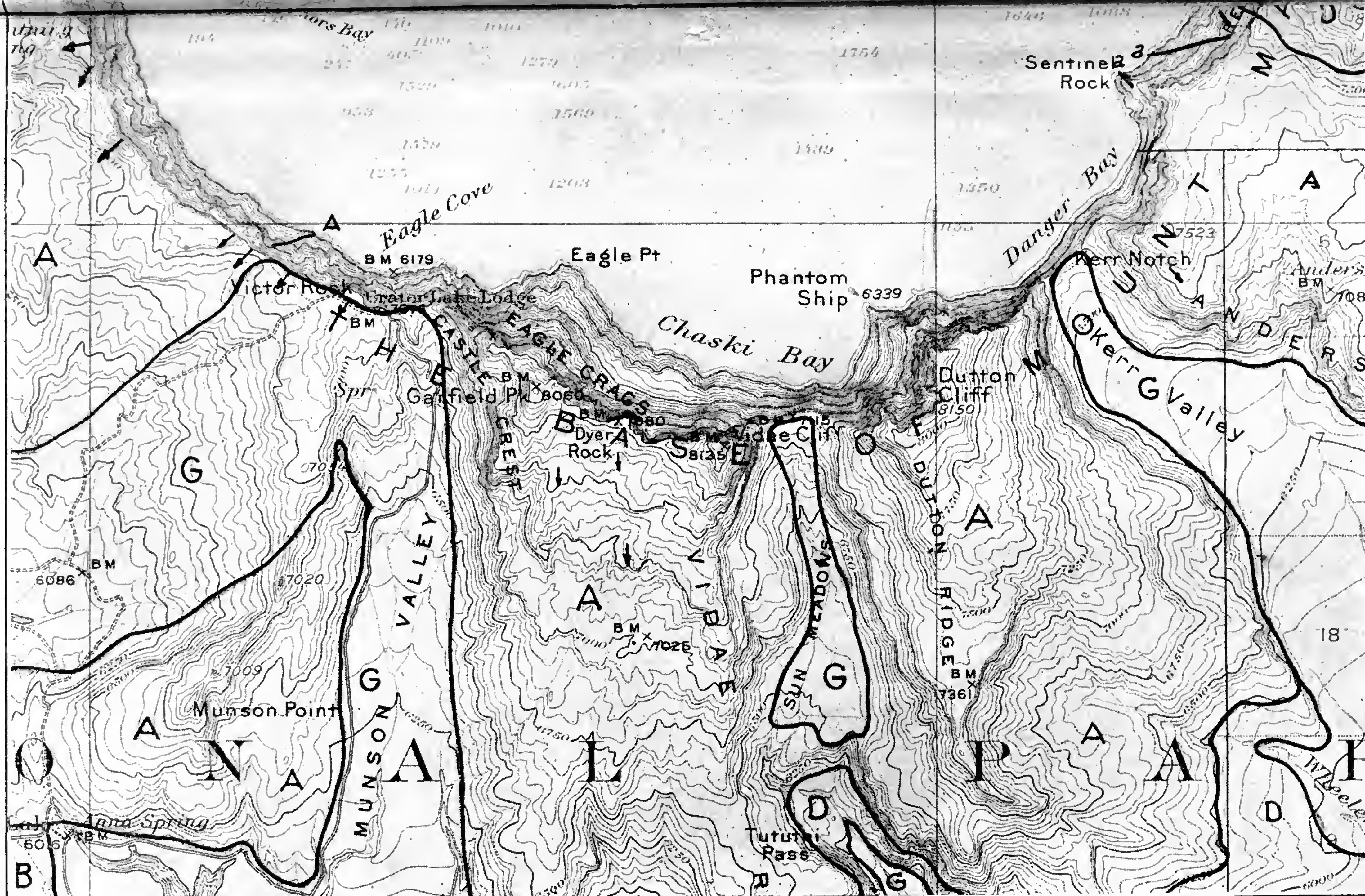


FIG. 13.—GEOLOGICAL RECONNOISSANCE MAP OF CRATER LAKE.

G. Glacial moraine and dacite tuff. D[1]. Tuffaceous dacite. D. Dacite. B. Basalt. A. Hypersthene-andesite. —a. Hypersthene-andesite dikes. —d. Dacite dikes. →. Glacial striae.

