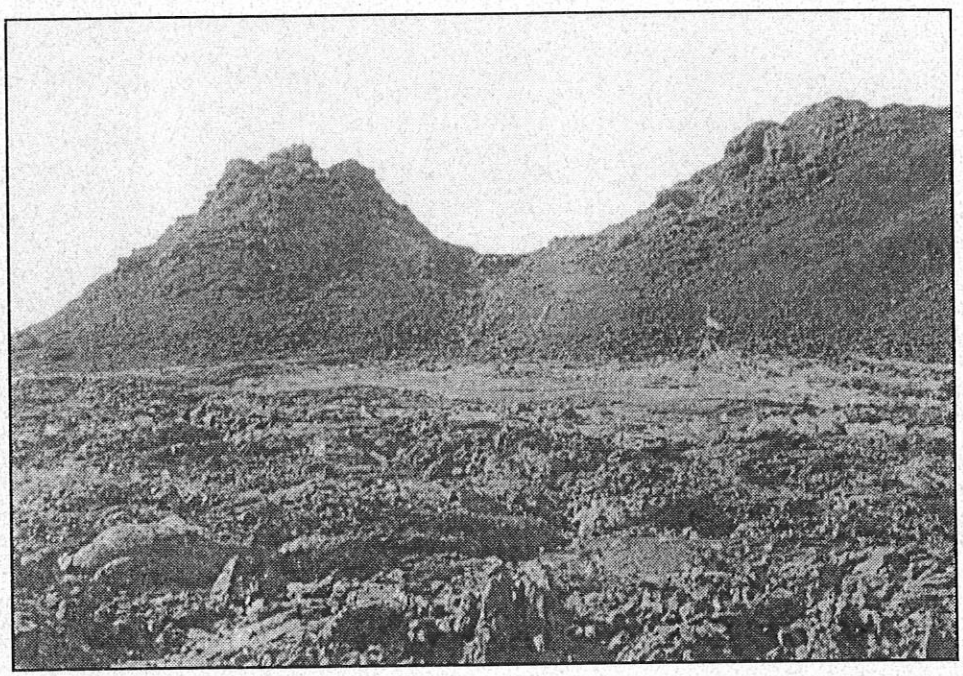
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A Mineral and Biotic Survey of Two Caves at Craters of the Moon National Monument

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December, 1995



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A MINERAL AND BIOTIC SURVEY OF TWO CAVES AT CRATERS OF THE MOON NATIONAL MONUMENT

In the summer of 1995, The U.S. Department of the Interior, National Park Service, Craters of the Moon National Monument contracted with the Environmental Science and Research Foundation to perform a mineral and biological survey of Crystal Pit and Snow Cone, two caves associated with spatter cones on the Monument. To avoid unnecessary damage to the sensitive cave resources, the Foundation agreed to a limit of two visits to each cave. The surveys were performed on 30 September and 7 October 1995. This document is the final report of the findings of those surveys.

There were six primary objectives of the surveys:

- To complete a comprehensive physical survey and map of Crystal Pit and Snow Cone.
- To photograph the two caves to show their general nature.
- To determine the mineral composition of the floor of each of the caves.
- To determine what families of insects inhabit each cave.
- To determine what species of lichens and mosses inhabit each cave including their distributions with depth and aspect.
- To document other cave inhabitants as observed.

We assembled a team of subject area experts from among the university community and elsewhere to participate in the surveys. The team for this project and their areas of expertise included:

- Randall C. Morris, Ph.D.; Environmental Science & Research Foundation, Inc. Dr. Morris was the project leader for the surveys and collected the mineral samples.
- Scott Earl; Idaho Cave Survey. Mr. Earl, with assistance from other members of the Idaho Cave Survey (ICS), a chartered internal organization of the National Speleological Society, was responsible for physical survey, mapping, and photography of the caves, and training the rest of the team in Single Rope Technique. Mr. Earl was also appointed as the Foundation's Safety Officer for this project.
- Michael McCurry, Ph.D.; Idaho State University, Department of Geology. Dr. McCurry was responsible for analysis and interpretation of mineral samples.
- Robert C. Anderson, Ph.D.; Cricket Science, Inc. and Idaho State University, Department of Biology. Dr. Anderson was responsible for collection, identification, and interpretation of faunal samples.
- Lorentz Pearson, Ph.D.; Private Consultant at Ricks College. Dr. Pearson was responsible for collection, analysis, and interpretation of floral samples.

In addition to this team of experts, the Foundation was assisted by a number of people whose help was invaluable. Jeff Baldwin, Dean Killian, April Earl, Eirik Fowler, Chris Jensen,

Scott Nelson of Idaho Cave Survey participated in the cave surveys and ensured our safety during the descents. Mary Anderson prepared the x-ray diffraction samples and Dr. J. Stevens assisted in identifying natrojarosite. Jason Workman collected vegetation samples for Dr. Pearson, and Drs. Roger Rosentreter and Larry St. Clair helped identify lichens and mosses. Vickie Snitzler-Neeck, Marshall Neeck, Scott Ryan, and Nataleen Cummings of Craters of the Moon National Monument helped with logistics and cave surveys, and supervised our operations within the caves. Mr. Neeck served as the Monument's Safety Officer for this project and coordinated his efforts with Mr. Earl.

Study Area

Craters of the Moon National Monument is located at an elevation of 1.8 km on the northern boundary of the eastern Snake River Plain in southeastern Idaho. The monument has an annual precipitation of 42.6 cm. The mean monthly temperature ranges between -1.7 and 28.7°C with a maximum recorded temperature of 36°C (August 1992) and a minimum recorded temperature of -31°C (January 1979)[1]. The monument is the site of the most recent volcanic activity in the eastern Snake River Plain. The last activity was approximately 2000 years ago.

Snow Cone and Crystal Pit are two caves associated with spatter cones on the monument. Each cave consists of a vertical throat that opens into an enlarged chamber at the bottom. Entrance to Snow Cone is gained through a 37-m drop, 20-m of which is beside a frozen waterfall which the surveyors named "Surprise Ice Cascade." The bottom chamber is approximately 465 m^2 in area. This cave also includes some small side chambers. Entrance to Crystal Pit is gained by an 26-m vertical drop to a bottom chamber approximately 140 m^2 in area. The throat of the spatter cone is fairly uniform and averages 1-m in diameter. Minerals encrust portions of the walls and floor of the bottom chamber.

METHODS

Physical Survey, Mapping and Photography

Surveying was performed using standard cave surveying techniques and equipment. Sight-through compasses and clinometers were used to measure horizontal and vertical angles. Distances were measured with fiberglass tapes and ultrasonic distance measuring devices. Survey stations were chosen throughout the cave, marked with light emitting diodes, and distance measurements were taken between stations. Foresights (and backsights, where possible) were read and recorded. At each survey station, distance measurements were also taken to the cave walls, ceiling, and floor. Discrepancies between foresights and backsights were resolved and sketches of both plan and profile views made.

[1]Personal communication, Ms. Vickie Snitzler-Neeck, Craters of the Moon National Monument.

At Crystal Pit, in addition to mapping the cave, we mapped the surface of the spatter cone and the adjacent cone to the northwest in order to create a profile of the outer surface of the spatter cones in relation to the cave.

Data were subsequently entered into a spreadsheet to calculate X, Y, Z coordinates for the survey stations. These coordinates were converted to a macro, run by a three dimensional computer aided design program, and the survey line was generated in three dimensions. The map was created on the computer by marking the vertical and horizontal distances from each station and then drawing in the walls, ceiling, and floor using the drawings in the sketch book. Symbols, details, descriptions of points of interest, and mineral/biota sampling locations were added, the results rotated and scaled to fit best on the paper, and printed. Each map was digitized in dxf format for inclusion in the National Park Services GIS system.

