

CRATERS OF THE MOON NATIONAL MONUMENT
Arco, Idaho

EXPLORATION OF ARCO TUNNEL

September 20, 1959

ABSTRACT

From August 6 through August 21, 1958, the longest lava tube yet found within the Monument was explored and mapped. It is located in the NW $\frac{1}{4}$ NE $\frac{1}{4}$ Sec. 6, T. 1 N., R. 25 E., in the north wall of a collapse sink 200 feet north of Beauty Cave. On the 1957 edition of the U.S.G.S. topographic map the cave is shown as "Lava Tube". While not officially approved, the name "Arco Tunnel" has been given to the lava tube. On August 20, 1958, Monument personnel informally accepted the name. It was chosen for two reasons: (1) Its trend is toward Arco; and (2) to honor Arco residents, past and present, for their cooperation in Monument development.

Arco Tunnel is about 2000 feet long, but a better visualization of the cave's extent can be gained by realizing that it is unlike the other caves within the boundaries, in that it is not merely a long, sinuous passage, but a complex assemblage of interconnecting tubes -- 4319 feet of passageways in all.

Perhaps the best way to describe the pattern of the cave is to draw an analogy to a surface stream. Arco Tunnel shows a pattern almost identical to a braided stream near its mouth. The lower portion of Arco Tunnel resembles a delta distributary.

Present field observations point to the fact that the cave is a continuation of Beauty Cave and likely is an extension of Indian Tunnel and perhaps Boy Scout Cave. If so, the former lava channel flowed for at least a mile. Upstream it moved as a single large feeder through Indian Tunnel and the other caves, and as it approached the margins of the flow, it separated to supply lava to the extremities of the flow through the numerous channels of Arco Tunnel.

Great varieties of formations are present in Arco Tunnel. One may study the structure of the interior of a flow and gain information regarding the manner of flow and the resulting structures. It is believed that this lava tube provides one of the better places for

such a study. For this reason it is suggested that the cave be preserved for scientific purposes and no new entrance or trail system be inaugurated to permit entry by the general public. Vandalism, which undoubtedly would result, would destroy the delicate formations.

HISTORY

No record of the discoverer or the date of discovery can be found. The writer was certainly not the first person to enter the cave. Far beyond the entrance, bits of paper were found at some passage junctions. Arrows were penciled on the paper and pointed to directions probably followed by the explorer. Contrary to common practice, many of the arrows did not point uniformly to the exit.

The only written information can be found in file N-48. Supervisory Ranger Robert Zink entered the cave on at least one occasion and wrote a brief report. From his record it appears that he explored only about 1100 feet.

GEOLOGY AND MINERALOGY

As mentioned, the cave provides a study area for information relating to lava flows. Evidence is plentiful for studies of lava stream flow, undersurface temperature of molten basalts, manner of deposition, mechanics of lava emplacement, etc.

Lava stalactites have been preserved excellently. While they are not rare, there are few places in the world where they are well displayed. Some in Arco Tunnel are over 12 inches long! Many types are represented. Stalactites formed by dripping lava during the formative stages of the tube are common and may be found up to 4 inches in length. In places, stalactites of this type have been modified by partial remelting and now have bulbous tips. Both of the above types show a glazed surface produced by hot gases, which circulated above the lava stream. Acicular spines line some parts of the cave. Close to the entrance of the tube, small white stalactites formed by the evaporation of percolating water were noted.

Flowage features such as lava cascades and folded pahoehoe lava indicate the directions of movement of the lava stream and the manner of formation of the cave. In one area a series of encased lava tubes is present. Work in determining just how they were formed still remains to be done.

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Several places where secondary mineral deposits have formed atop the lava floor were found. It is believed that this deposit is thenardite (file N-30). Positive analysis of an Arco Tunnel specimen is pending. When exposed to the atmosphere outside of the cave, the mineral appears to lose its water of crystallization and becomes a pure white amorphous mass. The clear crystalline crust fuses readily in a flame.

In some portions of the cave, bulbous excrescences of stringy lava, which partially enclose blocks and projections lower in the flow, appear to mark the base of the uppermost flow unit. It has been found that these forms serve as an indicator of the roof thickness, which rarely exceeds 6 feet in the area where they are visible.

Additional material of geological interest is included in the log of passages.

