

CRATERS OF THE MOON NATIONAL MONUMENT*

By HAROLD T. STEARNS
U. S. Geological Survey

"An area of about sixty miles in diameter, where nothing meets the eye but a desolate and awful waste; where no grass grows nor water runs, and where nothing is to be seen but lava."¹ Undoubtedly Irving's description has reference to the area now known as the Craters of the Moon region of Butte and Blaine counties, Idaho, a part of which is now set aside as a national monument. This region is situated 14 miles southwest of Arco, Ida., at the foot of the White Komb Mountains on the edge of the Snake River plateau, an extensive elevated lava plain covering most of southern Idaho. Westward this plain unites with the Columbia River plateau, and together they form a vast lava field over two hundred thousand square miles in area, surpassed in size only by the Deccan traps of India and the Paraná lava field in South America. The Craters of the Moon region received its name because of the similarity of its topography to that of the surface of the moon as seen through a telescope. The comparison is not highly exaggerated; for the topography, especially in the northern part, when viewed from the top of Big Cinder Butte, is simply a barren, rugged, black surface dotted thickly with pits and craters.

The remarkable phenomenon of the region is the "Great Rift" out of which the lava welled in a series of eruptions that terminated certainly not more than a few centuries ago. The rift begins in the sedimentary rocks in the foothills of the White Komb Mountains and extends for about 14 miles southeastward, whence it enters an unexplored portion of the Snake River plain. It is possible that the craters and black lava 18 miles west of American Falls belong to a southerly extension of this same rift. If so, the rift is over 50 miles long. While such rifts are common in the older volcanic regions of the United States, the surface phenomena accompanying them have been removed because of long periods of erosion, so that the dike, or the feeder, of igneous rock is all that remains. Up to the time of the discovery of the Great Rift, volcanic phenomena that accompany a fissure eruption were not known to exist in this country. Although the area was visited twice by I. C. Russell, who described it as the Cinder Butte region,² the rift was not discovered until May, 1921, when Mr. O. E. Meinzer, Geologist in Charge, Division of Ground Water,

*Published by permission of the Director of the U. S. Geological Survey.

¹ Washington Irving: The Adventures of Captain Bonneville, U. S. A., Hudson edit., New York, 1868, p. 203.

² I. C. Russell: Geology and Water Resources of the Snake River Plains of Idaho, U. Geol. S. Survey Bull. 109, 1902, p. 72.