Photographs were taken to document the general nature of the cave. Macro lenses were used for mineral closeups, and normal and wide-angle lenses, using multiple, optically-slaved flash units, were used to photograph the balance of the caves.

Mineral Survey

In order to determine the mineral composition of the cave floors and mineral coatings, we collected fist-sized samples of bulk rock and marble-sized samples of mineral coatings, where available. Samples were collected at the locations shown in Figs. 1 and 2. We collected bulk rock from several locations on the cave floor. For mineral coatings, we made an effort to collect any mineral which looked different in color, texture, or growth form from those already collected.

Methods used for mineral identification included visual inspections using a hand lens or binocular microscope, standard mineralogical tests (color, habit, hardness, solubility in water or dilute HCl, etc.) and, where sufficient sample was available, analysis by X-ray powder diffraction. In those cases distinctive crystals and/or coatings where removed from the basalt substrate surface.

Fifteen samples were examined by X-ray powder methods (e.g., Hutchinson, 1974; Zussman, 1977). Samples were ground gently to powder in a ceramic crucible and mounted into aluminum sample cups. These were mounted into a $\theta/2\theta$ goiniometer system on a Norelco X-ray powder diffractometer. Scans were generally run from 10° to 60° 2θ, at 1° 2θ /minute, using CuKα radiation, and a paired PHA-scintillator and Ni-filter system. Sample data were recorded to strip chart outputs, and interpreted using a modified Hanawalt search-match method. Representative examples of matches are shown in Tables 1-3.

Faunal Survey

Selection of a faunal survey method was complicated by the difficulty in moving large amounts of equipment into and out of the caves and by the restrictions on the number of visits permitted in order to protect the sensitive resources. These restrictions made it necessary to focus our selection on those methods most likely to produce results.

The biomass of individual animals and the biomass of animal populations are limited primarily by carbohydrates (which provide energy for metabolism and movement) and protein (which provides the amino acids necessary for growth and an increase in biomass). Other nutritional factors such as minerals are also required, but carbohydrates and protein are undoubtedly the primary components which limit both individual and population biomass of troglobitic (i.e., cave-dwelling) animal species. As resources, carbohydrates and protein are rare in caves. The nutrient resources that do exist are a consequence of (1) animals (or pieces of plants) that fall or are blown in and die, (2) limited production by photosynthetic organisms that may exist in regions where light penetrates through openings, (3) organic material produced by chemosynthetic species which can oxidize inorganic substances and obtain energy in the absence of light, and (4) a recycling of nutrients through death and decay of the troglobitic species which live in the cave. Because of these constraints, it was assumed that any animals dwelling in Crystal Pit and Snow Cone caves at the Monument would be, predictably, very small and few in number.

The hard volcanic and rocky "floors" of the caves precluded the use of pitfall traps (which collect crawling animals that fall in), and any species living in the cold and totally dark conditions of the caves would not be expected to be attracted to ultraviolet or other kinds of light traps.

To survive, cave-dwelling animals must have very sensitive and effective chemosensory systems, especially olfaction, to discover and utilize any sources of carbohydrate and protein. Plates of bait incorporating these nutrients were prepared as attractants, and for non-destructive sampling of animals which might be living in the caves. The plates consisted of a 11-cm plastic tray with a shallow trough around the edge. Each such plate was "baited" with a 8 - 16 cm^3 piece of (a) honey-soaked dry dog pellets, (b) ripe pear, (c) decaying pork liver, (d) decaying beef, and (e) decaying chicken (Fig. 3).

Four plates of bait were deposited in Crystal Pit cave on September 30. One of these was placed near the edge of the "lighted" area inside the cave and at the base of the entry tube, another was placed on a shelf about 1.5 m from the floor on the east side of the cave, a third was placed on the floor near the extreme northern end of the cave, and a fourth bait tray was placed near the south end of the cave (Fig. 1). Six bait trays were placed in Snow Cone; one on the floor at the base of the ladder in the Ladder Room, and five others on the floor at various locations in the lowest portions of the cave (Fig. 2). Of these five, one was placed beneath what is probably the trunk of a juniper in the cave, and another near an assemblage of small mammal (probably

ground squirrel) skeletons which existed in a small depression on the floor near an edge of the cave.

Additional efforts to detect living animals, given constraints of time and circumstances, were conducted using (1) visual examination with flashlight and an otherwise unaided eye, (2) removal of small bits of bark from the ladder in the Ladder Room of Snow Cone for collection of associated animals using a micro-Berlese apparatus (Fig. 4), and (3) on the first day of entry into both caves, a cursory examination with a shortwave blacklight (i.e., ultraviolet light) having a radiation peak of about 250 nm to check for fluorescent animals (and minerals).

Floral Survey

To ascertain how deep in the caves lichens and mosses grow, we rappelled into both caves and made careful observation of all vegetation at all levels. Prior to entering the cave, we studied the species most likely to be encountered. This included a list of 46 lichen taxa and 13 species of mosses which we located in the Boise State University, Ricks College, and Brigham Young University herbaria.

To aid in obtaining accurate cover data, metal frames 20-cm long by 5-cm wide, marked at 4-cm intervals on the long side, were placed against the northeast (maximum light energy), southeast, southwest, and northwest sides of the vertical tubes as we descended into or climbed out of the caves, at approximately 1.2-m intervals. We also examined the lichen and moss vegetation at, slightly below, and above the cave entrance, and collected thumbnail-sized specimens of species that, based on our prior examination, we did not believe were represented in the Craters of the Moon herbarium.

No attempt was made to collect lichens easily identified by quick visual observation unless we judged them to be species not already in the herbarium. Easily identified lichens included the bright orange species of *Caloplaca* and *Xanthoria*, the chartreuse species of *Acarospora* (*A. chlorophana* and *A. schleicheri*), the bright yellow species of *Candelariella*, and most foliose species such as umbilicate species of *Lecanora* and *Umbilicaria*.

Adnate specimens of *Lecanora* and *Physcia* and most crustose lichens were removed with the aid of hammer and chisel, location (depth and exposure) noted, and placed in paper bags. Specimens collected September 30 were taken to the lichen herbarium at Brigham Young University where they were identified by (1) use of keys, and (2) comparison with specimens in the BYU Herbarium. Specimens collected November 7 were taken to the Ricks College Herbarium where we keyed them out and compared them with herbarium specimens in the Ricks College lichen and moss collections and the INEL lichen collection. They were then prepared for inclusion in the herbarium at Craters of the Moon. Keys used were Pearson and Rope (1987), Hale (1979), Wetmore (1967).

Mosses collected in the caves consisted only of gametophytes in most cases, making certain identification difficult or impossible. We tentatively identified them from the detailed species descriptions and pictures in Flowers (1973) and Conard (1956), and by comparison with mosses in the Ricks College moss collection and the University of Utah Herbarium. As of this writing, identification of the moss specimens has not been confirmed by an experienced bryologist.

RESULTS

Physical Surveys and Cave Descriptions

Crystal Pit (Fig. 1)

Crystal Pit is a cave associated with a volcanic spatter cone in a chain of spatter cones at Craters of the Moon National Monument, Idaho. It was entered and described in an unpublished manuscript by Stearns (1927) and again by Peck (1961). Peck reported visits by Bob Limbert in 1922 and S.A. Paisley in 1925 but found no evidence that the cave had been entered since that time. Because this cave has been previously described, it will not be redescribed in detail here. In this manuscript we will focus on presenting the measurements, names, and maps resulting from our survey. We will, however, describe features which were not mentioned in earlier descriptions.