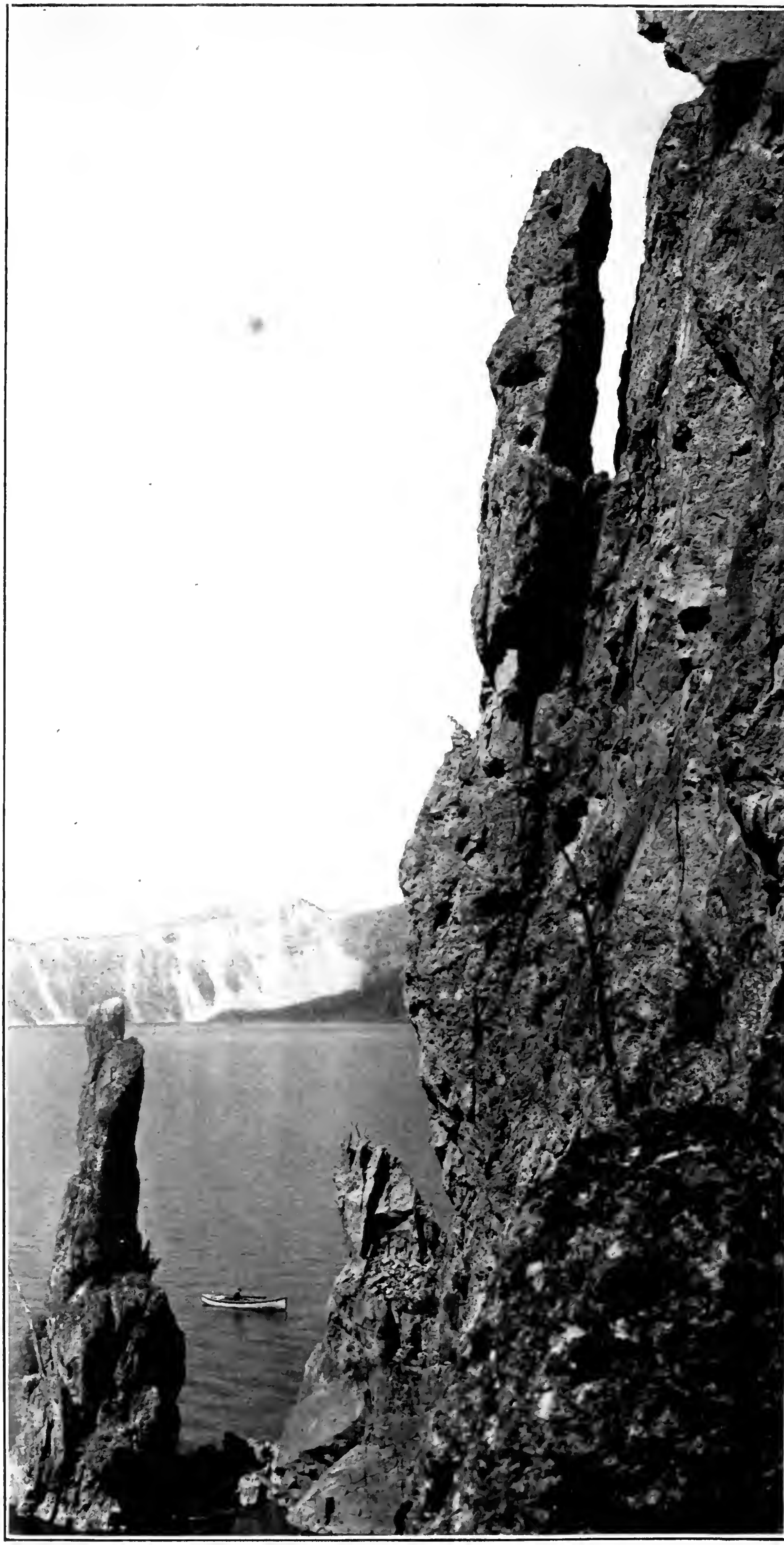


FIG. 14.—SHORE CLIFF, EAST OF EAGLE COVE.