BIOLOGY

Animals make little use of the cave. The largest animals believed to use the cave are rats. Their droppings are quite common. Occasionally, bones believed to be rats are found. In one place the mold-covered carcass of a rat was seen. Near the small opening through which daylight can be seen, near survey point 36, twigs were found. These probably are used as nest materials.

Neither bats nor their sign were seen. It is not unlikely that they may make some use of the cave, however.

The only other life found in the cave was a spider and several millipedes. Regarding the lower life in the caves, a personal communication of Dr. Rodger Mitchell, Biology Department, University of Florida, dated August 6, 1958, is quoted in part:

"In midsummer there is no apparent fauna of aquatic or semi-aquatic arthropods in the seeps or waters of the caves, and the absence of any number of spiders provides further confirmation of this.

"Millipedes and collembola are found in favorable zones of moss and algae and are doubtless widely distributed under the lava fields.

"An early spring aquatic fauna is likely to occur in the caves, but it may well be inactive by early June."

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Plantlife, naturally, is sparse. Moss was seen near the entrance and extended as far back as the penetration of sunlight. No ferns were found, though they are common in several other caves having similar environmental conditions. Mold spores apparently circulate freely throughout the passages, as evidenced by the mold-covered rat and other bits of moldy organic matter.

CLIMATE AND WATER

Little was done in this field outside of casual observations. Within the tube, beyond 100 feet from the entrance, the temperature during August 1958, remained a constant 42° F. in all passages. It is interesting to note that the annual average temperature for Arco, Idaho, is 41.7° F. (USWB data from Stearns, et al., Geology and Ground Water Resources of the Snake River Plain in Southeastern Idaho, WSP 774, 1938, p. 8). Unfortunately, regular temperature readings throughout the year cannot be made. Records from a recording thermograph placed in the cave should prove interesting, in that they might shed further light on the deposition of ice in the lava tubes.

No humidity readings were taken because no sling psychrometer was available. It is obvious, however, that relative humidity is very high. Future observations of temperature and humidity are planned by the writer.

Most of the water in the cave results from surface water percolation. Perched water in the caves has been described by Stearns (op. cit. and his Guide to Craters of the Moon). However, it also appears that some of the water is deposited in the cave by condensation. In many places on the ceiling considerable moisture is present, but secondary mineral deposits are lacking. Air currents in the tube are strong. The temperature within the cave is low enough to condense water from the outside air which enters the cave. Though daytime relative humidity is usually very low, it increases greatly at night (Climatology of NRTS, AEC paper 12003).

SURVEY METHODS

The survey was made with a tripod-mounted Brunton compass. Lines were run with a 100-foot steel tape. A light was hand-held above a station and a sight made on it. Compass bearings and station-to-station distances were then recorded. The Brunton was calibrated for a declination of 17° 30'; corrected readings were then plotted

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to draft the map. The magnetic properties of the basalt affected the bearings, but it is believed that the map is sufficiently accurate to guide any interested person through the labyrinth and to locate the features described in this report.

No levels were run. This was not believed necessary since the cave is essentially horizontal. Where stations were considerably higher than one another, as between points 36 and 36A, and 34 and 35, station-to-station distance corrections for the map plots were made.

LOG OF ARCO TUNNEL

The entrance to Arco Tunnel is marked by a rock cairn on the surface of the flow. It is visible from the Beauty Cave trail. The mouth of the cave lies in the north wall of a collapse sink, which is partially filled with angular blocks of vesicular basalt. At some places on the sink walls, lava drippings may be seen. These, plus the position of the sink, indicate a former connection of Arco Tunnel and Beauty Cave.

Inside the entrance, the pahoehoe floor indicates that the tube drained in a direction opposite from Beauty Cave -- inward, as one enters the tube. On the floor, among the pahoehoe folds, there is evidence that a shallow pond forms in the spring. The ceiling shows secondary mineral deposits in the form of small stalactites and a thin coating on the lava stalactites. These were dry when seen in August 1958 and 1959, and appear to have been dry for at least a month before seen. The floor shows a thin veneer of the deposit, also. Moss grows quite prolifically.

The room at the entrance is separated from the main tube by a lava-covered mound of early-formed breakdown. Broken blocks of rock which fall from walls and ceilings of a cave are termed breakdown. A crack reveals the interior structure of the mound. Flow structure on and about the mound shows the breakdown from the ceiling occurred while the lava stream which formed the tube was still fluid. As the stream level dropped, the mound was exposed and coated with lava 6 to 10 inches thick. The main stream continued to flow in a northeasterly direction. The lava level behind (upstream) the mound dropped due to draining, perhaps through a lateral tube. There are preserved eddies which seem to confirm this. The tube in the vicinity of the mound is 8 feet wide and 3 feet high.