Presently, the Crystal Pit spatter cone stands about 15 m above the surrounding landscape. The spatter cone is open to its magma chamber below and is entered by way of a vertical shaft of 1 m diameter. When a rope is rigged over the center of the shaft, it does not touch the walls for the full 26-m drop.

The walls of the upper 12 m of this shaft are non-symmetrical and slightly convoluted in nature, while the next 6 m of the shaft is smooth-walled and slightly larger. The shaft abruptly widens out at -17 m into a bell-shaped magma chamber. The landing point on the floor is 8.8 m below this point. The magma chamber is elongated is a northwest-southeast direction in alignment with the rift zone and its associated chain of spatter cones. The main portion of this chamber is 18-m long, 7.6 to 10.7-m wide, and 7.6 to 9.1-m high. Its most notable feature is a shelf which completely encircles the chamber at a depth of 22.9 m below the entrance. The shelf, which varies from 0.6 to 3-m wide, was probably created at the end of the eruptive phase by the magma remaining fairly constant at the level of the shelf long enough for significant edge cooling and solidifying to occur before the magma drained fairly abruptly. The lowering of the magma pool caused the viscous lava on the underside of the shelf to be pulled down into stretched lava projections. The magma probably drained from the chamber to the southeast end as evidenced by the stretch marks and grooved lava in the walls of the chamber near that end.

Below the shelf, there are room extensions at both the northwest and southeast ends of the magma chamber; the Dollhouse and Planetarium Rooms, respectively. Above the shelf, there is a room extension in the southeast end of the magma chamber; the Crow's Nest Room. The

extension below the shelf in the northwest direction is referred to as the Dollhouse because of lava formations which resemble a miniature table and shelves. The Dollhouse is 9.1-m long. It has an opening in its ceiling which continues through a mini-shelved area up to a point even with the highest point in the magma chamber proper, some 14 m above the floor of the Dollhouse. This upper room, called the Multi-Lining Room, has numerous lava lining ruptures that allow examination of the genesis of the spatter cone by viewing the two major linings and the loosely adhered lava clots which form the spatter cone outside the linings. This room, as can be seen on the profile map, partially underlies the next spatter cone to the northwest and may have supplied some of the lava that formed this cone.

The room at the southeast end of the main magma chamber is called the Planetarium Room for its shape and the raised podium rock in the center. This room has fascinating pulled-taffy-shaped lava with mineral coatings on its right hand wall.

Directly above the Planetarium Room, but entirely separated from it by the lava shelf, is the Crow's Nest Room. This room also contains numerous mineral features.

The floor of the main magma chamber is mostly breakdown from the high point in the chamber ceiling along with a few pieces of shelf and lining. The material that fell from the domed ceiling appears to be similar to the clotted lava in the Multi-Lining Room above the Dollhouse.

Photographs of the interior of this cave are found in Figs. 5-29.

Snow Cone (Fig. 2)

Snow Cone is also associated with a volcanic spatter cone at Craters of the Moon National Monument, Idaho. H. T. Stearns in his 1927 unpublished report talks of entering Snow Cone (then known as Ice Cave) by way of a wooden ladder. He described the cone and associated cave as follows (Stearns 1927):

> *"The first of the spatter cones is known as Ice Cave. It stands about five feet above the adjacent lava and is made up of clots of lava that adhered to each other when they fell. The throat of the cone, dark red in color, is descended by means of a wooden ladder. It is about 8 feet in diameter at the top but enlarges downward. The original depth of the pit was about 35 feet but it is now partly filled by a heap of ice and snow. With a light, one can enter a small cave about 20 feet long extending north from the bottom of the pit. On the roof and walls of this cave there are many long red stalactites and on the floor short red stalagmites."*

Peck visited this cave in 1962 and did a cursory inspection and report. He states the following (Peck 1962):

"It is the first of a series of 11 spatter cones and is the lowest in cone height. The depth is still the described 35 feet, but this is from cone rim to ultimate bottom. To the top of the talus pile which has undoubtedly resulted from heavy tourism, the depth is closer to 20 feet. The small cave extending to the north is not the 20 feet in length as Stearns says but only about 8 feet. His long red stalactites and short red stalagmites are no longer in existence. On June 10 the snow pile was about 10 feet deep. No snow was present this time last year. The accompanying section map shows this cone. Mirabilite is at the North heading of the cave."

Marshall Neeck, a staff ranger at the Monument, entered the spatter cone on August 8, 1994 on a cable ladder with rope belay to a depth of 7 m to retrieve dropped objects and rubbish from the newly exposed rock floor of the "snow cone." He saw a new opening on the north edge of the room at floor level and entered. He continued down the steep side of the snow cone to a rock landing some 7.6 m beyond. He then reported going deeper down an ice slide and seeing another drop in the distance, but was out of belay rope and returned to the surface. Based on this brief observation, he requested that Idaho Cave Survey make a more complete investigation.

Rediscovery of the Ladder Room in Snow Cone and subsequent initial discovery of the Balcony Room and the Magma Chamber Room occurred on September 13, 1994 by six members of Idaho Cave Survey: Jeff Baldwin, April Earl, Eirik Fowler, Dean Killian, Steve Peck, and Keith Pincock. The following description is based largely on their exploration, although the physical survey and photography were completed during the Foundation's mineral and biotic survey.

Snow Cone spatter cone is heavily visited and visitors are restrained from falling into the 7 m deep pit by a series of stone pillars connected with cables. The upper portion of the spatter cone is roughly hourglass-shaped so that the area of the rubble covered floor is about the same as the area contained within the stone pillars on the surface (about 46 m^2). At its narrowest, the throat is approximately 3 m across. This portion of the cave normally has a cone of snow on its floor and this is the reason for its current name. However, in the summer of 1994, all visible snow melted from this floor, revealing a rubble-covered ice plug. Combined with increased air flow and subsequent increased sublimation of the ice from below, this melting opened up a passage down the north side of the ice plug to two lower passages; the entrance to the Ladder Room, and a passage continuing counterclockwise down and around the lower base of the ice plug to the Balcony Room.

The Ladder Room - The entrance to the Ladder Room is on a rock floor 5.2 m below the current top of the ice plug. It is a low passage, 60 cm at its narrowest, which heads northwest from the base of the new passage. The entrance passage contains unique molten lava splash deposits, apparently placed after the previous lining had cooled, as well as the lava stalactites described by Stearns (1927). This passage contains several branching passages which are too small to enter.

The Ladder Room continues upward and to the north at a steep angle, coming within 3.7 m of the surface, and angles directly toward the smaller of the two spatter cones just north of Snow Cone.

Subsequent mapping showed the Ladder Room passage to be a possible lava source for this spatter cone.

In his descriptions, Stearns (1927) missed the true size of the Ladder Room. It is 8.8 m from the base of the ice plug to the base of the ladder and another 7.6 m from the base of the ladder to the ceiling of the upper alcove.