Photograph copyrighted by Kiser Photo Co., Portland, Oreg.

forces us to believe that it was erupted from a large volcano which once stood upon the site of the lake. Every layer of lava in the rim is a coulee, dipping away from the lake. This is especially well shown in the canyon of Sun Creek (see fig. 12), cut in its outer slope. The sections of these radiating flows exposed upon the inner slope of the rim all tell the same story as to their source. By projecting the lavas in their course toward a common center we can reconstruct in fancy the great volcano, Mount Mazama, which once occupied the place of the lake, and, like Shasta or Rainier, formed a great landmark of the region.

Proceeding eastward from Llao Rock the rim loses somewhat in height, and at the head of Cleetwood Cove one sees the remarkable spectacle of a

FIG. 15.—LLAO ROCK FLOW FILLING AN EARLIER VALLEY OF THE RIM.

lava stream descending the inner slope of the rim. It is the only one that has behaved in this way, and its action throws much light upon the disappearance of Mount Mazama.

The Palisades are less than 600 feet in elevation above the lake, and are composed almost wholly of one great flow. The streams of lava extending northeast from this portion of the rim are broad and much younger in appearance than those forming the great cliffs south of the lake, where the flows are thinner and more numerous.

Roundtop is a dome-shaped hill over the eastern end of the Palisades, and is made up chiefly of the lava stream that formed the Palisades, overlain by two sheets of pumice separated by a layer of dacite. The upper surface of the Palisade flow, where best exposed upon the lakeward slope of Roundtop, bears glacial striæ, that extend beneath the layers of pumice and dacite of later eruption from Mount Mazama. (See figs. 11

FIG. 16.—SOUTHERN RIM OF CRATER LAKE AS SEEN FROM WIZARD ISLAND, SHOWING THE NOTCHES ON BOTH SIDES OF DUTTON CLIFF.
Photograph copyrighted by Kiser Photo Co., Portland, Oreg.

and 19.) It is evident from this relation that Mount Mazama was an active volcano during the glacial period. The occurrence of eruptions from a snowcapped volcano must necessarily produce great floods, and these conditions may account in some measure at least for the detritus-filled valleys of the streams rising on the rim of Crater Lake.

Returning from this glacial digression to the boat trip on the lake, it is observed upon the eastern side of the lake that Redcloud Cliff is rendered beautiful by the pinnacles of reddish tuff near the summit, where it is capped by a great, dark flow of dacite, filling a valley in the older rim and extending far to the northeast. Here the springs begin to gush from the inner slope and cascade their foaming rills to the lake. They recur at Sentinel Rock, Dutton Cliff, and especially under Eagle Crags, as well as farther westward. Their sources in many cases can be seen in the banks of snow above, but in others they gush forth as real springs, whose water must find its way in from the snow upon the outer slope.