Inward from this point, the tube widens to 23 - 25 feet, and the ceiling is 8 feet above the flowage folds of the pahoehoe floor.

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The folds are very pronounced here. Average height from crest to trough of the folds is approximately 4 inches. The lava stalactites on the ceiling are rather small, but they increase in size toward the walls. Several narrow but deep contraction fissures penetrate the floor. Some of these contain water; some contain ice.

Inward, about 230 feet from the entrance, the stalactites are longer and more numerous. Water slowly drips from them. To the left, 325 feet from the entrance, there is a lava cascade. Broken blocks show that the lava flowed quickly, probably from a "hot pocket" above, now to be seen as a dome in the ceiling above the cascade. The stalactites here show a glazed surface undoubtedly formed by hot gases within the tube.

The tube is constricted here by breakdown on the right. Passage may be made to the left, however. Once past this breakdown, a small room is entered. This room was the terminus for most explorers who entered the cave and believed that it did not continue. There is, however, a low crawlway 3 feet wide and $11\frac{1}{2}$ inches high. It opens on the inward side to the main tube, which is 9 feet high and again 25 feet wide. The constriction has low clearance for about 15 feet of its length.

Once beyond the crawlway, ironically, the stalactites become larger. Vandalism is nonexistent. There is little evidence of secondary mineralization. One hundred twenty-five feet from the crawlway, a small, impassable lateral tube branches to the left. On the floor near this lateral tube, a small whirlpool can be seen preserved in the rock. Forty feet downstream (inward) a contraction crack 53 inches deep and 3 inches wide may be seen in the floor. Another lateral tube branches to the right but may not be entered because faulting has reduced overhead clearance to only a few inches.

Twenty-five feet beyond this lateral junction lies another huge pile of breakdown, but it is passable to the left. Forty feet farther inward the main tube bends to the left. To the right of the gentle bend is a rather large room, measuring 58 feet across.

A short distance from this room another lateral tube leads to the left. This tube forms a loop, connecting with the main tube 180 feet downstream. The length of the loop formed by the lateral is slightly under 220 feet. The loop may not be traveled by man because of a constriction having a head clearance of only 6 inches. On either side of this constriction, the tube averages 11 feet in width and 4 feet head room. The depth of the lava on the floor of this lateral tube is considerable. The dimensions of the main tube still remain rather

constant. The width is 25 feet and height is 9 feet. A steel tape was lowered into a floor crack near the center of the tube, and it measured slightly over 6 feet, but it is believed that had the lava stream drained completely, the ceiling would now be close to 10 feet higher.

The floor of the main tube in this vicinity is extremely rough. There are isolated patches of rather smooth pahoehoe bounded by the dominant surface -- a rough aa scum. The surface of the scum lies about 3 inches higher than the pahoehoe surfaces. The rough fragments may not be cleared aside to see what forms lie below; the fragments have been welded together. The line of demarcation between the boundary of the aa and pahoehoe is very sharp.

One hundred feet beyond the point where the lateral loop tube rejoins the main tube, small masses of thenardite (?) may be seen occasionally on the aa floor. The width of the tube at this point is 28 feet; the height is 10 feet.

One hundred sixty-five feet from the downstream end of the loop tube there is a cove from which cold air enters the cave. The stalactites here are very stringy; the lava must have been in a plastic rather than a fluid state when these were formed. The stalactites are literally needle sharp. Many of them reach 6 inches in length. Formations in this area are covered with a glaze. The width of the tube here is 37 feet; the height is 11 feet. A cairn, erected by an unknown explorer, marks the area.

A room, 170 feet farther inward, is a major junction of the lava stream. The person who ventures this far should mark this place mentally, for it is the beginning of a labyrinth. Three branches fork from here. The uninitiated may find himself roaming back to this room several times in his effort to search out the branches. This room is shown on the map as "The Forum".

The Forum is about 80 feet long and 60 feet wide. There are two levels, the lower one being the main lava channel. The upper level is a gently-sloping bench which drops steeply on its margins to the main level about 10 feet below. The name "Forum" was given to this room because from the upper level "stage" an interpretive talk on the formation of the cave was given to a group of teenagers from Arco. The room provides a natural setting for the discussion of interpretive topics to cave visitors.

