The Land of the Burnt Out Fires
Lava Beds National Monument, California

by RAYMOND G. KNOX

With notes on geology and cave life by RICHARD T. GALE

Schonchin Butte which rises nearly 500 feet above its base was named for the Modoc Indian Chief Old Schonchin. This basaltic cinder cone was formed by gaseous eruption. An easy trail takes one to the fire lookout tower on top.

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Lava Beds National Monument encompasses part of the largest pseudokarst area in the United States. In its 46,238 acres are 293 lava tubes and caves. The tubes are up to 98 feet in diameter, and up to a mile long; several are multilevel. Floors of the large tubes have uniform slope; many have a rough clinker floor. Access to the tubes is through collapse sinks. Seven major caves in the monument contain ice that lasts throughout the year. Pleistocene fossils as well as archeological material have been recovered from the caves. Historically the lava fields are known as the site of the Modoc Indian war 1872-1873 when the Indians made use of the pseudokarst features for strong defense emplacements.

Lava Beds National Monument is located in extreme northern central California in Siskiyou and Modoc counties. The northern boundary is twelve miles south of the Oregon state line. The monument covers 46,238.69 acres (Figure 1).

The area was set aside in 1925 by presidential proclamation to create the Lava Beds National Monument. The United States Forest Service administered the area as a part of Modoc National Forest until 1933 when the National Park Service assumed responsibility. During the later 1920's roads, stairways, and cave trails were started to make this unique area available to the public.

The earliest human history of the monument is in the petroglyphs or carved symbols and in the pictographs or painted symbols. These apparently existed before white men recorded trips to the west as the Indians encountered in these trips made no mention of these paintings and carvings in their folklore.

The old Fort Hall Trail and parts of the Oregon Trail wound their way around the northern section of the Lava Beds. When Kit Carson and John Fremont visited the area it was known as the "Dark and Bloody Ground of the Pacific" as emigrants were extremely exposed to Indian attack here.

The most significant historical event in the monument was the Modoc Indian War of 1872-1873. This war was the only major Indian engagement in California and has the dubious distinction of being the only Indian war in which an United States Army general (General E. R. S. Canby, the peace commissioner) was killed.

The first cave discovered by white men in the area received its name from bear paws nailed on an old ponderosa pine. Trappers working the area in the early 1880's killed a bear in their camp near a large butte. This butte was named Bear Paw, and the two nearby caves Little Bear Paw and Big Bear Paw. Years later the settlers remember seeing the bear paws nailed on the pine tree. In the later 1880's nearby settlers ranged cattle and sheep over the country and utilized the only available water which was found within the caves.

About this time the valley settlers started using the area as a picnic ground. They would load up their wagons with youngsters and the makings for ice cream and stop at the Bear Paw Ice Caves. Ice chipped from the cave deposits made the ice cream. No