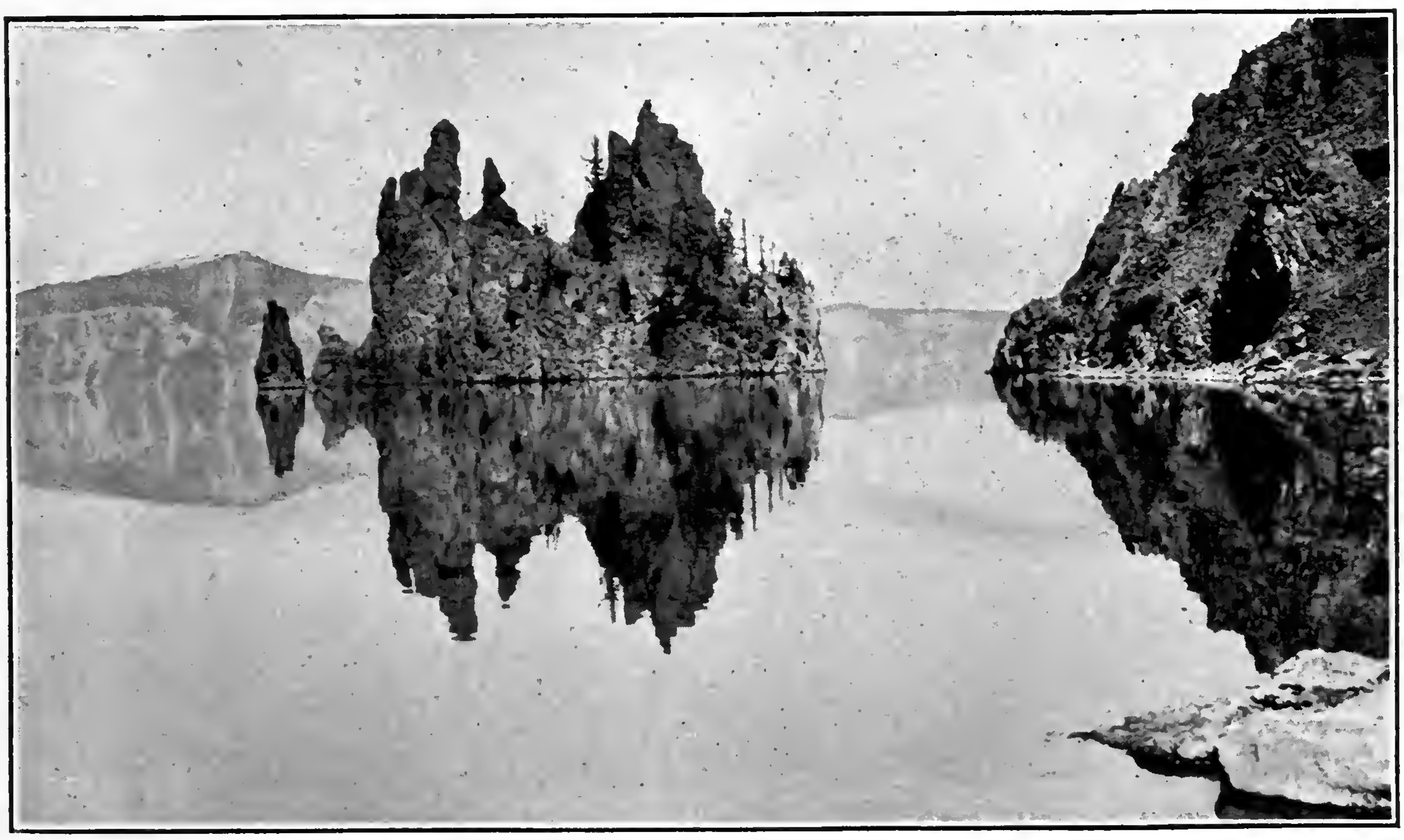


FIG. 17.—THE PHANTOM SHIP.

The boldest portion of the rim, excepting perhaps Llao Rock, is Dutton Cliff, which is made more impressive by the deep U-shape notches on either side. The notches mark points where the canyons of Sun and Sand Creeks pass through the rim to the cliff overlooking the lake, as shown in figure 16. These canyons, due to erosion on lines of drainage, belong to the period when the topographic conditions in that region were quite unlike those of to-day. They were carved out by streams of ice and water descending from a point over the lake, and their presence, ending as they do in the air hundreds of feet above the present water level, affords strong evidence in favor of the former reality of Mount Mazama.

The Phantom Ship (fig. 17) is a craggy little islet near the border of the lake under Dutton Cliff. Its rugged hull, with rocks towering like the masts of a ship, suggests the name, and, phantom like, it disappears when viewed in certain lights from the western rim. Standing in line with an arête that descends from an angle of the cliff, it possibly marks a continuation of the sharp spur beneath the waters, or perhaps, but much less likely, it is a block slid down from the cliff. Whatever its history, it attracts everyone by its beauty and winsomeness.

At times of volcanic eruption the lava rises within the volcano until it either overflows the crater at the top or, by the great pressure of the

FIG. 18.—THE DEVILS BACKBONE AS SEEN FROM WIZARD ISLAND.

column, bursts open the sides of the volcano and escapes through the fissure to the surface. In the latter case, as the molten material cools, the fissure becomes filled with solid lava and forms a dike. The best example of this sort about Crater Lake appears along the inner slope directly north of Wizard Island, and is locally known as the Devils Backbone. It is shown in figure 5 across the left end of Wizard Island and in figure 18 a nearer view from the island itself. This dike rock, standing on edge, varies from 5 to 25 feet in thickness and cuts the rim from water to crest. Dikes are most numerous in the older portion of the rim under

Llao Rock. They do not cut up through Llao Rock and are clearly older than the lava of which that rock is formed. Dikes occur at intervals all around the lake and radiate from it, suggesting that the central volcanic vent from which they issued must have been Mount Mazama.