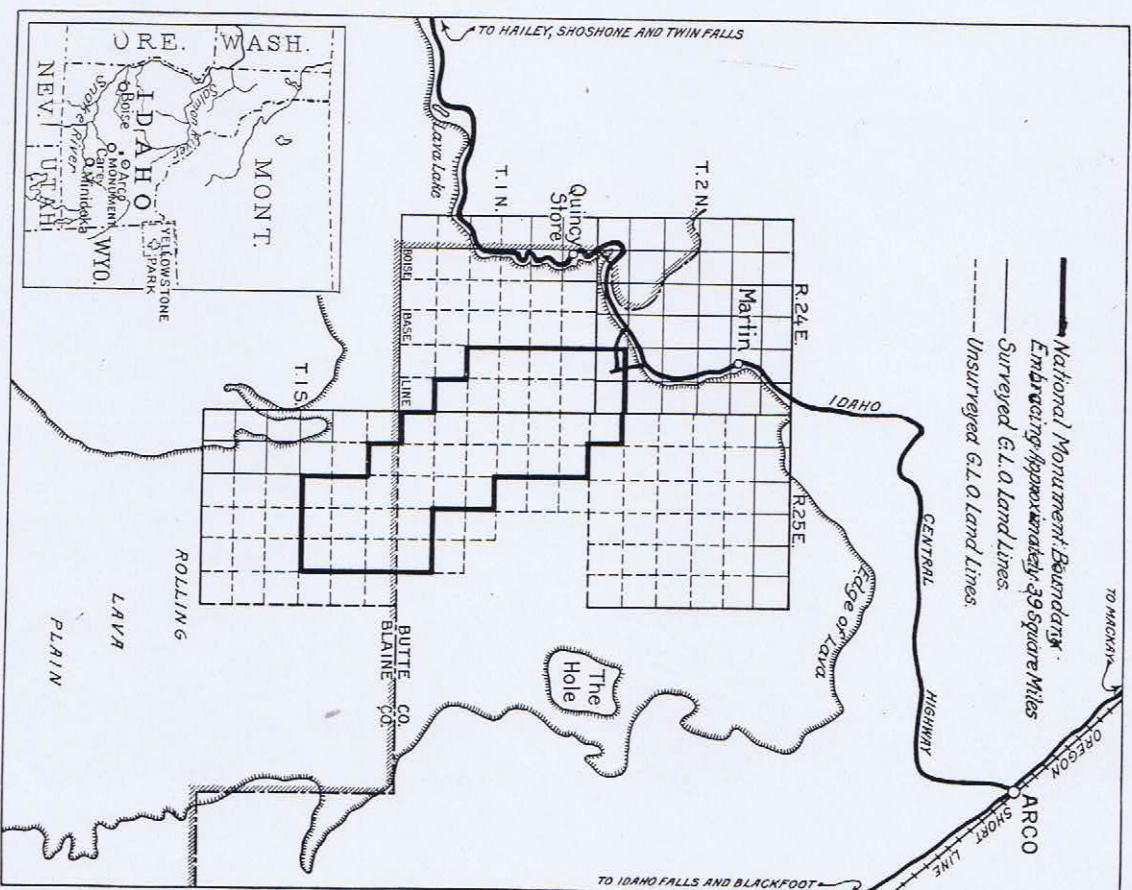


FIG. 1.—The Craters of the Moon National Monument, Idaho, from a map by the National Park Service accompanying the proclamation. The inset shows the general situation of the Monument.

U. S. Geological Survey, made a note of it. Following his advice the writer visited the area the same year; but it was not until August, 1923, when Dr. F. E. Wright, of the Carnegie Institution, Washington, D. C., accompanied the writer on a second visit, that the full significance of the discovery was known. Dr. Wright, who had seen similar fissures in Iceland, recognized it immediately as a true fissure eruption. In 1921 R. W. Limbert, of Boise, Ida., visited the area and gave it considerable publicity because