One of the most interesting features of the Ladder Room is the ladder itself. It is old and fragile as demonstrated by the poor judgement of one of the cavers who tested the bottom rung of the ladder and snapped it. However, on first inspection, the ladder appears sturdy and of recent fabrication. This illusion is enhanced by its excellent construction. It is about 2.1-m tall and constructed of debarked 7.6 cm diameter upright logs with 6.4 cm diameter rungs. The type of wood is currently undetermined. All pieces have been sawn to length. Each end of each rung has been shaped with an axe or similar tool to a flattened contour on both sides allowing for secure mounting against the uprights and for flat nailing surfaces. Four nails fasten each rung to the uprights. Surprisingly for the age of the ladder, the nail heads are round, not square. The surface of the wood is very dark, nearly black, with only the break in the bottom rung revealing bright, white, clean wood. The wood's surface is spongy soft, slippery, decayed, and moldy. The temperature and relative humidity in this room were recorded on 8 October 1994 as 1° C and 92%, respectively. The wood was covered with tiny droplets of moisture and is likely always wet. The damage to the ladder is regrettable and was especially disturbing to the cavers upon discovery that it is very old and has historic significance. Much more care was taken from this point on.

The Balcony Room - After exiting the Ladder Room the passage continues counterclockwise around the lower base of the ice plug down an ice slope to the Balcony Room. The floor of this room is ice-covered rock. It is perched above the lower Magma Chamber Room on the southwest side of its connection with that room. The ceiling of the Balcony Room is currently the bottom of the ice plug which is precariously poised about 4.9 m overhead. It is composed entirely of snow and ice except for a frozen cylinder of rocks and debris about 1.8 m in diameter on the southwest side of the ceiling. This cylinder may be the remnant of a spot which was previously open to the surface during a warm spell, similar to the current one, which later filled with rock and debris. As warming and sublimation continues, the exposed rocks and trash occasionally fall to the Balcony Room floor. In the two-week span between ICS's first and second survey trips, a large piece of paper and an old pencil fell down.

A 30-cm tall dike of ice forms the edge of the Balcony Room and keeps one from easily falling from the balcony to the Magma Chamber Room floor 19.8 m below. This dike is a continuation of the spectacular ice formations which start at the base of the ice plug and flow down to the dike and beyond. The columns and icicles which continue from the dike are fused together at the dike forming a curtain. This formation was named Surprise Ice Cascade by ICS.

The Magma Chamber Room - It is 19.8 m from the floor of the Balcony Room to the floor of the Magma Chamber Room. To traverse the distance, one must rappel alongside the Surprise Ice Cascade, a curtain of ice, ice columns, and icicles up to 12-m long, onto the side of the ice mound below and then down its slope to the ice covered floor. The Magma Chamber Room is kidney-shaped and is typically 9-m wide, 12-m high, and 52-m long. The highest point on the floor of this room is directly below the opening to the Balcony Room in the ceiling, as would be expected since anything coming down the shaft of the spatter cone would land here. Much of the floor is covered with breakdown boulders even though most of the ceiling of the room is in very good condition and is covered by its original lava lining. The southern end of the room contains many huge rocks, some of which came from the lower walls. Remnants of a thick shelf surround most of the rom, demonstrating ponding of the molten lava for a period of time before subsequent draining of the chamber. Many of the boulders on the floor appear to be pieces of this thick shelf which broke loose and fell upon cooling. Another interesting and uncommon feature in this room is the southwest wall, a huge section of which has peeled away from the rest of the wall and is leaning out into the room about 60 cm. This slab varies in height from 4.5 m to 7.5 m, is 16-m long, and typically is 30-cm thick at the top and 1.5 to 2.5-m thick at the base. At the lower end of this leaning wall, a large slab of rock leans against it as if holding it in place. We could not ascertain its origin. It exhibits unusual air pockets and inclusions of different colors and textures of lava.

Fine crystals cover most of the breakdown boulders in the room, and in the northern reaches of the room areas of mineral crust are abundant. At about the midpoint of the northern half of this room is an area with exceptional crystal growth containing several hexagonal to octagonal shaped, translucent crystals of gypsum, standing on end on a boulder. Most are very small, about 0.3 cm in height, but one is 2-cm tall and 1 cm in diameter. Under a large rock to the west of this spot are gypsum stalactites which are 7.5-cm long and 0.3 cm in diameter. In the lower end of the north extension are mineral secondary deposits so thick and widespread that we did not negotiate the area for fear of damaging them. As a result, a small alcove on the wall in that area was left unexplored.

A very high chimney is situated in the ceiling almost directly above the deepest spot in the cave. The height of the ceiling and this chimney were measured with an optical triangulating rangefinder and a powerful spot light. The ceiling is 15-m high in this spot and the chimney extends another 11 m straight up to a height of 27 m. Later examination of the three dimensional plot showed that this chimney may have been the magma source for the taller of the two spatter cones on the surface, just north of Snow Cone. This chimney appears to have an ice plug at its top, or perhaps a rock plug that is coated with ice crystals. The second highest spot in the ceiling, which is near the room entrance, is full of huge ice crystals.

Photographs of the interior of this cave are found in Figs. 30-46.

Mineral Survey

Descriptions of the samples collected in this survey and their mineral composition are given in Table 4. Visual examination of the samples and photographs indicates that the bulk substrate material from both caves consists of moderately vesicular to scoraceous aphyric basalt. Because of the fine grain size, a more detailed classification of the basalts would require geochemical and petrographic work beyond the scope of this study. However, it should be noted that basalts of the Craters of the Moon area are texturally and modally distinctive from typical Snake River Plain basalts (Kuntz et al., 1986). The dominant assemblage of minerals includes plagioclase, augite, olivine, Fe-Ti oxides, and apatite. Minor intersertal glass is also common; and xenocrysts of anorthoclase, sodic plagioclase, ferroaugite, fayalitic olivine and zircon occur in some rocks.

Basalts from both caves are partially coated or have patchy overgrowths of three types of minerals: gypsum, thenardite and natrojarosite. The minerals are easily distinguished by color and habit. Gypsum tends to be colorless, translucent, medium to coarse grained, and has a distinctive bladed habit where crystals are well formed. Thenardite is a powdery white material which occurs as tiny colloform clumps a few tenths of a millimeter across, or, where abundant, has produced snow-like rounded white mounds several millimeters to centimeters thick. Natrojarosite has a distinctive pale buff to medium yellow color. Where the minerals occur together, gypsum is typically the first to have formed, followed by thenardite and natrojarosite. All formed as efflorescences.

Faunal Survey

Crystal Pit

Several kinds of animals, living and dead, were discovered in Crystal Pit. A sample of moss collected at the mouth of the entry tube was checked for the presence of protists, nematodes, tardigrades and rotifers by adding a small amount of sterile water to the sample and examining wet mounts prepared from the sample on several occasions over two weeks. One large Ciliophora species was present in the sample within several days, as were two other smaller species of ciliates. One species of Monostyla (Phylum Rotifera) was also present in the sample, but nematodes and tardigrades were absent.

A geometrid moth (Lepidoptera: Geometridae) was observed on the wall of the entrance shaft, about 7 m from the surface during the ascent October 7.

Several animals were found on the floor of Crystal Pit at the base of the entrance shaft where light from the surface penetrates and contacts the floor. These animals included one dead and partially decayed stink bug (Hemiptera: Pentatomidae) which probably accidentally fell into or entered the cave, two living specimens of a very small (1.5 mm) dermestid beetle (Coleoptera: Dermestidae) trapped in the rim depression of the bait tray and discovered October 7, and one specimen of a small (3 mm), living, light colored and long legged cave spider (Araneida:

Leptonetidae) found September 30 beneath a basaltic rock (Fig. 47). A small vertebrate bone, rodent fecal pellet and the remains of an owl pellet were also collected from the "sunlit" area at the base of the entrance shaft of Crystal Pit.