There is another important feature concerning the kinds of volcanic rocks and their order of eruption and distribution about the rim of Crater Lake as shown on the accompanying reconnoissance map, figure 13, that is of much interest to the geologist. All the older lavas comprising the inner slope of the rim, especially toward the water's edge, are andesites. The newer ones, forming the top of the rim in Llao Rock, Pumice Point, Roundtop, and the Rugged Crest about the head of Cleetwood Cove as

FIG. 19.—LAYERS OF DACITIC PUMICE AND TUFF IN PUMICE POINT. THE UNDERLYING ANDESITIC LAVA BEARS GLACIAL STRIÆ.

well as at Cloudcap, are dacites. Other later flows, all of which escaped from the smaller adnate cones upon the outer slope of the rim, are basalts. The eruptions began with lavas containing a medium amount of silica (andesites), and after long-continued activity lavas both richer (dacites) and poorer (basalts) in silica follow, giving a completeness to the products of this great volcanic center that make it an interesting field of study. Furthermore, the remarkable opportunity afforded by the dissected volcano for the examination of its structure and succession of lavas is unsurpassed. It should be stated, before dismissing the kinds of lava, that there are some dacites in the Sun Creek Canyon south of the lake that appear to be older than those upon the north side, and that the final lava of the region on Wizard Island is andesite.

The glaciation and structure of the rim clearly establish the former existence of Mount Mazama, but there may well be doubt as to its exact form and size. Judging from the fact that Mount Shasta and the rim of Crater Lake have the same diameter at an altitude of 8,000 feet, and that their lavas are similar, it may with some reason be inferred that Mount Mazama and Mount Shasta were nearly of equal height. The slopes of Mount Shasta may be somewhat steeper than those of the rim of Crater Lake at an equal altitude, but the glaciation of the rim is such as to require a large peak for its source. A restoration of Mount Mazama

FIG. 20.—RESTORATION OF MOUNT MAZAMA.

based on a photograph of the rim of Crater Lake as seen from the southwest is shown in figure 20.

In figure 22 is given a section of Crater Lake and its rim, with the probable outline of Mount Mazama, and in figure 23 is given a profile and surface sketch of a cross section of the natural park through Crater Lake. Wonderful as the lake, encircled by cliffs, may be, it serves but to conceal in part the greatest wonder—that is, the enormous pit or caldera which is half filled by the lake. The caldera is 4,000 feet deep. An impressive illustration of it is seen in figure 21 which was prepared from a photograph of a model of Crater Lake now in the United States National Museum. The water surface is represented by glass, so that one may see through to the bottom and get the full impression of the depth of this tremendous hole in the ground. It extends from the top of the rim, which is the very summit of the Cascade Range, halfway down to the sea level, and nearly a square mile of its bottom is below the level of Upper Klamath Lake at the eastern foot of the range. The volume of the caldera is nearly a dozen cubic miles, and if we add the volume of the lost Mount Mazama that amount would be increased by at least one-half. How was it possible to remove so large a mass and in process develop so great a depression?