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At the north end of the upper bench, a 15-foot extension leads slightly upward. It terminates directly over point 29, which is a survey point on the first loop to the east of the Forum.

On the opposite side of the room, there is another upper level still higher than the 10-foot bench. This ledge lies partly over the north-west branch from the Forum. Because of the almost perpendicular face below the ledge and no safety equipment at hand, an attempt to explore it was not made. From the form of the ceiling as seen from the bench opposite, it is believed to extend only to the limits as shown on the map.

From the map of Arco Tunnel, it can be seen that downstream from the Forum the tube resembles the delta distributary of a river. Because of the complexity of passages, survey points (shown on the map) will be mentioned in the following descriptions.

It is believed that the principal distributary channel is the complex marked A on the map. About 55 feet along the left (NW) branch from the Forum, beyond point 31, the floor changes from pahoehoe surface to an extremely jagged aa surface. Once viscous, stringy stalactites $\frac{1}{4}$ inches to 9 inches long cover the ceiling. Many do not hang vertically.

At the entrance to the lateral tube near point 31A, there is a boulder of clinkery aa. Between points 34 and 35, the formations on the ceiling are glazed. On the NW wall, opposite point 35, the ceiling is only one foot high. Near the center of the tube at this point there is a water pocket in a depression of a large block which fell from the ceiling. The water has been drunk on several occasions; no ill effects were noticed. However, this is no indication that the water is safe for human consumption and the practice is not recommended. If a long stay in the cave is planned, it would be wise to carry a canteen filled from an approved water supply.

Here the ceiling of the tube lies just below the upper surface of the lava flow. Characteristic bulbous protuberances of stringy lava comprising the base of the uppermost flow unit provide the evidence. Whenever these rust-red features are seen in any cave within the Monument, it indicates quite accurately that the thickness of the overlying roof is not greater than 6 feet.

Point 36 lies near the base of a huge pile of breakdown. Almost directly above this point some of the longest stalactites have been found. The longest measures $12\text{--}3\frac{3}{4}$ inches. This stalactite and those associated

with it have elliptical cross sections, with the major axes markedly longer than the minor axes. The surfaces of these are somewhat ribbed. It is doubtful they were formed by freely dripping lava. If this was the case, their cross section would approach the circular and ribbing would not be so pronounced. A stretching due to gravitational force on the plastic ceiling surface seems to be the most reasonable explanation both for the general form and extreme length of the stalactites.

Almost due east of point 36 the ceiling domes upward as a result of spalling of the rocks. This is one of the thinnest parts of the roof. A small hole only a few inches across is located in this dome. It is planned to mark this hole on the surface, then make a surface survey from the entrance to check errors in the map which undoubtedly exist because of the iron in the basalt.

Northward from point 36 through point 32 the tube is quite straight. This is the most prevalent area of breakdown, however, and a straight line cannot be walked. Many of the huge blocks, some weighing several tons, appear to be precariously perched. The blocks were scrutinized and seem safe. (The area was traversed within two weeks after the West Yellowstone, Montana, earthquake of August 17, 1959, and no new breakdown was found.)

Continuing downstream from point 30, several sharp bends are encountered. Southward from point 27 a small room is entered. A small low passage leads upward and almost due south from this room. It cannot be followed far, for the opening closes down to the point that it is impossible to enter. From point 27 there is an incline dropping gently downstream to point 26. This portion of the cave has a pahoehoe floor.

One of the farthest downstream extensions of the tube may be entered at point 25. Crawling is necessary. Rough pahoehoe floors the crawlway and beyond, but less difficulty in negotiating the constriction is encountered here than at the extremely narrow one, 436 feet from the mouth of the cave.

Near point 39 there is a small lava cascade which appears to have joined the main lava stream from a slightly higher level. The end of this tube shows, in plain view, a "pincers", where the lava seemingly sinks below the floor. The cave cannot be travelled farther, but judging from the size of the tube it is possible that the tube extends beyond, for a short distance, at least. Nevertheless, it is believed that this part of the cave lies quite close to the marginal lobes of the flow, and that interesting observations of the interior of the lobes can be made.

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Passages from the Forum to the end of the tube described above (regions marked A and B on the map) are believed to represent the principal distributary channel. It is for this reason that descriptions followed the foregoing sequence rather than describe the smaller loops near the Forum.