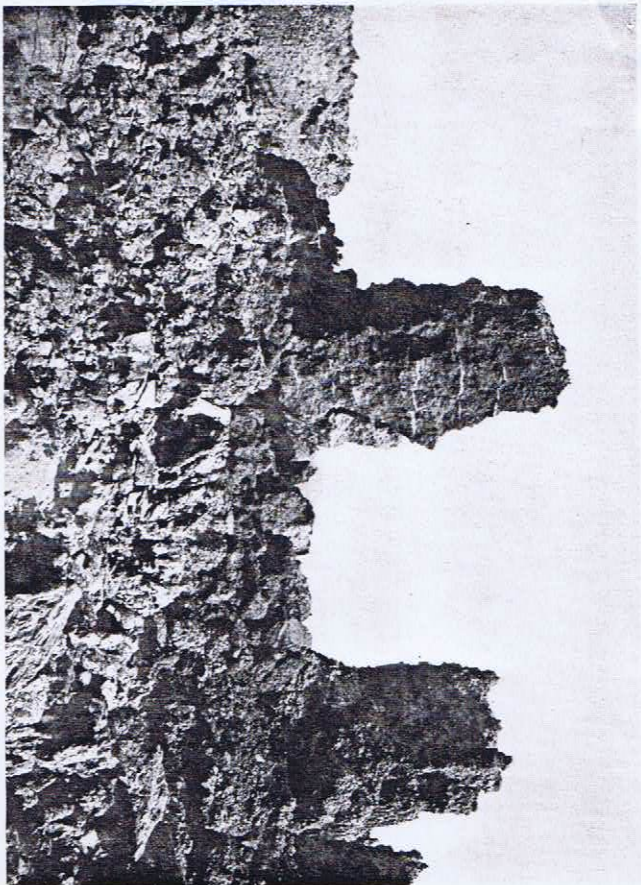


FIG. 2

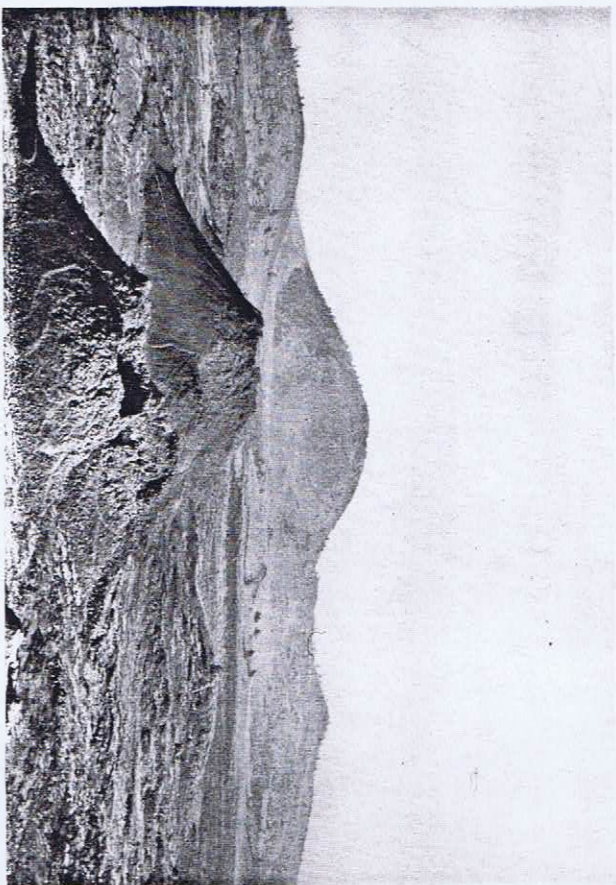


FIG. 3

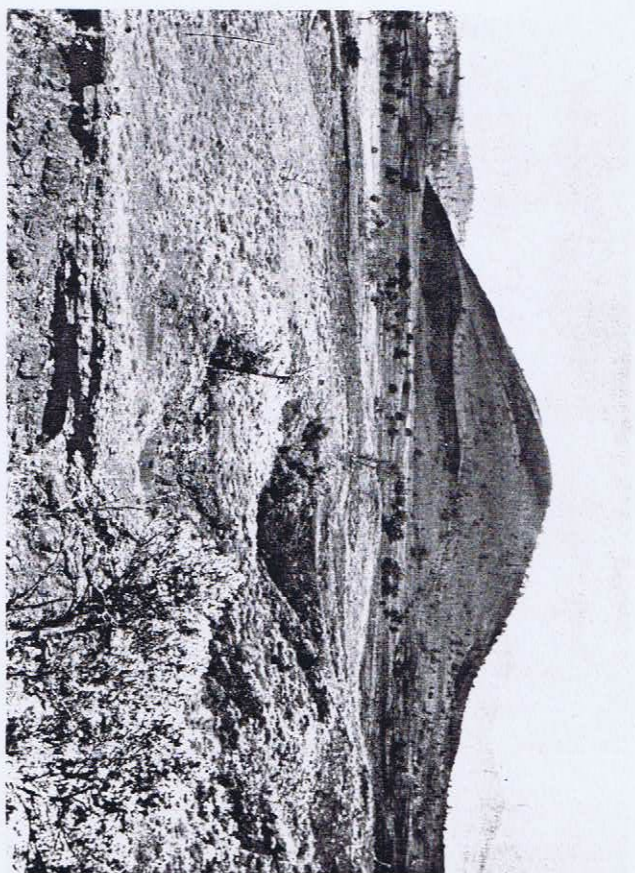


FIG. 4

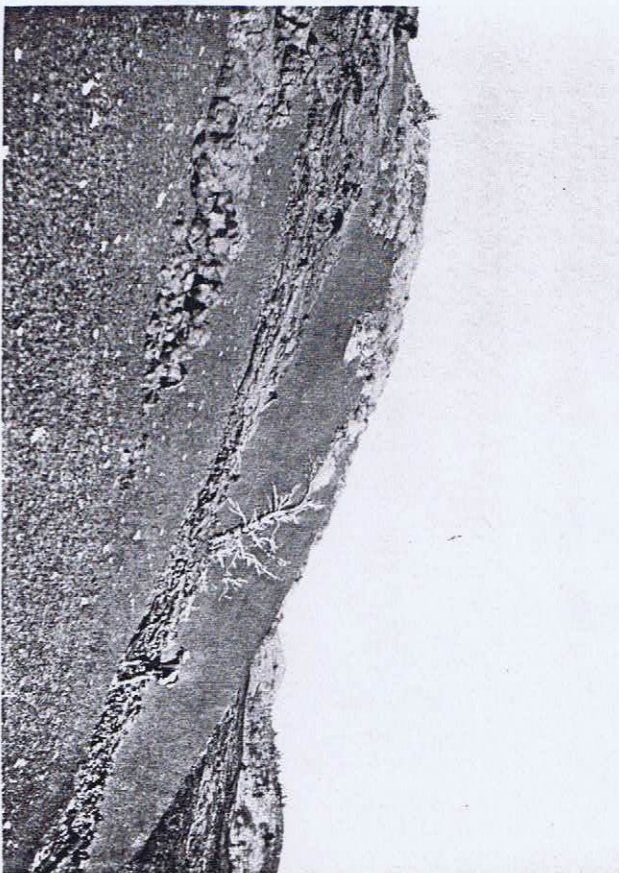


FIG. 5

Fig. 2—Cinder crags, portions of cones floated away on the surface of a lava flow near the entrance to the Craters of the Moon National Monument. Note that the original stratification is still preserved. (Courtesy of U. S. Geol. Survey. Photograph by I. C. Russell.)

Fig. 3—A row of hornitos along the Great Rift with Big Cinder Butte and its encircling crater rings rising 1000 feet above the plain. The hornito in the foreground is the natural ice well. (Photograph by Harold T. Stearns.)

Fig. 4—Looking northeast along the fissure toward Big Cinder Butte, showing the crater pits 10-20 feet deep in the foreground. (Published by permission. Photograph by F. E. Wright.)

Fig. 5—The last trickle of lava that spilled out from the crater of a cinder cone. (Courtesy of U. S. Geol. Survey. Photograph by I. C. Russell.)

of the remarkable caverns, natural bridges, craters, and other features he found there.³

Such, in fact, is the unique character of the region that in January, 1924, the writer was asked by the National Park Service to submit a report describing the area, delineating the boundaries, and stating the reasons for its preservation as a national monument. This was done, and on May 2, 1924, the area was created a national monument by presidential proclamation.

GENERAL VIEW OF THE AREA

The plant life of the region is scant. The younger lava flows are entirely devoid of vegetation except for a few lichens that cling tenaciously to the barren surface. On the cinder cones there are occasional tufts of wild buckwheat and a few scattered, stunted piñon pines. The older lava flows, however, support a sparse growth of grass, brush, and stunted pines. Animal life is similarly limited. There are a few chipmunks, ground squirrels, rock chucks, and small desert birds. However, people living near the area say that not many years ago the caves and caverns were favorite places in which bear would "hole up" during the long winter months, and here, as elsewhere in our western country, the occasional yelp of a coyote indicates that this nightly prowler frequents the few scattered water holes of the region.