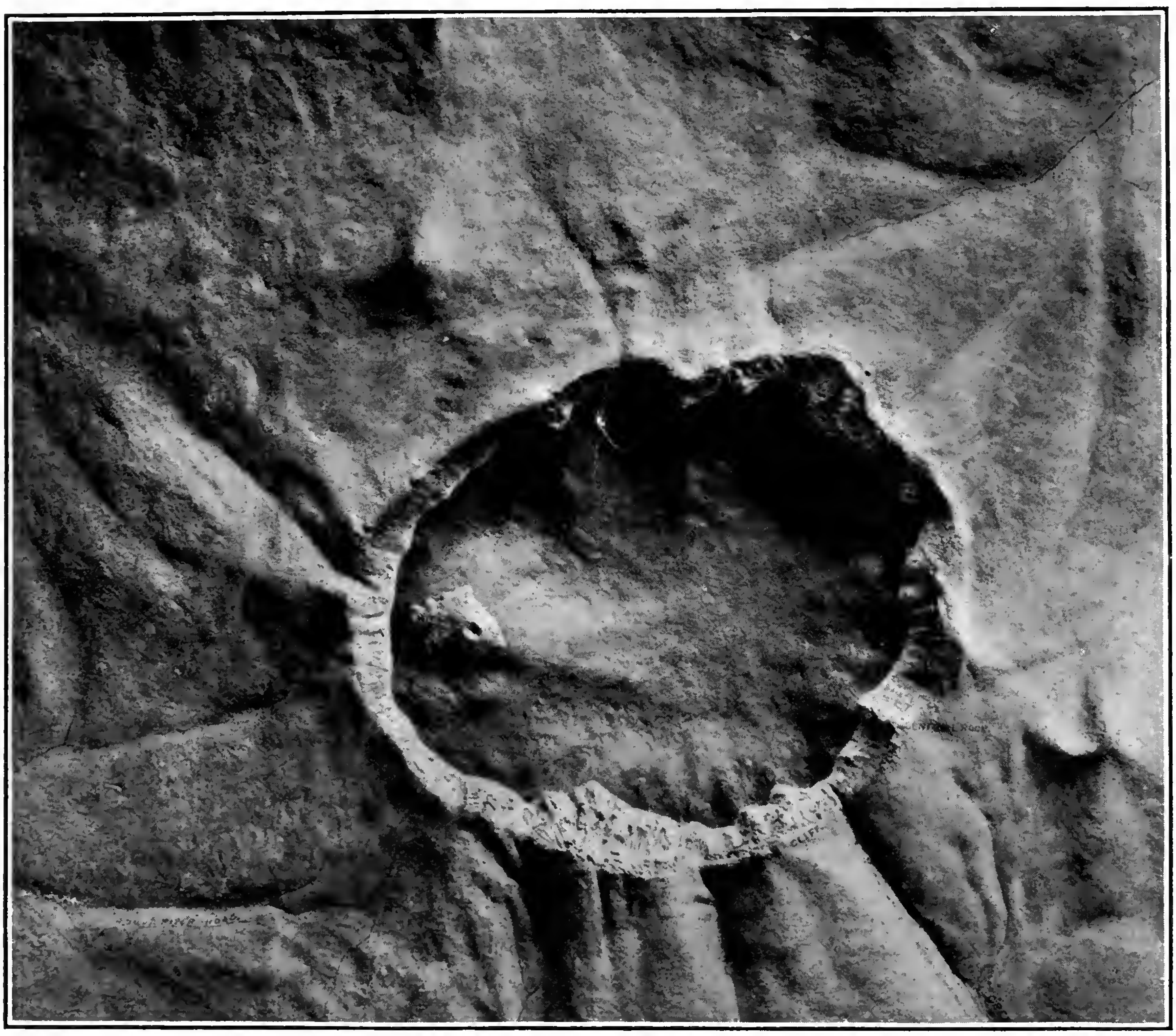


FIG. 21.—CALDERA OF CRATER LAKE LEFT BY THE ENGULFMENT OF MOUNT MAZAMA.

The caldera is completely inclosed, so that it can not be regarded as an effect of erosion. The volcanic origin of everything about the lake would suggest in a general way that this great revolution must have been wrought by volcanism, either blown out by a great volcanic explosion or swallowed up by an equally great engulfment. It is well known that pits have been produced by volcanic explosions, and some of them are occupied by lakes of the kind usually called crater lakes. Depressions produced in this way, however, are, with rare exceptions, surrounded by rims composed of the fragmental material blown out from the depression.

At first sight the rim about Crater Lake suggests that the caldera was produced by an explosion, and the occurrence of much pumice in that region lends support to this preliminary view; but on careful examination we find, as already stated, that the rim is not made up of fragments blown from the pit, but of layers of solid lava interbedded with those of volcanic conglomerate erupted from Mount Mazama before the caldera originated. The moraines deposited by glaciers descending from the mountain formed the surface around a large part of the rim, and as there is no fragmental deposits on these moraines, it is evident that there is nothing whatever to indicate any explosive action in connection with the formation of the caldera.

We may be aided in understanding the possible origin of the caldera by picturing the conditions that must have obtained during an effusive eruption of Mount Mazama. At such a time the column of molten material rose in the interior of the mountain until it overflowed at the summit or burst open the sides of the mountain and escaped through fissures.