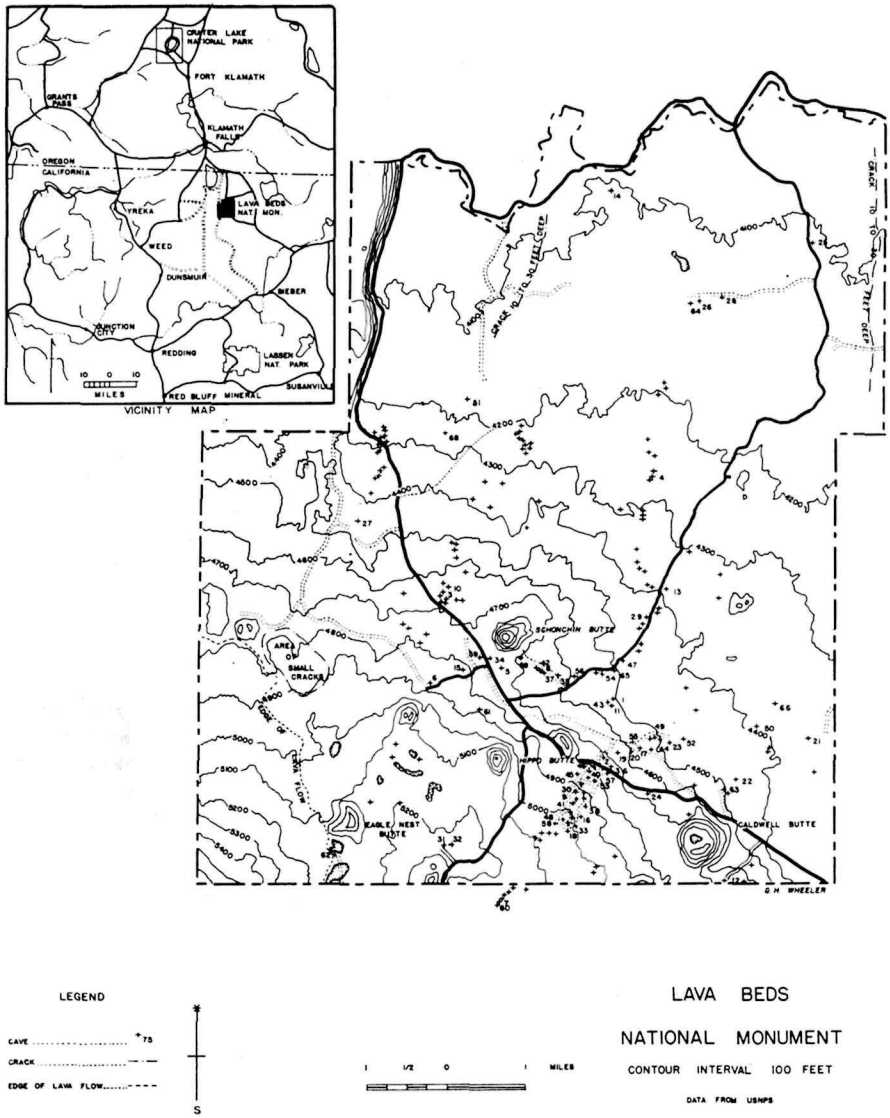

Figure 1

Map of Lava Beds National Monument

Major caves of Lava Beds National Monument

1. Angleworm, 2. Arch, 3. Balcony, 4. Bat, 5. Beaconlight, 6. Bearpaw, 7. Berthas Cupboard, 8. Big Painted, 9. Blue Grotto, 10. Boulevard, 11. Bowers, 12. Caldwell Ice, 13. Captain Jacks Ice, 14. Captain Jacks, 15. Castle, 16. Catacombs, 17. Chest, 18. Compound Bridge, 19. Coopers, 20. Cox Ice, 21. Craig, 22. Crawfish, 23. Dragon Head, 24. Dynamite, 25. Fern, 26. Flat Arch, 27. Fleener Chimneys, 28. Fossil, 29. Frozen River, 30. Garden Bridge 31. Heppe, 32. Heppe Chimney, 33. Hercules Leg, 34. Igloo, 35. Incline Cavern, 36. Indian Well, 37. Irish Bridge, 38. Juniper, 39. Kirk White's, 40. Labyrinth no. 1, 41. Labyrinth no. 2, 42. Little Painted, 43. Lost Pinnacle, 44. Mahogany, 45. Maze, 46. Mushpot, 47. North Bend, 48. Ovis Bridge, 49. Post Office, 50. Rock, 51. Ross Chimneys, 52. Schonchin, 53. Sentinel, 54. Ship Cavern, 55. Silver, 56. Skull, 57. Stinking, 58. Sunshine, 59. Symbol Bridge, 60. Tecnor, 61. Trapper, 62. Upper Ice, 63. Valentine, 64. Wedding Cake, 65. White Lace, 66. Wild Cat, 67. Winemas Chimneys, 68. Wright Chimneys.

one worried about the cause and preservation of the huge ice pendents. They were just something to give off a musical tingle as the picnickers tossed rocks.

By the 1890's several men had settled in the Lava Beds area. Ernest Heppe, a remittance man from England, set up his camp near the southwest corner of the present day monument. His name was given to Heppes Cave and Heppe Lava Chimney located near his camp. Birds and other wild animals drink from the crystal-clear pool of water below the natural arch in Heppes Cave. The ice beneath the water is solid the year round.

To the east, near Caldwells Butte, is the tumbled-down cabin of Caldwell, an early sheep man. To the south of his cabin is Caldwells Ice Cave (Figure 2). At one time he supplied his sheep troughs with water from the caves.

Early visitors named many of the caves from first impressions. One man in particular, J. D. Howard of Klamath Falls, Oregon, became interested and would spend days and weeks walking from one rift to another in search of caves. Seeing a bobcat run into an entrance, he named that cave Wildcat; another had an inclined entrance, so he called it Incline Cave. He had a great deal to do with marking and measuring the caves. he and several others first mapped Catacombs, a cave well-named because of its similarity in complexity to the Catacombs of Rome.

Of the 293 caves known to exist in the Monument, approximately 190 have been explored. When winter temperatures fall below zero, lava cracks, collapsed trenches, and even innocent-looking rock piles "smoke" and steam from the condensation of warm air emerging from the caves. During Civilian Conservation Corps days, one man was assigned to drive up and down Monument roads or walk cross-country, exploring the "smokes" during subzero weather. Today his calling cards—small weathered lath sticks—are found throughout the area. Some of the caves will never be entered by man, unless some hardy individual pulls away the entrance-blocking debris. Not all the Monument caves, however, have obstructed openings. The caves made available to the public today are generally entered through lava trenches which are collapsed portion of old lava tubes.

Photo by William R. Halliday

Figure 2

Entrance to Lower Caldwell Cave.

Within the Caves — Floor Formations

It is not monotonous, as one would think, to visit so many caves in the same area, for all are distinct in floor, ceiling or wall development. Many unique formations are built up in the floors by the varying rates of cooling and rates of flow of the old lava flows. Where the lava was quite fluid and flow rate very slow, pavement-like floors similar to those in Boulevard Cave were created. Slow cooling with a constant level made a very smooth floor. The terrace or cornice-like formations of nearby Balcony Cave indicate partial cooling with frequent changes of flow level. As cooling progressed inward from the edge, varying widths of terraces were created.