A small fungus gnat (Order Diptera, family unknown) was observed flying near the bait tray at the north end of Crystal pit on October 7. This tray also contained a living, active specimen of a 6 mm eyeless beetle, *Glacicavicola bathyscoides* Wescott (Coleoptera: Leiodidae?) (Fig. 48). An S-VHS video recording of this rare and unusual insect was obtained, but within 10 min. the beetle had dispersed from the tray and could not be rediscovered for preservation. Prints were made (for the figures) from selected, digitized frames of the video recording. This specimen was the only one seen in both Crystal Pit and Snow Cone.

All bait on the trays in Crystal Pit was placed in alcohol and examined for microscopic arthropods in the laboratory, but no animals were found.

Snow Cone

Although the presence of the leiodid cave beetle, *G. bathyscoides*, in Crystal Pit cave was established, this insect was not found on any of the bait trays (or elsewhere by visual searching) in Snow Cone. All bait on the trays in Snow Cone was placed in alcohol and examined for microscopic arthropods in the laboratory, but no animals were found. Except for a variety of skeletons of small mammals in the lowermost portions, no evidence of animal life was seen in this region of Snow Cone. Unlike the bait in Crystal Pit, the bait on the six trays in the lowermost region of Snow Cone seemed dry and shrunken. Although ice and melted water were present in this region of the cave, the humidity must be very low to exhibit such a desiccating effect on the bait after one week.

The only living animals in Snow Cone were discovered in association with the bark and rotting wood of the ladder in the Ladder Room. A small (60 g) sample of bark and wood was removed and placed in a micro-Berlese apparatus (Fig. 4) in the laboratory to extract small arthropods. This procedure yielded one specimen of a small (1 mm), whitish springtail insect (Collembola: Entomobryidae) and four specimens of mites: two belbids (Acarina: Sarcoptiformes: Oribatei: Belbidae) and two rhagidiids (Acarina: Trombidformes: Rhagidiidae). Although the bait in the Ladder Room had not dried (as did the bait in the Magma Chamber Room), no animals were discovered on the bait or tray.

Several carcasses of small animals were found throughout the room and their locations are marked on the map. Our past experience in ice caves indicates that the carcasses which still have fur on them are fairly recent additions to this room. That the animals survived all three falls and then made their way to the far reaches of the cave is intriguing.

Floral Survey

A list of the species found during this survey is shown in Tables 5 and 6 and cover data are shown in Tables 7 and 8.

The iron bacterium is tentatively identified as *Leptothrix ochracea* Kützing in the family Chlamydobacteriaceae of the order Chlamydobacteriales. The thallus is slimy, like a slime bacterium (Myxobacteriales), but we found no evidence of sporangia.

Nine specimens of moss were collected, tentatively identified, and prepared for inclusion in the herbarium at Craters of the Moon; these represent seven species. Certain identification was impossible in some cases because only gametophytes were found and sure identification is usually dependent on the presence of sporophytes; nevertheless, we made tentative identifications based on leaf and stem characteristics.

We collected 27 specimens, representing 25 species of lichens, for inclusion in the Craters of the Moon Herbarium. The identification of most of these was confirmed by Dr. Larry St. Clair on October 2 and 3 immediately after our first descent into the caves; we also compared most of them with herbarium specimens in the BYU Herbarium or in the Ricks College Herbarium (including specimens in the Idaho National Engineering Laboratory Herbarium that had been confirmed by Dr. Roger Rosentreter).

Some lichens are impossible to identify with complete certainty unless a microscopic examination of the ascocarp is made; this, of course, was not practical in all cases, either because of the time and expense involved or because the fruiting bodies were immature. Nevertheless, by carefully observing the general morphological characters, correct identification was possible in most cases and tentative identification in all cases. We did not collect the easily identified species which we knew were already curated in the Craters herbarium.

DISCUSSION

Cave Features

Although it is a matter of some debate, we feel that the large chambers under the Crystal Pit and Snow Cone Spatter Cones are properly called magma chambers or magma reservoirs. The existence of multiple original linings indicate that these caves were filled with magma, which drained and refilled multiple times. The presence of lava benches and shelves further supports this interpretation and the fact that the benches and shelves are present on all sides of the rooms indicate that these were not lava tubes which collapsed at either end.

Chambers of this size beneath spatter cones are unusual. In most cases, passages beneath spatter cones are small tubes, much like the entrance shaft to Crystal Pit, which terminate abruptly. The large magma chambers under Crystal Pit and Snow Cone are two of three such formations known

to the authors world-wide. The third, Þríhnúkagígur (pronounced three-noo-ka-gee-gur) Pit in southwest Iceland (Stefánsson 1992), is much larger than either Crystal Pit or Snow Cone, reaching a maximum depth of 200 m. At 121-m deep, Þríhnúkagígur Pit measures 65-m long, 48-m wide, and 60-m high. Similar to Crystal Pit and Snow Cone, the original lava lining and a number of shelves are evident. The long axis of Þríhnúkagígur Pit is aligned with a string of spatter cones, also similar to the situation in both Crystal Pit and Snow Cone. It is possible that such chambers exist beneath other spatter cones in Craters of the Moon National Monument or elsewhere but that the entrances are plugged with lava or ice. Such chambers might be revealed with gravimeter or ground-penetrating radar surveys.

The historical significance of the ladder in the Ladder Room of Snow Cone is, to some extent, dependent on its age. It may be possible to estimate the age of the artifact from the records of earlier cavers. Stearns (1927) describes the Ladder Room but does not mention a ladder and, while it is possible that the ladder currently in the room was present, it seems unlikely given his detailed descriptions in this and other caves. However, note that Sterns says he entered Snow Cone on a wooden ladder. It is quite possible that the ladder he entered on was later shortened and placed in the Ladder Room, making the ladder older than 1927. Peck (1962) did not enter the Ladder Room, reporting only a 2.4-m side tube. Because we know of no other visitors to the cave, we believe the ladder was placed in the Ladder Room shortly after Stearns' visit in 1927 where it remained undisturbed until its rediscovery in 1994.

If the sublimation continues over the next several years, the ice cap which forms the ceiling of the Balcony Room and the floor of the entrance shaft in Snow Cone may become unstable and fall into the room below. This has been the case in several ice caves in the Kings Bowl area, a continuation of the Great Rift, 48-km south of Craters of the Moon. These caves include Crystal Ice Cave, Great Cavern, and King's Bowl South Cave. In all of these caves, ice floors from upper rooms are collapsing into rooms below. The loss of integrity of the floors is not due to melting, since the temperatures are below freezing, but due to sublimation. They exhibit very similar erosion from below as is currently seen in Snow Cone. We suggest that future trips to Snow Cone require attachment to a rope while on the ice plug in case it should give way.

Surprise Ice Cascade, the curtain of ice found in Snow Cone, appears to be of very recent origin. Past experience in the King's Bowl area leads us to believe most of it was formed in the spring and early summer of 1993 following heavy winter snows and a wet spring (34.2 cm, November 1992-May 1993[2]). In King's Bowl South Cave, this large volume of meltwater and spring precipitation carried external heat with it as it flowed into the normally 0° C cave and melted a perched ice floor, the residual flowing into a colder room below forming huge ice columns in the space of a few months. The ice dike at the edge of the Balcony Room, on the other hand, exhibits annual banding and is probably much older, perhaps a remnant of the original ice plug which must have formed after the last eruption at Craters of the Moon had cooled and snow began filling the Balcony Room, forming the now missing base for the current ice plug. It is

[2]Personal communication, Ms. Vickie Snitzler-Neeck, Craters of the Moon National Monument.

possible, but unlikely, that the base of the ice plug once reached all the way to the Magma Chamber Room floor. Looking up from the Magma Chamber Room it appears that snow entering the original shaft of Snow Cone would soon bridge over at the Balcony Room. It is possible that over the past 2000 years the ice plug formed, filled the entrance shaft of the spatter cone, and then eroded away from beneath until it collapsed. This may have occurred several times in the history of the cave.