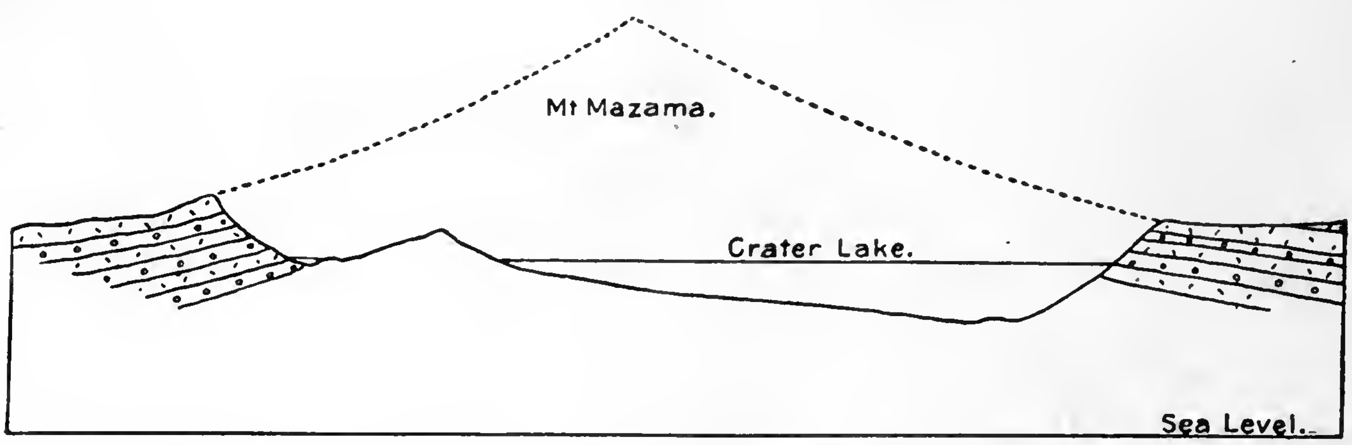


FIG. 22.—SECTION OF CRATER LAKE AND ITS RIM, WITH THE PROBABLE OUTLINE OF MOUNT MAZAMA. STRUCTURAL DETAILS GENERALIZED.

Vertical and horizontal scales the same.

Diagram furnished by Smithsonian Institution.

Fissures formed in this way usually occur high on the slopes of the mountain. If instead, however, an opening were effected on the mountain side at a much lower level—say some thousands of feet below the summit—and the molten material escaped, the mountain would be left hollow, and the summit, having so much of its support removed, might cave in and disappear in the molten reservoir.

Something of this sort is described by Prof. Dana as occurring at Kilauea, in Hawaii. The lake in that case is not water, but molten lava, for Kilauea is yet an active volcano. In 1840 there was an eruption from the slopes of Kilauea, 27 miles distant from the lake and over 4,000 feet below its level. The column of lava represented by the lake of molten material in Kilauea sank away in connection with this eruption to a depth of 385 feet, and the floor of the region immediately surrounding the lake, left without support, tumbled into the depression. In the intervals between eruptions the molten column rises again toward the surface, only to be lowered by subsequent eruptions, and the subsidence is not always accomplished by an outflow of lava upon the surface. Sometimes, however, it gushes forth as a great fountain a hundred feet or more in height.

The elevated position of the great caldera occupied by Crater Lake makes its origin by subsidence seem the more probable. The level of the lowest bed of the lake reaches the surface within 15 miles down the western slope of the range. That Mount Mazama was engulfed is plainly suggested by the behavior of its final lava stream. The greater portion of this last flow descended and spread over the outer slope of the rim, as shown in figure 13, but from the thickest part of the flow where it fills an old valley at the head of Cleetwood Cove (see fig. 24) some of the same lava, as already noted, poured down the inner slope. The only plausible explanation of this phenomena seems to be that soon after the final eruption of Mount Mazama, and before the thickest part of the lava effused at that time had solidified, the mountain collapsed and sank away and the yet viscous portion of the stream followed down the inner slope of the caldera. It should be observed also that the lava stream collapsed and formed Rugged Crest, as shown in figure 25.