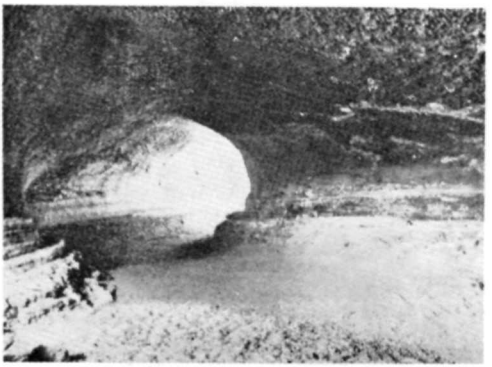

Figure 3
Valentine Cave, curb and terrace along walls mark a former lava level.

Valentine Cave presents varied examples of rates of flow level cooling. Just inside the entrance are found curbing-like structures several feet above the floor line and encircling the walls (Figure 3). Farther in the cave there is a large terrace-like ledge. However, the finest terrace development is found in Lower Caldwell Cave. Here, terraces, ten to fifteen feet in width line certain walls. At the center is a depressed, gutter-like formation.

In Golden Dome Cave, the large ropy ridges of the floor indicate flow movement after the floor surface was nearly complete. Likewise, the delicate rippled surface in Catacombs was caused by partial completion of the floor when the flow resumed, dragging the surface downstream. The ripples resemble those found in marsh mud flats.

The clinker-like surface of many cave floors was caused by gases frothing out to the surface as the magma cooled (Figure 4). A majority of cavern floors with this type of surface are slightly rounded and separated from the walls by low gutters known as contraction valleys. As the lava cooled it contracted, leaving cracks in nearly every type of floor formation. These cracks vary from paper width to several inches across, with unlimited depths.

During the time the floors were being formed, parts of the ceiling often dropped and were carried along with the flow. Such a picturesque island, imbedded in the floor, is found in Golden Dome Cave.

Within the Caves — Ceilings and Walls

Temperature, viscosity and fluctuating supply of magma have made the ceiling and wall decorations of the caverns. As the magma drained away from the crust, solidification on the interior began. In caves where cooling progressed with a constant lowering of temperature, a glaze developed. When the gas temperature fluctuated, this glaze remelted and created unique formations.

In many places drip pendants were formed. These resemble small icicles. Their size depends on the viscosity and the temperatures of the gases during development. More viscous lava and higher temperature produced the more massive pendants. Thin, rapidly cooling glaze developed the smaller pendants, such as are found throughout the caves near Indian Well. In White Lace Cave the pendants are shaped like rose thorns with a globular tip, while in Catacombs, Golden Dome Cave and others, they taper uniformly.

Where drip pendants were created in frothy lava, highly charged with gases, the pendants are in uneven clusters, and are less highly developed than the freely flowing glaze pendants. Protection of these fine drip pendants is a serious problem in the National Monument.

Often, however, drip pendants were not formed. In many caves, the glaze sagged around the ceiling protuberances and down the walls, creating flow ridges of varying

Photo by Eastman's Studio

Figure 4
Clinker surfaced gutter with a lava terrace bordering it.

depths and widths; in such cases drip pendants did not form. The vertical ridges which are narrow (¼″ to ¾″) and project ½″ to 1½″ from the wall are defined as projecting ribs. Where the glaze flowed rapidly, with gradual slowing, wrinkled ripple marks similar to those on the floors were created. It appears as the too-thin cake frosting of an amateur baker. The wrinkled flow ridges of Hercules Leg Cave are excellent examples.

Evidence of the passage of more than one flow through a single cavern is clearly shown by laminations of the walls. Apparently, the "welding" of the built-up glaze gave way, and whole sections of wall pulled away from the original crust. This occurred in Merrills Ice Cave. Here, too, there are variations in color—a dark gray inner wall of basalt contrasting to an outer redstained wall.

The lava caves in the older flows, such as Post Office Cave, Craig Cave, Fossil Cave, and Guano Bridge, have ceilings that resemble the rough limestone quarry tunnels of the Middle West. Here the original ceiling has fallen. Often the weight crushed lower tunnels, thereby enlarging the caverns. The weakness of the ceiling, acted upon by frost and by contraction, brought on the collapse. An excellent example of this is Skull Cave which contained at one time three or more lava tubes in tiered formation. A series of collapses broke down the separating ceilings creating a channel-like cave with the rubble deposited on the ceiling of the lowest tube. Thus, the entrance to Skull Cave is two stories high—98 feet; four hundred feet from the entrance it is three stories high, and a fourth tube lies beneath the rubble. At the stairway leading to the ice floor of the cave this history of change within the caves is shown by the natural bridges, which are remnants of the old tubes.

It is difficult to find continuous single level tubes in the area of the National Monument. Caves located in the same flow are generally separated by lava trenches. In others, the walls and ceiling gradually meet, terminating the cave. Here the outflow of lava was blocked and began solidification before it could push on. In other caves the outflowing lava melted its way through walls and ceilings of nearby tubes. Pouring through these holes, the last remnants of magma cooled into cascades. Nearly every cave open to the public has at least one of these features. The tubes seem to be pouring out a never-ending supply of "cake batter".