Minerals

Peck (1974) identified gypsum, mirabilite and jarosite in Crystal Pit Cave. Our analyses differ in that they yielded no mirabilite, and we identified natrojarosite rather than jarosite. Absence of mirabilite in our samples may be accounted for by transformation of mirabilite to thenardite after sampling, as indicated by Peck (1974), because our samples were stored at room temperature. Peck does not describe his determinative methods so we are not sure how he identified jarosite. However our analysis of a clean separate by X-ray diffraction indicates a better match for natrojarosite than for jarosite (J. Stevens, personal communication, 1995) (Table 2).

The source of the Na, Ca and (SO_4) in the sulfate minerals is not clear. The young age (~2000 y) and paucity of alteration of the host rocks suggest it is unlikely they were derived from weathering of the young basalts. We speculate that they may have been derived by reaction between meteoric water and surficial eolian sediments at the surface and sediments which had infiltrated into fractures. However, Italian investigators (Paolo Forti, personal communication) entered a lava tube on Mt. Etna which was formed during the flows of 1991-93. The cave was still quite hot (over 80°C) when they entered the first time. They found stalactites, stalagmites and helictites of a variety of colors, all of which, upon analysis, proved to be composed almost entirely of thenardite. After a few months, when the temperature of the cave had dropped to about 25°C, the formations had changed in shape and mineral composition, probably due to drip erosion and mineral deposition. They also found evidence around several hot air vents that deposits of thenardite were formed by aerosols. These observations may imply that the mineral formations in Crystal Pit and Snow Cone were formed quite early in the history of the caves and have been slowly degrading since then.

Fauna

The faunal survey of Crystal Pit and Snow Cone caves on Craters-of-the-Moon National Monument provided some cursory information on the kinds of animals that occur or live in these cavernicolous habitats. The information that could be acquired and assessed was limited by several factors, including (1) time of year the study was undertaken, (2) the hours available for in-cave sampling and visual survey, and (3) opportunities for research to determine, experimentally, the best or potentially most productive of several sampling methods or strategies.

In spite of the shortcomings, however, information and specimens obtained during the animal survey reinforced several ideas, as Crystal Pit and Snow Cone are similar to many other

cavernicolous habitats. First, larger organisms may fall in or be trapped in the caves and dying there, may have nutrients of their bodies support other forms that may be attracted from the outside into the cave, or survive from one generation after another on the nutrient "windfall." Second, the animals present in the caves that have the largest individual biomass are not troglobitic species, but exotic in the sense they are temporary residents from the outside that lack appropriate traits to survive for very long in total darkness, constant near-freezing temperatures, and insufficient or unsuitable carbohydrate and protein. Third, the animals living in Crystal Pit and Snow Cone have a small individual biomass and are not common.

The "exotic" species (or intruder animals) evidenced in Crystal Pit and Snow Cone include--among the vertebrates--owls and a variety of small mammals, probably ground squirrels. Rodent pellets in the caves were probably associated with wood rats (*Neotoma* sp.) which have the ability to climb on the walls and ceilings, and enter or leave caves--including those existing as part of the Great Rift--without apparent difficulty. The geometrid moth and dead pentatomid bug associated with Crystal Pit were also exotic species, and are not adapted to a cavernicolous existence.

On the other hand, the few arthropods found alive in the caves represent types that could survive a somewhat "indefinite" cavernicolous existence provided suitable nutrients remain available. The leptonetid spider at the base of the entry tube in Crystal Pit would unlikely survive very far (elsewhere in the cave) from the microhabitat in which it was found, as all spiders are predaceous and the specimen collected was undoubtedly surviving on similarly small or smaller animals (intruders or others associated with the limited photosynthetic support system) present nearby. All known Leptonetidae are small (1-3 mm), long-legged, six-eyed spiders which live in caves under rocks or debris. They have been reported from regions of the Mediterranean, Japan, and rarely in North America.

The dermestid beetles collected in association with bait placed in the same microhabitat in Crystal Pit where the leptonetid was collected were undoubtedly attracted to the odors emanating from decaying meat. Although these beetles may have been attracted as "exotics" from outside the cave (the location at the base of the entry tube suggests this possibility), they are a small species and may have been offspring from others which had been surviving on other animals that had been trapped and died elsewhere within Crystal Pit. The species collected in the cave is unusually small for a dermestid beetle, which suggests it may be a cavernicolous or troglobitic species. Nearly 140 species of Dermestidae are known from North America, and most of these are 2.5 mm in length or larger.

The minute fly observed near an isolated bait trap in Crystal Pit exhibited flight behavior of a fungus gnat (family unknown), and was likely a cavernicolous fly species that developed from a maggot which fed on fungus or other organic material in the cave.

The only living animals found in Snow Cone were found in association with wood of the ladder in the Ladder Room. The largest of these was the single, 1-mm long springtail insect

(Collembola: Entomobryidae) found under a small piece of bark of the wood composing the ladder. Two species of mites representing different families were also collected from a small wood sample removed from the ladder.

The Entomobryidae constitutes one of seven families of springtail insects, which are common in soil and organic litter. Nearly 150 species of entomobryids are known from North America. Species in this family are typically nocturnal in habits, and are often associated with wood, bark, man-made structures and protected habitats.

Little is known about the habits or life histories of the four mites (Arachnida: Acarina) collected with the micro-Berlese apparatus from wood from the ladder in the Ladder Room in Snow Cone. The smallest are the two specimens of trombidiform Rhagidiidae. The long-legged quality of these mites suggest they are runners or fast movers, and that they may be predaceous. The larger species, represented by two specimens, are oribatid mites of the family Belbidae. Belbids have leg segments which are expanded into peculiar bulb-like shapes. Little is known of the life of belbid mites, but many mite species in the Supercohort Oribatei are associated with decaying wood and are known to feed on fungal spores.

The largest living animal found during the survey was the single, 6-mm specimen of leiodid cave beetle, *Glacicavicola bathyscoides* Wescott (Coleoptera: Leiodidae) found associated with a piece of decaying chicken on one of the bait trays in Crystal Pit. Much about this beetle is an enigma. First, its identity as a member of the family Leiodidae remains in question (Westcott, personal communication). *G. bathyscoides* is the only known species in the genus, and the entomologist who described it (R. Westcott) placed *G. bathyscoides* in a new subfamily (Glacicavicolinae) of the Leiodidae. However, he assigned the species to the family Leiodidae only on a tentative basis pending the acquisition of new and critical information relating to development and larval morphology. No larvae of this insect have ever been seen, and specialists only speculate on how the beetle lives. A variety of ideas, many contradictory, exist among cavers who have experienced seeing this beetle in its living state within volcanic caves. It is a long-legged beetle, and as can be demonstrated in video footage obtained October 7, it is a fast-moving insect and can apparently cover a wide area of territory within an hour's time. The species is known only from certain ice and volcanic caves in Idaho and Wyoming. New research is required to obtain basic and definitive taxonomic, biological, and ecological information on the life and habits of this unusual and rare animal.

Finally, it is important to note that the occurrence or survival of animals within Crystal Pit, Snow Cone and other caves may be influenced not only by temperature, light (or lack of it), area and volume of the cave habitat, and availability of nutrients, but also by relative humidity. The presence of water and ice cannot be used to assume that the humidity in a cave is high. The humidity in such caves or subregions within caves may be so low that the atmosphere can have a desiccating quality that may make life difficult. Such an atmosphere appeared to have been present the first week of October in the lowest portions of Snow Cone.