It has been suggested, but perhaps not in serious thought, that the cone on Wizard Island may represent the summit of the sunken Mount Mazama projecting above the water. To determine the truth of the matter we must cross over to the island. Wizard Island has two portions—an extremely rough lava field and a cinder cone. These parts may be distinguished in a view of the island from the Watchman but are more distinct in an illustration, figure 26, as seen from the lake. Only a small portion of the lava field is shown in the foreground. The lava is dark and has a much more basaltic look than any seen in the main body of the rim. It has evidently been erupted from the base of the cinder cone in its present position. The cinder cone, too, is a perfect little volcano, with steep symmetrical slopes 763 feet in height, and surmounted by a crater 80 feet deep. A portion of this crater is shown in figure 27. It is so new and fresh that it is scarcely forested, and shows no trace of weathering. Instead of being a part of the sunken Mount Mazama, it is an entirely new volcano built up by volcanic action upon the bottom of the caldera

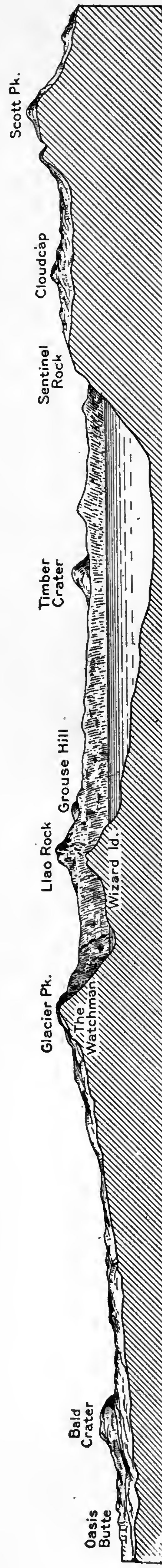


FIG. 23.—PROFILE SECTION OF CRATER LAKE NATIONAL PARK.

since the subsidence. Were it not for the lake the whole bottom of the caldera could be examined, and it is possible that other small volcanic cones might be found. This suggestion is borne out by the soundings of the lake, which appear to reveal two other cases, but they do not rise to within 400 feet of the surface of the water. It is evident that the volcanic eruptions upon the bottom of the caldera have partially filled it up. Originally it may have been much more than 4,000 feet deep.

Given the caldera with water-tight walls, there is no difficulty in forming Crater Lake, for in that region precipitation is greater than evaporation. Extensive observations upon precipitation and evaporation have not been made at Crater Lake, but, judging from those made

FIG. 24.—A PORTION OF THE COLLAPSED LAVA STREAM AT RUGGED CREST FLOWING DOWN THE INNER SLOPE OF THE RIM.

at nearest points, the annual precipitation should be between 60 and 70 inches, while the annual evaporation is about 46 inches. The average diameter of the lake is nearly 5 miles. Its area, including Wizard Island, is about 21.30 square miles. The drainage area inclosed by the rim of the lake, according to Mr. E. C. Barnard, is 27.48 square miles. During the winter great masses of snow drift within the rim, and thus considerably augment the normal precipitation of the lake. The lake does not fill up and overflow. The surplus water must have a subterranean outlet, probably toward the southeast, where the region is traversed by extensive breaks in the rocks, and abounds in excellent springs.

FIG. 25.—COLLAPSED LAVA FLOW OF RUGGED CREST. THE BOLD CLIFFS AMONG THE TREES ON BOTH SIDES ARE REMNANTS OF THE COLLAPSED FLOW.

FIG. 26.—WIZARD ISLAND, CINDER CONE AND LAVA FIELD.

Fig. 27.—Center of Cinder Cone on Wizard Island.

The color of the lake is deep blue, excepting along the borders, where it merges into various shades and tints of green. It is so transparent that even on a hazy day a white dinner plate 10 inches in diameter may be seen at a depth of nearly 100 feet. The fish it contains have been introduced. A small crustacean flourishes in its waters, and salamanders occur in abundance locally along the shore.

The level of the lake oscillates with the seasons. During the rainy winter it rises, and in the summer it falls. In August, 1896, observations were made for 22 days, and the lake sank at the rate of 1 inch for every five or six days, depending somewhat on the conditions of the weather. The Mazamas have established a water gauge, and it was hoped that an extended series of observations would be obtained, but the ice broke it off the next winter. The annual oscillation of the lake is about 4 feet.

The temperature of Crater Lake has been the subject of considerable investigation. While the earlier observations appeared to indicate that the lake received heat from its bottom, later observations show that the temperature of the lake everywhere below a depth of 300 feet is approximately 39° and the bottom contains no appreciable volcanic heat.

Aside from its attractive scenic features, Crater Lake affords one of the most interesting and instructive fields for the study of volcanic geology to be found anywhere in the world. Considered in all its aspects, it ranks with the Grand Canyon of the Colorado, the Yosemite Valley, and the Falls of Niagara, but with an individuality that is superlative.

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