The dome-like rooms found in some caves were formed by gas pressure belling out the upper crust of the tube. The gold ceiling domes of Golden Dome Cave show the effect of a weakened crust and tremendous gas pressure. Many of the interlacing caverns of Catacombs present unique structures. The crater-like opening in one of the side passages, with its broken floor plates radiating around a hole which leads to a lower tube, is the result of a weakened floor collapsing into a partial vacuum.

Many of the walls have broken gas bubbles. Gas, building up behind a hardened crust, ruptured the wall. Often the molten material cascaded over the lips of the bubble and resolidified into pendants, such as found in Hercules Leg Cave.

Cave Color

Lava coral is common in many of the caves. Its short, thick, clinker-like formations appear to be studded with blunt tapered spines, generally less than one inch long and radiating from a central mass. The vitreous luster of the coral is thought to be opal. Variations in color enhance this formation. In Fern Cave, a sulphur-stained variation festoons the contraction cracks. In other caves, such as Golden Dome, it is stained frost white by calcium carbonate compounds. Formation of the coating of the coral is believed to be the result of ground moisture brought to the spines by capillary action. Evaporation then builds the delicate portions.

Reds, browns and grays of the lichen-covered rocks at cave entrances are open invitations to visitors. Soft green moss has followed to the end of the light rays within the caves. Beyond this fringe are other colorations. Oxides of iron provide most of the colorations within the rocks, the black and light gray basalt contrasted to the red-

stained lava gravel. Many of the surface stains are produced by calcium carbonate precipitated from ground moisture. Nearly every cave has these types of colorations. Notable for uniqueness are the sulphur compound deposits clinging like gold crystals to the ceilings of Golden Dome. Because of condensation small droplets of water add sparkle to each rock surface in the lantern light.

Photo by Eastman's Studio

Figure 5

Fern Cave, pictographs.

Cave Atmosphere

Atmospheric pressure changes, as well as temperature fluctuations, cause movement of air within the caves. Of lesser importance is the effect of wind entering one entrance and passing out another. In only a few caves is the latter possible as the majority have a single restricted entrance. The greatest air exchange in the caves occurs during the winter months. The cold heavier air displaces the lighter warmer air of summer trapped in the caves. Atmospheric breathing, the result of changing air pressure either drawing air into caves or forcing it out, accounts for most of the air exchange during the warm months. Because the interior of the cave is insulated from solar heat air temperatures are approximately 15 to 25 degrees cooler than outside air temperatures. Even during August one finds Merrill Ice Cave uncomfortable without a light jacket. Crystal Cave has a below-freezing temperature the year round.

Fern Cave, with a circular opening in the ground crust, is protected to a certain degree from wind currents. During the winter months the sun's angle allows some rays to create a warm micro-climate near the entrance. Here the warm, moisture-laden air rising from the cave condenses above the opening producing the humid conditions necessary for coastal ferns.

Lava Chimneys

Other unique formations in the Lava Beds offer opportunities. No one has explored the volcanic necks of Fleener Chimneys, although some years ago a lantern-carrying line was dropped down one 18 inch gas orifice nearly 100 feet before obstructions were encountered. Adjacent to Fleener Chimneys, near the head of the Homestead flow, are many shallow caves which have been visited by very few people. Although visited by more people, the Thomas-Wright Chimney group is outstanding for its volcanic story. In one location it is possible to walk beneath the chimney and look upward to see the sky.

Schollendoms differ from the lava tube caves in size and shape, and are large cavities created by trapped gases. Later, the confining crust cracked, exposing the cavities. These caves are seldom more than fifteen or twenty feet in depth. Wind-blown dust has partially filled the lava cracks, building natural paths through them. Schollendoms were used by the Modocs as natural forts during the battle in 1872.

Archeology

At Fern Cave the ten-foot circular entrance opens directly onto the low fern-covered mound ten feet below. To the south of the mound is a large vaulted room with a gently sloping floor. On both walls are pictographs (Figure 5). Archeological reconnaissance was carried out here by National Park Service crews in 1935. The shallow test trenches dug in the debris mound directly beneath the entrance revealed evidence of man's occupation. The water worn pebbles found among the charcoal in the test trenches were probably from water-fowl gizzards. Stone awls and obsidian chips in-

dicate a simple way of life. No pottery or vessels for storage of food or water were found. It is probable that the inhabitants of the cave were nomadic, living off the land. These people did not create a culture with architectural trends nor cultivate crops because everything was readily available throughout the year. The layered charcoal deposits with alternate layers of soil accumulations from the ceiling and wind-blown dust indicate intermittent use of the cave.

The wave cut caves of the Petroglyph Point, located northeast of Fern Cave, were investigated by University of Oregon representatives in 1940. Apparently, the caves were used by historic Indians. The water-washed pumice and other debris indicate that one cave was used continuously and the other for an occasional burial at a time when Tule Lake was at a lower, less fluctuating level. Had the caves been used by prehistoric Indians nearly all of the occupational material would have been washed away by wave action of the lake when it stood at a higher level.