The east passage from the Forum, from point 21 through point 25, is readily travelled. The floor is rough in places, but no crawling is required. Width varies from 5 to 14 feet, but averages about 10 feet. Height varies between 3 feet and 11 feet; considerable stooping is necessary.

From point 25 another loop back to the Forum leads roughly southwestward. Northeastward from point 25 the tube extends straight for 37 feet, then branches into another complex of distributary loops, and eventually to a large loop over one thousand feet long leading back to the Forum.

In the passages beyond, small cairns and arrows drawn on small pieces of paper marking the trail of some unknown explorer were found at junctions. It is likely that some very adventurous tourists entered the cave but did not report their findings, believing that Monument personnel had already known about the extent of the system.

Along the straight passage from point 25 to 1, the floor is aa, littered with some breakdown. The ceiling is glazed. Between points 1 and 2 there are large blocks of breakdown resulting in a domed ceiling. Bulbous protuberances of lava can be seen in the dome, indicating that the outside surface is close above.

From points 2 through 5, the tube cross section is very symmetrical. The floor is flat and composed of gradational pahoehoe-aa. The walls arch gracefully overhead. They are lined with small glazed stalactites.

Between points 6 and 7 the floor is again aa. Beyond point 7, a crawlway can be seen for 50 feet. No attempt was made to search out this passage until the map was drawn. Judging from the trend of the passage, it seemed that no further information could be gained from an exploration of it. Near point 7 the mold-covered remains of a rat were found.

Going from point 5 to point 8, an extremely rough aa floor is encountered. Spines on the lava are literally needle sharp. These were probably semi-fluid portions of the ceiling which partially melted because considerable heat remained within the tube. Parts of the ceiling which did not collapse show glazed surfaces. Acicular spines similar in structure to those found on the floor cover parts of the ceiling.

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Bulbous-tipped stalactites formed by partial remelting are found between points 8 and 9. Aa covers the floor.

From point 11 the tube leads due north. Flow folds on the pahoehoe floor indicate positively that the lava moved northward (from point 11 toward point 12). The east side of this passage is choked with a huge block of breakdown forming a shelf.

From point 12 to point 13, a junction point, there is an aa floor. There are a few small stalactites on the ceiling.

The other of the two farthest reaches of the tube extends generally eastward from the point 13 junction. From here to point 20, aa covers the floor. Stalactites are not common. Beginning at point 14, breakdown litters the floor for approximately 10 feet on the south side of the tube. At point 15, large flat slabs of lava breakdown block the north side of the passage. The average height of region C is 4 feet. Average width of the tube is 10 feet. The breakdown actually makes the passage seem narrower.

Another crawlway begins at point 20. The aa floor is exceedingly jagged. The roughness of the floor and a mere 18 inches of headroom make travelling in this passage painful.

At point 21 there is a junction. A pahoehoe-floored passage trending NE-SW extends a short distance. It is possible that this area represents a continuation of the distributaries of region E on the map. Point 22 represents the easternmost extremity of the tunnel.

The region D, shaded in red, indicating a level higher than the main tube level, reveals some interesting features within a flow. From point 9C1 to 9C4 the grade is upward. Pahoehoe lava cascades are prevalent. The walls and ceiling were glazed by hot gases. At point 9C3, stalactites modified by hot gases are found. They have a mammillary form and vary from 1 inch to 4 inches long.

From between 9C4 and 9C5, a person can look back from a small room to the tube through which he crawled and see that it is encased by a larger one. Scum lines on the wall of the room mark former levels of the lava stream which flowed through the tube (similar in appearance to the Devil's Sewer) into the main passage of Arco Tunnel proper. Concentric folds, broken by contraction (tension) cracks about 4 inches deep, cover the slope on the northwest side of the room. At the highest point there is a small crawlway leading down to a reniform room 15 by 40 feet. The dotted line at the northern end of this room shows the approximate boundaries discernible beneath the 1 to 4 inch headroom.

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This is one of the higher parts of the cave. While taking notes, a roaring noise was plainly heard overhead. Undoubtedly it was the sound of a dust devil passing. No air disturbance within the cave was observed. A spider and web, plus numerous rat droppings, were found here. Large mammillary stalactites, 4 to 10 inches long, hang overhead.

The foregoing log of passages is intended merely as a guide to point out the features found in Arco Tunnel. More study is needed -- geological, biological and climatological. Work should also be done in the other nearby caves. Studies by the writer are planned. When completed, the findings should give a much clearer picture of the lava flows in the Cave Area.

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