A journey of about ten miles in a southerly direction from Arco through a few irrigated ranches in the valley of Big Lost River brings one to Martin, a solitary outlier of civilization at the foot of the White Komb Mountains. Here is caught the first glimpse of the frozen stream of barren black lava that poured out of a crater along the rift on the hills to the west and flowed down through a near-by valley. On the crest line of these hills, a thousand feet or more above the plain, can be discerned, sharply defined against the white sedimentary beds of the White Komb Mountains, several cones composed of red cinders. Upon leaving Martin, the edge of the foothills is skirted for about three and a half miles, and now and then glimpses of black lava are caught on the east side of the road.

As soon as the area of the Craters of the Moon National Monument is reached the entire character of the topography changes. In front is a vast plain sloping southward from an elevation of about 5000 feet at the entrance of the monument to about 4000 feet above sea level at the southern end. Progressing southward one comes upon a huge black stream of lava spread out on the plain for miles. One is reminded of Thoroddsen's description of the view from the Icelandic volcano, Ódádahraun, "the weirdness of desolation itself. As far as the eye can see, the surface of the earth resembles a gigantic stiffened corpse, petrified, black as the night."⁴ Although

smooth from the distance, upon closer inspection it appears astonishingly rough, covered with jagged fragments of lava and floated crags of cinders. Continuing southward, one is confronted by cinder cones one after another, large and small, high and low, until one is lost in amazement at their sameness.