North of wave cut caves are the Indian carvings on a wall of cemented volcanic ash of an old volcano. When the old Tule Lake completely surrounded the petroglyph volcano, wave action on the western edge created a nearly vertical wall of approximately 200 feet. It is believed that Indians, standing in their canoes, scratched the petroglyphs into the soft walls. Other Indian writings are found in Symbol Bridge and Painted Cave. These are pictographs like those of Fern Cave.

Caving in the Lava Beds National Monument has been made popular by the building of access roads and by the installation of self-guiding trails and stairways within certain caves. Gasoline lanterns are provided free of charge by the National Park Service. Guide Service is not provided. Local residents, during the hot summer months, find in the caves a cool, welcome afternoon haunt. Even throughout the fall and winter they return again and again. Many prefer a trip to the Lava Beds caves to the more extensive trip to beautiful Crater Lake National Park. Even the Scout Troops utilize the area, combining overnight stays in Indian Well campground with caving explorations. Approximately forty caves have been made accessible to the touring public and bring caving enjoyment to approximately 60,000 visitors each year.

Information on many of the caves of the Monument was supplied by Superintendent Don C. Fisher, Lava Beds National Monument; his aid is gratefully acknowledged. Photographs were supplied by J. H. Eastman, Eastman Studio, Susanville, California, Dr. William R. Halliday, Seattle, Washington and the University of California.

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GEOLOGY OF LAVA BEDS NATIONAL MONUMENT

by RICHARD T. GALE

The monument is entirely covered with volcanic rocks. The Medicine Lake Highlands to the south are the center of the regional volcanic activity which started about thirty-five million years ago.

The oldest rock in the monument is the ryholitic-pumice tuffs (Lewis and Anderson 1936) with which the Indian petroglyphs are associated. These may be Early Tertiary (Swartzlow 1934).

The main flow which covers the monument is the Modoc Basalt Flow, Late Pleistocene or Early Recent in age. This flow originated in the Medicine Lake Highlands and has not been weathered or subjected to erosion in any degree. In texture this flow is fine granular to glassy, but is not obsidian. It is about half plagioclase feldspar and half pyroxene and basic glass. However, olivine is found in abundance, some-

times as high as twenty percent. Small amounts of iron oxide are common (Lewis and Anderson 1936).

The olivine basalts along the fault scarp at the northwest end of the monument are Early Pleistocene or possibly Late Pliocene. These flows, which probably average over one hundred feet in total thickness, underlie much of the Modoc basalt flow.

To the northwest of the monument are a series of step faults in the olivine basalt. These extend into the monument and such volcanic structures as craters, cinder cones, and spatter cones or chimneys are apparently developed along extensions of these faults (Lewis and Anderson 1936). The extreme northeastern corner of the monument is a horst cutting the tuffs. There are several other faults along the northern boundary of the monument which are associated with the graven that Tule Lake occupies immediately to the north of Lava Beds (Swartzlow 1934).

In Fossil Cave there are remains of camel and mastodon but unfortunately these cannot be of much help in determining the age of the Modoc basalt flow. The mastodon lived into modern times and the exact time of the camel's disappearance from this area has not been determined. Only a rough estimate of the age of the flow is possible; it is thought to be between twenty thousand and sixty thousand years old (Lewis and Anderson 1936).

The oldest flow is the Juniper Butte flow, which is estimated to be up to 60,000 years. Later flows from Caldwell, Hippo, Schonchin, Mammoth Crater and Glass Mountain built up successive layers covering much of the older flows. The flows branched out from central sources; secondary flows developed where gas pressure or molten magma broke through contraction cracks in cooling lava to form large secondary (toy) fields. As a consequence many lava tubes cross at right angles on different levels. Cascades of lava in tubes may also reflect action of the secondary flows.

The youngest flows in the monument are perhaps five hundred years old. These are the Devils Homestead Flow in the northwestern part of the monument and the Black Flow (the largest lava flow in the monument) partly in the southwestern corner of Lava Beds. Black Flow has few caves; Devils Flow has many "miniature" caves, few of which have been explored. These flows support only scant vegetation in isolated pockets where pumice has collected. This pumice indicates that there has been volcanic activity since the flows. Indeed, Glass Mountain, a mass of obsidian about six miles south of the monument, is supposed to contain a steam vent on its northern slope.

Lava Tubes

There are about three hundred lava tubes or caves in the monument and most of them have several characteristics in common. The tubes are normally much longer than they are wide, are circular to oval in cross section, have low (up to ten feet high) ceilings, straight main passages, and the floors tilt along the general slope of the terrain (Figure 6).

The tubes were probably formed in the following manner. As the lava flowed out from the various cinder buttes and spatter cones it began to cool on the outer edges which soon solidified into rock. Beneath this confining crust the lava was still molten and fluid. The force of gravity and gas pressure pushed the fluid lava onward leaving a tube sealed at both ends.