A variety of other cavernicolous animal species, including other arthropods as well as nematodes, will undoubtedly be found in both Crystal Pit and Snow Cone should they be examined in greater detail during Spring and Summer, and for longer examination periods, in the future.

Flora

The iron bacterium found in Crystal Pit was tentatively identified as *Leptothrix ochracea* Kützing in the family Chlamydobacteriaceae of the order Chlamydobacteriales. It is likely to be a source of food for the blind cave beetles (Naseath 1974) that were observed in Crystal Pit near where the bacterium was found. The iron fixing species of Chlamydobacteriales are reported to convert ferrous iron into ferric iron and use the energy released by this reaction to combine carbon dioxide and sulfides to form carbohydrates (Waksman 1952). Only swarm cells were observed in the sample collected; they were approximately 0.3 µm in diameter. Examination of fresh material should reveal the presence of long, slender filaments typical of this family. One specimen was collected for the herbarium; when collected it was "tacky," but it soon dried out and the dry specimen was prepared for curating.

Because the iron bacteria are chemoautotrophic, light is not necessary for their survival in the caves as long as a reduced form of iron is present. They can therefore live and grow in total darkness and the blind insects which feed on them can also live in total darkness. The mosses and the lichens, on the other hand, are photoautotrophic and require light. There are two ways in which light can reach the bottom of the cave where species of lichen and moss were found. (1) Light reflected from one mineral surface to another may eventually reach chlorophyll molecules in sufficient quantity to split water molecules in the first step of photosynthesis. This has been demonstrated in the so-called *Fensterflechten* or endolithic lichens (Vogel 1955). The human eye cannot detect individual photons of light energy, but each photon is capable of splitting one water molecule with the aid of chlorophyll. (2) Considerable light, much of it reflected from the sides of the vertical lava tube, reaches the bottom of Crystal Pit Cave. Once one's eyes have adjusted to the darkness, there is sufficient light to maneuver on the cave floor near the entrance. This may be the only source of light for the mosses at the bottom of the cave for there are no known reports of any mechanism in mosses comparable to that in the *Fensterflechten.*

Lichen cover decreased with increasing depth in both caves with the exception of a sudden increase in cover in Crystal Pit Cave at -24 m or cave bottom (Table 7). The number of species also decreased with increasing depth (Table 7). At the greatest depths at which lichens or mosses were found, 12-24 m in Crystal Pit and 4.9-7.3 m in Snow Cone, *Lepraria lesdainii* was generally the only species observed with the exception of the cave floor in Crystal Pit.

As expected, lichen cover was greatest on the south to southwest exposures (north to northeast walls) of the caves (Table 8). Lichens are reported to be the most drought tolerant of all plants as well as the most cold tolerant (Henssen and Jahns 1974, Pearson 1995) but generally favor high light conditions (Pearson 1969, Pearson and Benson 1977).

CONCLUSION and RECOMMENDATIONS

The caves examined in this survey are delicate environments, containing a number of fascinating, but little understood, geological, biological, and historical features. Because of their delicacy, the Foundation recommends that the National Park Service continue to restrict access to the caves. However, we further recommend that research into the cave features be continued. This survey raised questions about how the caves were formed, how the mineral features were formed, the life history and ecology of the plants and animals which inhabit the caves, and the history of human exploration of the caves. Developing answers to these questions would add significantly to fields of geology, biology, and history.

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Table 1. X-ray diffraction powder patterns for thenardite[1].

Thenardite Na_2SO_4 JCPDS 5-631			Sample CP-2			Sample SC-5			Match
d A	I/I_1	hkl	2θ	d A	I/I_1	2θ	d A	I/I_1	
						11.80	7.49	*	Gypsum
4.66	73	111	19.15	4.63	55	19.10	4.64	46	Thenardite
						20.80	4.27	*	Gypsum
3.84	18	22	23.2	3.83	15	23.30	3.81	11	Thenardite
						23.50	3.78	*	Gypsum
3.178	51	131	28.1	3.17	45	28.10	3.17	37	Thenardite
3.075	47	40	29.1	3.07	36	29.10	3.07	31	Thenardite
2.783	100	113	32	2.79	100	32.30	2.77	100	Thenardite
2.646	48	220	33.9	2.64	49	34.00	2.63	37	Thenardite
2.329	21	222	38.7	2.32	25	38.80	2.32	20	Thenardite
2.211	5	151	40.9	2.20	5	40.90	2.20	4	Thenardite
			45.6	1.99				*	?
1.919	4	O44	47.4	1.92	3	47.50	1.91	4	Thenardite
1.891	4	311,062	48.1	1.89	3	48.10	1.89	4	Thenardite
1.864	31	153	48.9	1.86	36	48.90	1.86	48	Thenardite
1.841	6	115	49.6	1.84	5	49.60	1.84	4	Thenardite
1.798	4	224	50.8	1.80	5	50.80	1.80	6	Thenardite
						54.70	1.68	13	Thenardite

[1]See Appendix I for reference to the original strip chart recordings; dA = d-spacing in angstroms; I/I_1 = intensity ratio; hkl = Miller Indices of diffracting lattice plane.
*Gypsum 100% peak is 14% the intensity of the thenardite 100% peak.

Table 2. X-ray powder diffraction pattern for a sample consisting of natrojarosite[1].

Natrojarosite $NaFe_3(SO_4)_2(OH)_6$ JCPDS 11-302			Sample SC-5			
d A	I/I_1	hkl	2θ	d A	I/I_1	Match
5.94	40	101	15.95	5.55	32	Natrojarosite
5.57	50	003	-			
5.06	100	012	17.55	5.05	100	Natrojarosite
3.67	20	110	23.35	3.81	50	Natrojarosite
3.49	20	104	26.50	3.36	24	Natrojarosite
3.12	70	021	28.60	3.12	82	Natrojarosite
3.06	80	113	29.20	3.06	91	Natrojarosite
2.96	20	202,015	-			
2.78	20	006	32.30	2.77	24	Natrojarosite
2.53	40	024	35.60	2.52	21	Natrojarosite
2.24	60	107,116	40.60	2.22	29	Natrojarosite
2.13	20	300	-			
1.98	60	O18,303	45.60	1.99	26	Natrojarosite
1.91	5	O27	-			
1.83	50	OO9,220	49.80	1.83	21	Natrojarosite

[1]See Appendix I for reference to the original strip chart recordings; dA = d-spacing in angstroms; I/I_1 = intensity ratio; hkl = Miller Indices of diffracting lattice plane.

*Gypsum 100% peak is 14% the intensity of the thenardite 100% peak.

Table 3. X-ray Powder diffraction pattern for a sample consisting mostly of gypsum[1].