From the top of one of the cones, let us say Big Crater, a remarkable view of the numerous craters and their arrangement is obtained. To the east stretches black, barren lava until it fades into the desert haze. Not a sign of life or vegetation breaks the monotony except one small, yellow, grass-covered knoll that was not inundated by the floods of lava and now stands like an island in a black sea. To the west for about six miles the lava has flowed against the southern spur of the White Komb Mountains, filling the valleys as if they were bays and leaving the ridges like projecting headlands in a black sea. Black and barren as it is, the lava surface yet has a weird scenic charm.

To the southeast extends the trough of the Great Rift. In the foreground it is studded with pits, but farther away it opens into dark yawning craters and finally loses its identity in the chaos of high cinder cones. To the northwest the plain is covered with cinder cones, craters, and hornitos, most of which are strung along the trough of the Great Rift. These cones vary in size from small cinder piles 20 or 30 feet high to huge cones which rise a thousand feet above the lava plain. On the tops of many of them crater pits are discernible, especially when viewed under the lengthened shadows of evening. Some of the cones, however, such as Crescent Butte, are merely remnants of larger cones partially destroyed by subsequent explosions.

UNUSUAL SOURCES OF WATER

There are no streams in the whole area, the entire precipitation either sinking into the ground or being returned to the atmosphere by evaporation. Nevertheless, water is available to the traveler in several unusual ways. There are three distinct types of occurrence of water in the region. Most striking is the natural ice well near the Bottomless Pit. It is the throat of a small cone on the lava surface with an opening about four feet in diameter. A crude ladder 30 feet long reaches the bottom of the pit resting on a heap of snow about eight feet high. Here on a hot summer day one can refresh one's self with ice water or clean white snow. The bottom of this spatter cone is in the shadow of its walls except for about an hour each day, which is not long enough for the sun to melt the snow of the previous winter.

An interesting spring, which must be supplied by melting ice, occurs about 600 feet southeast of North Crater in the bottom of a pit filled with fragmental lava. On August 25, 1923, the temperature of the water was 34° F. while the air temperature was 87° F. Several other springs of this type are found among the lavas.

³ R. W. Limbert: Among the "Craters of the Moon," *Natl. Geogr. Mag.*, Vol. 45, 1924, pp. 303-328.

⁴ Thoroddsen: Thoroddsen: Explorations in Iceland During the Years 1881-98, *Geogr. Journ.*, Vol. 13, 1899, pp. 251-274 and 480-513; reference on p. 270.

A third type of occurrence is that of the lava tunnels. Here the water is due to the precipitation percolating downward through cracks into long tunnels and caverns developed in the lava at the time of eruption. The water collects on the floor of the tunnels in pools; and in winter, when conditions are right for cold air to circulate through the tunnels, the water freezes. In some tunnels ice so formed during winter never entirely melts in summer so that year after year the mass of stored ice increases.

CRATERS AND HORNITOS

After the opening of the Great Rift the liquid basalt welled out in tremendous amounts, spreading over the adjacent plains in the form of a huge sheet from 25 to 75 feet thick and covering many square miles. Concurrent with the first welling out of the lava and occupying an important rôle at the close of the period of volcanism, were many explosions along the rift during which ash, cinders, and volcanic bombs were ejected. Evidently some of the explosions were long and continuous while others were very brief. At Big Cinder Butte the explosions must have been on a gigantic scale, although varying in force. They built up a cinder cone 1000 feet high representing about 7,000,000 cubic feet of fragmental lava. Judging from the remnants of the craters encircling it, Big Cinder Butte itself must represent merely the last stage of the eruptions. In the top of this cone there are several crater pits, two of them several hundred feet deep. These are elongated in the direction of the rift.

Evidently slight changes in the fissure caused the point of outflow to shift, and this resulted in the building of successive intersecting crater rings. In some places, as, for instance, in the middle portion of the rift, the lava welled out without actually forming a crater. There is only a band of red scoriaceous lava to mark the site of the fissure. In other places the fissure is marked by a line of cinder pits from 10 to 20 feet deep.

In some cases the lava rose in the throat of the cone until it spilled over the lowest place in the rim, whence flowing down the side it eroded channels several hundred feet deep and floated off on its surface huge fragments of the cone. In other places the lava spilled over the rim of the crater as a mere trickle, not even reaching the plain below.