Access to the tunnel was brought about by the collapse of the roof. In a few caves, such as Hercules Leg Cave, the entrances may have been blown out by gas pressure. Usually collapse formed two caves, one upgrade toward the source of lava and one downgrade, toward the end of the rift or trench.* If the collapse occurred in two adjoining areas and the debris did not fill the tube, a natural bridge resulted (Figure 7). There are more than twenty such bridges, the best known being Symbol Bridge, which contains the Indian pictographs.

* There is a difference in terminology in refering to lava flows. It has been the custom to refer to lineal vents of the flows as rifts. Stearns (1928) suggests that trench is a better word, as rift is commonly used to refer to a fault structure.

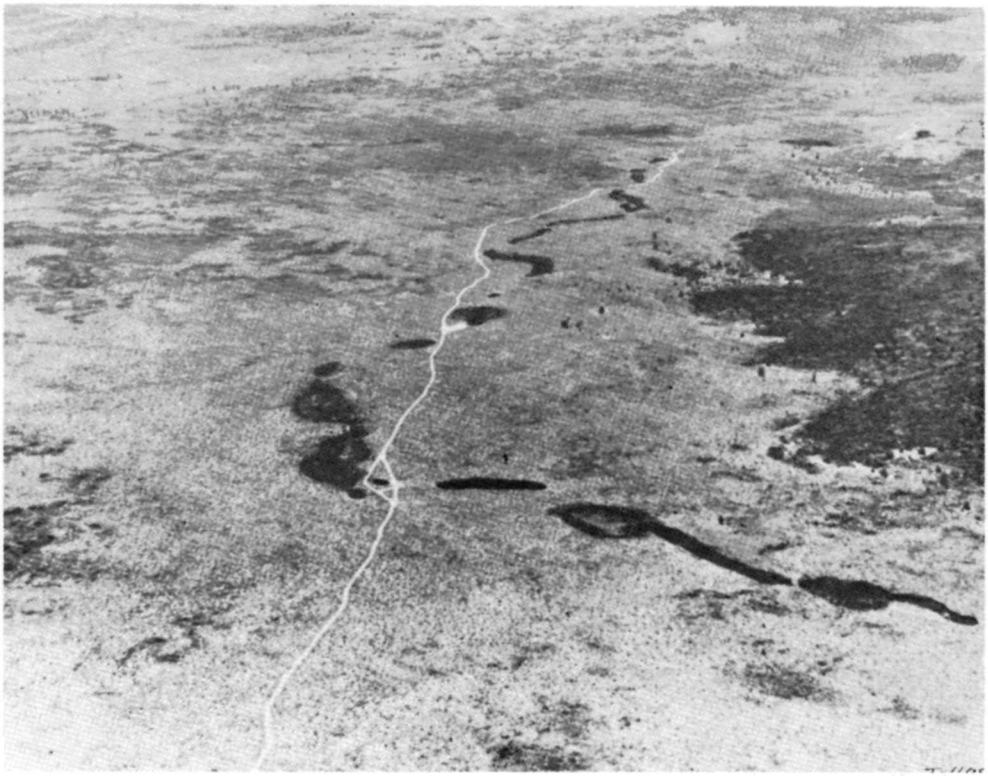

Photo by Eastman's Studio

Figure 6
Aerial view of a portion of Lava Beds National Monument. Sinuous dark areas along road are trenches. Dark area on right is the Schonchin Lava Flow.

Cave floors exhibit a variey of shapes and forms. Since molten lava is a fluid, the flow encountered obstacles similar to those encountered by streams and rivers. Several caves, notably Valentine Cave, Golden Dome Cave, and Lava Brook Cave, exhibit such common stream features as rapids, falls, and eddy currents, well preserved in the basalt. This occurs mainly when the lava is highly fluid, swiftly moving, and is accompanied by rapid cooling.

Smooth floors, as in Catacombs Cave, have resulted from slowly cooling lava flows within the tubes. If, on the other hand, the flow was highly charged with gases, steam or water vapor, rough cinder-like floors, as in Silver Cave, are produced.

As the lava tubes, still filled with moving molten lava, began to drain, curious wall formations were left. Shelves were formed by rapid cooling of the lava as the flow "hesitated." If the flow was stationary for a long enough period, the entire surface hardened or "froze," forming a two level cave. Some caves, namely Crystal Cave, have several well-defined levels.

In places the hot gases above the lava remelted the ceiling and wall crusts, allowing them to drip and flow downward forming drip pendants (Fern Cave) or "lavacicles." Another feature, lava "coral" (Swartzlow and Keller), is found only in caves in which the crust that formed the ceiling is broken into shards or fragments. The coral forms by the deposition of calcite along the shards of basalt. The calcite is present in the ground water in the form of calcium carbonate probably originating in the weathering of plagioclase feldspars and the pyroxenes. Some of the deposits produce

a branching effect which greatly resembles coral. The best displays of this coral are in White Lace Cave, Hercules Leg Cave, and Valentine Cave. (Swartzlow and Keller 1937).