The structure displayed in the walls of the cinder cones is simple, as a rule. The beds consist largely of cinders and bombs dipping away from the crater and increasing in steepness progressively from the bottom of the cone upwards. Sometimes thin beds of lava are interstratified with the cinders, but generally the structure indicates a continuous explosive eruption either before the lava flowed out or as the last phase of the extrusion.

In some places along the Great Rift, as between Big Crater and Big Cinder Butte, and again at several places south of Big Cinder Butte a row of hornitos was developed. The hornitos are miniature cones from 10 to

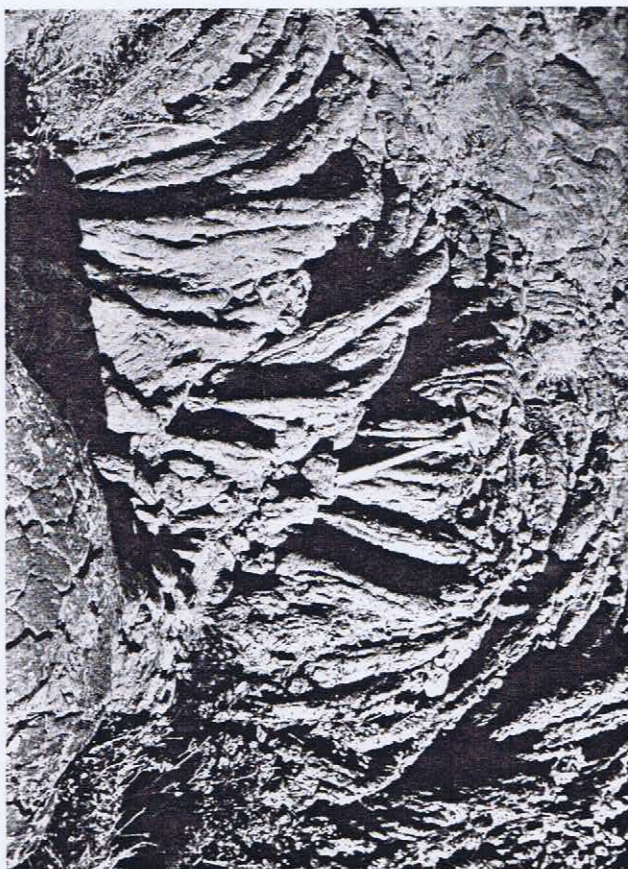


FIG. 6

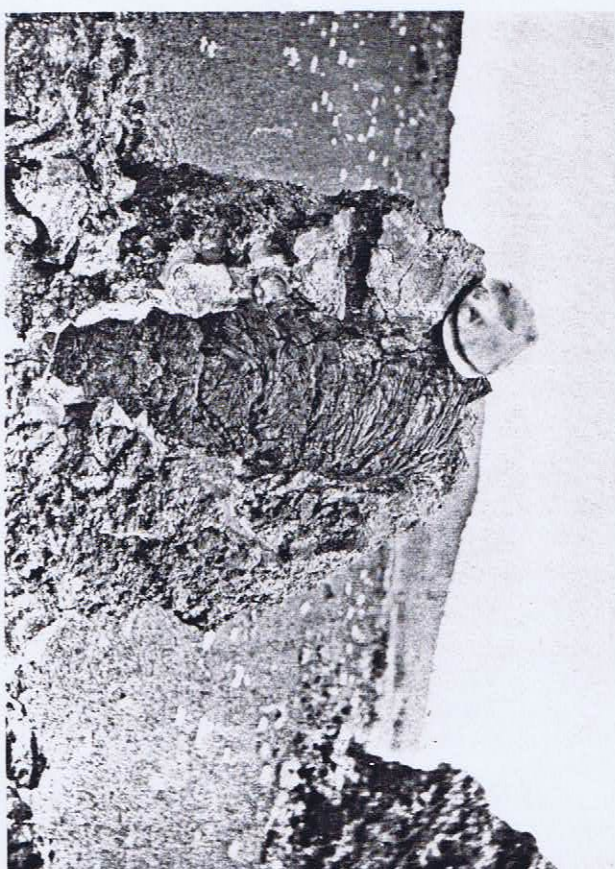


FIG. 7

FIG. 6.—Four-ply lava rope on surface of lava flow near Big Cinder Butte. (Published by permission. Photograph by F. E. Wright.)
FIG. 7.—Lava mortar showing beautiful rifling in the throat. Near Big Cinder Butte. (Photograph by Harold T. Stearns.)

50 feet high caused by the blowing out of lava by jets of steam or gas. In fact, some of them seem to have been produced by lava fountains such as are frequently seen today at the volcano of Kilauea in the Hawaiian Islands.

In all these features there is close resemblance with the results of volcanism in Iceland.⁵ The characteristic terraces formed by subsidence along the sides of the fissures are, however, absent along the Great Rift of the Craters of the Moon.

DETAILED FEATURES OF THE FLOWS

Both *pahoehoe* and *a-a* lavas are found in the region. The *pahoehoe* lava comprises the streams of lava with broad, relatively smooth surfaces that spread out like thick molasses over the plain. The *a-a* lava was extruded with a high gas content and moved very slowly. As a whole, it is more crinkly, vesicular, and broken than *pahoehoe*. An especially striking feature of *pahoehoe* lava is theropy structure. While this feature is common in most lava flows, it is here developed almost in perfection.

The lava caves, and tunnels are perhaps the most interesting features in the flows. The tunnels were formed when the lava flowed out from under a cooled crust that was strong enough to remain standing. Some of the tunnels in the Monument are 30 feet in diameter and several hundred feet in length. The interiors exhibit beautiful blue and red stalactites and stalagmites of lava. In some caves the stalactites are a foot or more in length, and where the lava has dripped to the floor of the cavern stalagmites equally large have been built up. The walls of some of the tunnels are scored by parallel horizontal lines, marks left by a gradually subsiding river of lava that flowed through the cavern while it was in the process of formation. Large portions of the roofs of these tunnels have fallen, and in some places natural bridges have been formed by a part left standing. The most notable example, known as the Bridge of the Moon, occurs in the southern part of the region.

A peculiar group of surface features is developed southwest of Big Cinder Butte. A few feet from the edge of the fissure there are a dozen little towers of lava from two to five feet high, apparently developed by lava accumulating around jets of steam or gas. The throats of most of those examined exhibited a spiral structure. Similarity of this structure to the rifling of a cannon and similarity in size and shape to the mortars used in the Civil War have led to the term "mortars" for these forms. The rifling is beautifully displayed in the one shown in Figure 7. Others, like the one in Figure 8, show several bores which taper inward and finally unite to form one main tube. The shape of one mortar showed clearly that after the column of steam or gas had quieted down the mobile walls had slumped

inward, partially sealing the opening. The bores of the mortars are usually filled with debris from 10 to 20 feet below the surface. The openings probably do not go to great depths and most likely connect with the fissure near the surface.

Lava gutters (Fig. 9) form another curious feature of the flows. These are formed partly by a process of levee building by the lava current and

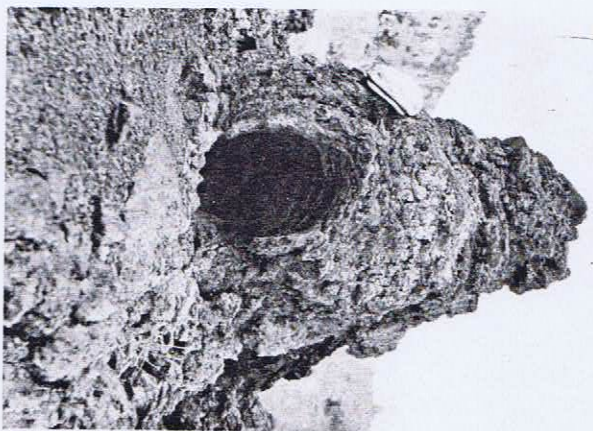


FIG. 8



FIG. 9

FIG. 8—Mortar with two openings which taper inward to unite in one main tube. Black spot on the right is second opening. (Photograph by Harold T. Stearns.)