Ice Caves

About one hundred caves in the monument contain ice or water or both. The water is thought to be of meteoric origin which percolated downward through the porous basalt to the lower levels of the caves (Swartzlow 1935). If the lower ends of the cave are sealed to prevent seepage, a sufficient quantity may collect to form ice.

According to Harrington (1934), the angle of the sun's rays is a fairly uniform factor in the formation of ice in caves. As the various ice caves in the monument face in all directions, this factor cannot be used in theory postulation of Lava Beds.

Another factor which does not hold is that air circulation through rock fissures is an important factor in the formation of ice. If air circulated through fissures in the summer, the ice would be warmed sufficiently to melt, in most cases probably totally. There is a minor amount of atmospheric circulation through rock fissures in a very few ice caves in the monument, but in the great majority there is no noticeable circulation (Swartzlow 1935).

The explanation of ice caves centers around the fact that there is active circulation of air in winter but comparatively little circulation in the summer months. The density of surface air increases in winter, and will tend to seek lower levels. This effectively pushes out the warm air that may be in these lower levels. This cycle repeats until the lower end of the cave is below the freezing point of water. Ice may then form from the water that has previously collected there or that seeps after the freezing temperature has been established.

During the hot summer months, the air is heated and expands, tending to rise in the atmosphere. As the colder air is lower in the lava tube, there is very little air circulation in the cave in the summer. A person may note the usually tremendous difference of air temperature when entering ice caves in the summer. This "buffer zone" is usually confined to the entrance and there may be as much as forty degrees of temperature change in a few vertical feet.

Another factor in ice caves formed in porous basalt is the dead air spaces in these basaltic rocks. These spaces act as an insulator surrounding the ice, helping to prevent the ice from melting in summer.

In most ice caves the ice does not change much in volume throughout the summer. Ice is known to be greatly reduced or disappear from some caves during an excep-

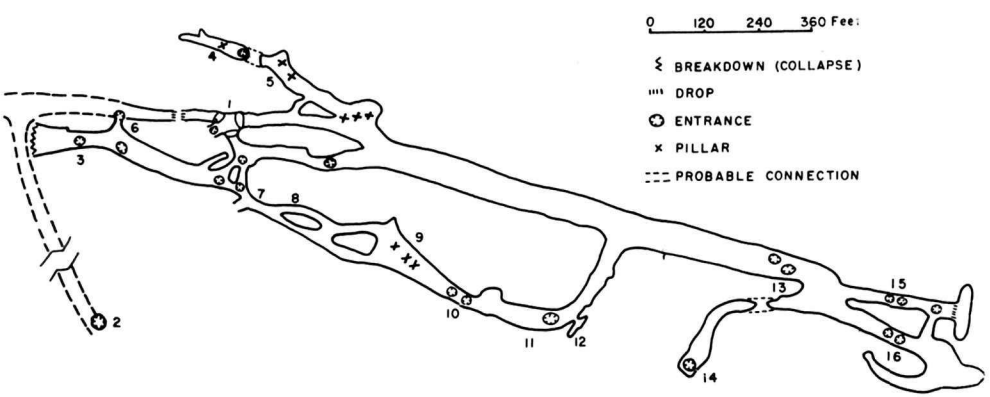

Figure 7

Map of a lava tube complex; modified from S. D. Howard's map 1920. (1) Natural Bridge, (2) Sentinel Cave, (3) Juniper Cave, (4) Sunshine Cave, (5) The Witches Chamber, (6) Hercules Leg Cave, (7) Blue Grotto Cave, (8) Pop Corn Chamber, (9) Balcony Chamber, (10) Golden Dome Cave, (11) Mitertyte Cave, (12) Pool of water, (13) Lava Brook Cave, (14) Muspot Cave, (15) Thunderbolt Cave, (16) Labyrinth Cave.

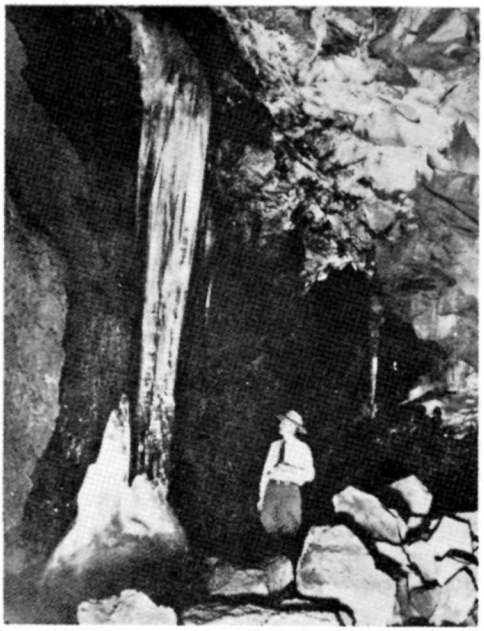

Photo by Eastman's Studio

Figure 8

Crystal Cave, ice pendant.

tionally long dry period, but generally returns when normal precipitation is again the standard. For example, Heppe Cave contained ice in the summer of 1956 and 1958 but not in 1957. The rainfall and snowfall of 1956 and early 1957 was considerable below normal. As the precipitation in 1958 has been well above normal, Heppe Cave should have a greater volume of ice in 1959 than there is at present.