FIG. 9—Lava gutter near the ice well. (Photograph by Harold T. Stearns.)

partly by channel erosion while the current flows down a relatively steep grade on a partially congealed lava flow. They are usually from 1 to 3 feet wide, from 1 to 4 feet deep, and from 50 to 150 feet long. In some places the liquid lava in flowing through the gutters became cooled at the surface so as to form a crust. In some gutters this crust extended from one wall to the other, forming a slightly arched roof above, while the still-liquid lava beneath flowed out. In this way some of the gutters became tubes or small tunnels. The one illustrated in Figure 9 shows clearly that this gutter had been a tube, but the roof collapsed when the lava finally drained out.

⁵ Thorvaldur Thordarson: Island, Grundriss der Geographie und Geologie, Petermanns Mit. Erdk. 153, 1905, and No. 153, 1906.

AGE OF THE LAVA FLOWS

It is evident that the eruptions along the rift were spasmodic and occurred during a period of at least a thousand years. Some of the flows in the southern part of the area have a thin mantle of wind-blown soil, whereas in the northern part they are free even from dust and as fresh as though poured out yesterday. Although various guesses have been made regarding the age of the fresh lavas, it is generally agreed that they must have been extruded since the discovery of America. Further evidence will probably be found by a more detailed study of the region. In more humid areas, like the Hawaiian Islands, lava flows only 30 or 40 years old support more vegetation. However, under the semiarid conditions of this portion of Idaho the growth of vegetation cannot be compared with that of the humid Hawaiian Islands.

The Great Rift, with its crater chain, not only exhibits many unusual volcanic phenomena but offers a solution to the problem of how the Columbia River lava plateau was formed. The origin of the Columbia River lavas has always been a problem. Erosion has exposed great thicknesses of lava without, however, exposing a sufficient number of vents apparently large enough to account for their origin. In all probability when erosion has removed the cones and craters of the Great Rift, the solidified feeder of lava that supplied it will prove to be not more than 50 feet in width and possibly only 10 or 20 feet. Some of the small and insignificant dikes that are exposed in the Columbia Basin, therefore, might well be lower portions of a large rift and have supplied the numerous sheets of lava that cover hundreds of square miles.

GEOGRAPHICAL NOTES ON ESMERALDAS,
NORTHWESTERN ECUADOR

By CARLOS M. LARREA

Some five hundred miles from Panama, on the Pacific Coast of South America, lies a region which may be considered a veritable paradise from the point of view of the beauty of its landscapes, the astonishing fertility of its soil, and its rich minerals. There flourished, in remote epochs, very advanced civilizations intimately related to those of Yucatan and Central America. Nevertheless the province of Esmeraldas is very little known. Although it is so short a distance from the Canal which unites the two oceans; although its coast was the first point of the vast Inca Empire to be trodden by the *conquistadores*; and although from that moment attention was attracted by the wealth of the country and reports of the famous emeralds to which this province owes its name, it remains to the present time one of the least familiar sections of the Republic of Ecuador.

The province of Esmeraldas is the northernmost one along the Ecuadorian coast. On the north is the recently demarcated international boundary with Colombia.¹ Eastward Esmeraldas marches with the Andean provinces of Imbabura and Pichincha, southward with the coastal province of Manabí. The area of Esmeraldas is reckoned at 5,500 square miles. Of this the greater part is still unexplored. The small towns—taken together they have in all not more than 25,000 inhabitants—are situated on the coast or on the banks of the large navigable rivers, the only easy means of communication except for a few trails connecting some of the outlying settlements and villages. The extensive plains of the interior between the Río Blanco and the Guallabamba, the mountainous regions between the Cayapas and Esmeraldas Rivers, the sources of the Río Verde and the Santiago, and even other parts of the country nearer the coast but hidden under virgin forests remain unknown and for the most part uninhabited, and this in spite of the fact that the province of Esmeraldas has an ample coast line with inlets easy of access and that, as already stated, it is one of the richest and perhaps the most beautiful and splendidly dowered by nature of the Ecuadorian provinces.

EXUBERANCE OF THE VEGETATION AND ITS CAUSES

Differing from Manabí and part of Guayas where the vegetation, although most vigorous, loses its beauty in summer when woods and plains are parched by the heat of the tropical sun, the verdure in Esmeraldas is perennial. Furthermore, it extends as a single mantle from the slopes of

¹ The Colombia-Ecuador Boundary, *Geogr. Rev.*, Vol. 11, 1921, pp. 296-297, with map.