The following caves are the best and most well-known ice caves in the monument. The direction that the entrance faces has been included to illustrate the fact that the angle of the sun's rays is not an important factor in the formation of ice caves in Lava Beds.

CRYSTAL CAVE. Crystal Cave contains the most beautiful and spectacular display of ice in the monument. The entrance is a vertical descent of 20 feet. The cave is in five levels. Inside the entrance, which faces east, a solid sheet of ice covers the wall and floors. This ice is remarkably clear, as rock fragments can be seen up to depths of two or more feet. Farther westward are three tremendous ice pendants, twenty feet high and four to six feet thick (Figure 8). Portions of these are almost transparent. In the lowest level of Crystal Cave there is a huge mound of ice, about five feet thick and twenty feet square. A tunnel about two feet high leads completely through the ice. This tunnel apparently has been in the ice since 1936 (Lewis and Anderson 1936). The most beautiful ice formations in Crystal Cave are the ice crystals. Portions of the cave are completely covered with these crystals, which range in size up to one inch in width and are found in groups which are six inches in diameter. The crystals are hexagonal in shape and sparkle with a brilliant luster in lamplight. Another form of crystal exists in the lower level and are formed into ribbons, looking very similar to transluscent gypsum flowers. Unfortunately, there are only two of these ribbons remaining, the other having been vandalized. Crystal Cave contains more ice than any other cave in the monument.*

FROZEN RIVER CAVE. Frozen River Cave, which faces southwest, has a tremendous mass of ice. The ice chamber is about one hundred feet below the surface. The ice is several hundred feet in length and about five to six feet thick. It is covered by a thin pool of water.

MERRILL ICE CAVE. This cave, which was formerly Bearpaw Ice Cave, faces north. The ice in this cave is similar to a frozen river, fifteen feet wide and four hundred feet long. The middle of the ice river contains a fifteen foot deep pit, into which the ice cascades.

COXS ICE CAVE. Coxs Ice Caves faces southwest and contains a dome room about fifty feet square full of ice. As in Frozen River Cave, two inches of water covers the ice.

SKULL CAVE. The ice chamber in Skull Cave (the entrance faces west) is about one hundred and fifty feet below the surface. The ice is similar to that in Merrill Ice Cave.

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* *Editors Note* — Raymond G. Knox, in November 1949 found one of the ice formations in Crystal Cave entirely covered to a depth of one quarter to one half inch with a deposit of gypsum. The gypsum was sampled and proved to be 98% pure. A month later the same formation contained only crystal-clear ice.

WHITE LACE CAVE. The entrance to White Lace Cave faces northeast and the ice is in small thin patches scattered throughout the tube.

HEPPE CAVE. Heppe Cave, one of the very few ice caves with two entrances, faces west and east. The ice in Heppe Cave is covered by a pool of water two to three feet deep. The floor of this cave is composed of collapse from a tube and the ice is formed in a low depression in this breakdown.

Cave Life

Plant life in the lava tubes is limited to lichens growing in the sunlit areas of the caves, with the exception of Fern Cave. As its name suggests, Fern Cave contains a luxuriant growth of ferns in the entrance, flourishing in spite of the semi-desert conditions.

The vertebrate animal life of the tubes does not remain permanently underground. The most common mammal observed in the caves is, of course, the bats. In Blue Grotto Cave, Long-Eared bats (*Corynorhinus rafinesquii*) are fairly common. The western *Pipistrellus* has been observed in Coxs Ice Cave, Sentinel Cave, and Juniper Cave. It is thought that perhaps a variety of *Myotis* also occurs in the monument caves. Bat Cave contains guano ten feet thick and was said to house over three million bats at one time (K.A. Murray and J. D. Howard personal communication).

Wood rats nests are seen in almost every cave. Bobcats have been reported in the Caldwell Caves, and a pika or cony has been seen in the entrance to Thunderbolt Cave. Purple Martins roost in the entrance to Fossil Cave. Dragonshead Cave and Skull Cave have yielded the skulls of a now extinct bighorn sheep. Antelope skulls have also been found in Skull Cave and Coyote Cave was named for the skelton of a coyote that was found in it. Gopher snakes, attracted by toads and mice in Fern Cave, startled many visitors who were conducted through this cave.

The Indians knew and probably occupied certain caves, as the pictographs suggest. These are found in Big Painted Cave, Little Painted Cave, and Ship Cavern (all located in approximately the same area). Two human skeltons are said to have been found in Skull Cave, which is quite near the three above caves.

Fossil Cave, in the northeastern part of the monument, has been named for several fossils found in the lava tube. It has recently been suggested that perhaps the lava flow uncovered the fossils, rather than burying them (K. S. Murray and J. D. Howard personal communication). The first fossils were found in 1931 and included two teeth (upper and lower molar) of a camel (*Camelops* sp?), portions of two teeth and a part of a lower jaw of a young mastodon (*Mammut americanum*), and a tooth of a carnivore. These fossils are in the Museum of Paleontology at the University of California (Lewis and Anderson 1936).

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