Gypsum $Ca(SO_4)•2H_2O$ JCPDS 6-46			Sample SC-5			
d A	I/I_1	hkl[2]	2θ	d A	I/I_1	Match
7.56	100	O20	11.8	7.49	100	Gypsum
4.27	50	12$\underline{1}$	20.85	4.26	16	Gypsum
3.79	20	O31,O40	23.55	3.77	27	Gypsum
3.163	4	11$\underline{2}$	28.3	3.15	1	Gypsum
3.059	55	14$\underline{1}$	29.2	3.06	25	Gypsum
2.867	25	OO2	31.25	2.86	4	Gypsum
2.786	6	21$\underline{1}$	32.2	2.78	1	Gypsum
2.679	28	O22,051	33.5	2.67	4	Gypsum
2.591	4	150,20$\underline{2}$	34.7	2.58	1	Gypsum
2.53	<1	O60	35.55	2.52	1	Gypsum
2.495	6	200	36.1	2.49	1	Gypsum
2.45	4	22$\underline{2}$	36.8	2.44	1	Gypsum
2.4	4	141	37.5	2.40	1	Gypsum
			38.5	2.34	3	
2.216	6	15$\underline{2}$	40.8	2.21	3	Gypsum
2.139	2	24$\underline{2}$	-			Gypsum
2.08	10	12$\underline{3}$	43.4	2.08	2	Gypsum
2.073	8	112,25$\underline{1}$	43.6	2.07	2	Gypsum
			44.7	2.03	2	
1.99	4	170	45.7	1.98	1	Gypsum
1.953	2	211	-			Gypsum
1.898	16	O80,062	48	1.89	6	Gypsum

[1]See Appendix I for reference to the original strip chart recordings; dA = d-spacing in angstroms; I/I_1 = intensity ratio; hkl = Miller Indices of diffracting lattice plane.

[2]Underscore indicates negative Miller Index.

*Gypsum 100% peak is 14% the intensity of the thenardite 100% peak.

Table 4. Descriptions of mineral samples taken from Crystal Pit and The Snow Cone at Craters of the Moon National Monument.

Crystal Pit Cave Samples:

1. Prominent yellowish coating consisting of powdery natrojarosite* and minor, granular gypsum* on basalt.
2. White, slightly colloform, highly friable powder from floor of cave consisting of very pure thenardite (XrD*).
3. White, slightly colloform, highly friable powder from floor of cave consisting dominantly of thenardite (XrD*); sparse grey patches on bulk sample may include fine grained gypsum.
4. Granular aggregate of bladed white to clear translucent gypsum crystals ~0.5 to 4 mm long (confirmed by XrD*).
5. Red scoraceous aphyric, aphanitic basalt with a spotty encrustation of clear gypsum crystals 0.1 to 0.5 mm across.
6. Coarse bladed white translucent crystals of gypsum form a discontinuous encrustation along parts of the cave floor. Identification confirmed by XrD*.
7. Dull, chalk-white, highly porous powdery material. XrD* analysis indicates the material consists mostly of thenardite with minor amounts of gypsum.
8. Angular block of aphyric, aphanitic vesicular basalt; note a thin (~0.1 mm) discontinuous coating of dull, light to medium yellow, very fine grained natrojarosite along surfaces and within many vesicles (nonreactive with HCl)
9. Angular block of aphyric, aphanitic vesicular basalt; note a thin (~0.1 mm) discontinuous coating of dull, light to medium yellow, very fine grained material along surfaces and within many vesicles; Identified with XrD* as a mixture of natrojarosite (an alunite group mineral with the composition NaFe3(3+)(SO4)2(OH)6) and gypsum.
10. Angular block of aphyric, aphanitic vesicular basalt; note a thin (~0.1 mm) discontinuous coating of dull, light to medium yellow, very fine grained natrojarosite along surfaces and within many vesicles. On three sides of the sample, there is also a thin encrustation of fine grained, clear, translucent material (probably fine grained gypsum) which appears to have formed over the natrojarosite. In some places it is colloform; some large bladed crystals of gypsum also occur in vesicle cavities. Yellowish material separated and identified as an aggregate consisting of gypsum>natrojarosite by XrD*.
11. An angular block of highly vesicular, black aphyric, aphanitic basalt; very sparse granules of thenardite (?) on surface.
12. An angular dark reddish grey, nonvesicular to highly vesicular aphyric, aphanitic basalt which has been partially encrusted by fine to medium grained, light grey gypsum.

Snow Cone Cave Samples:

1. (Ladder Room) Angular block of aphyric, aphanitic, very dark reddish grey, vesicular basalt; note a thin (~0.1 mm) discontinuous, smooth patch ~7mm across of clear translucent gypsum and small (few tenths mm) colloform patches of white fine grained thenardite.
2. Angular block of aphyric, brownish scoria block with sparse patches of white and translucent materials similar to sample #1
3. Two angular blocks of dark reddish grey, aphanitic, aphyric, scoraceous basalt. Parts of the scoria blocks are partially coated with numerous subidiomorphic crystal of clear to light grey gypsum from ~0.1 to 1 mm across. The bag also contained several large idomorphic, bladed gypsum crystals which may have broken off from the scoria fragments.
4. An aggregate of subidiomorphic, intergrown coarse, clear gypsum crystals from 1 to 10 mm across. Identification confirmed by XrD* analysis.
5. Dull, chalk-white, highly porous powdery thenardite. Thenardite ID confirmed by XrD* analysis (contains a trace of gypsum).
6. An irregular block of dark reddish grey, aphyric, aphanitic, very dark reddish grey scoria, partially coated by a clear, translucent material, which is turn partially covered by colloform clumps of chalk white material a few tenths of a millimeter across. Translucent material separated and identified as gypsum by XrD*. Insufficient white material for XrD* analysis; it is probably thenardite.
7. A whitish grey fine grained granular material. XrD* analysis indicates the material consists mostly of thenardite with minor gypsum.
8. An irregular block of dark reddish grey, aphyric, aphanitic, very dark reddish grey scoria, partially covered by colloform clumps of chalk white thenardite a few tenths of a millimeter across.
9. Buff colored granular aggregates of fine to medium grained gypsum. Gypsum was identified by XrD* analysis, which also indicated the sample contains a minor amount of thenardite.
10. An irregular block of dark reddish grey, aphyric, aphanitic, very dark reddish grey scoria, sparsely covered by colloform clumps of chalk white thenardite a few tenths of a millimeter across.

* XrD = Indicates that the mineral identity was confirmed by an X-ray powder diffraction analysis using methods described by Zussman (1977) and Hutchinson (1974), and reference to a determinative manual by Walker and Renault (1972) and JCPDS data sets.

Table 5. List of lichens, mosses, and chemoautotrophic bacteria found in Crystal Pit and Snow Cone caves at Craters of the Moon National Monument, September 30 and October 7, 1995. (Under Status, * = collected for herbarium, identification certain; + = identification certain, herbarium specimens not collected; o = identification somewhat tentative)

Species	Status (*, +, o)
Lichens	
Acarospora americana Magn.	+
Acarospora chlorophana (Wahlenb. ex Ach.) Mass	*
Acarospora fuscata (Schrad.) Arn.	*
Acarospora smaragdula (Wahlenb. *in* Ach.) Mass.	o
Acarospora schleicheri (Ach.) Mass.	+
Acarospora strigata (Nyl.) Jatta	*
Aspicilia calcarea (L.) Mudd	+
Aspicilia cinerea (L.) Körber	*
Aspicilia desertorum (Krempelh.) Mereschk.	*
Aspicilia quartzitica W. Weber	*
Caloplaca arenaria (Pers.) Müll. Arg.	+
Caloplaca epithalina Lynge	+
Caloplaca fraudans (Th. Fr.) H. Olivier	o
Caloplaca saxicola (Hoffm.) Nordin	+
Caloplaca tominii Savicz	+
Caloplaca trachyphylla (Tuck.) Zahlbr.	+
Candelariella aurella (Hoffm.) Zahlbr.	*
Candelariella rosulans (Müll. Arg.) Zahlbr.	+
Candelariella vitelina (Hoffm.) Müll. Arg.	+
Catapyrenium lachneum (Ach.) R. Santeson	+
Cladonia chlorophaea (Flörke ex Sommerf.) Sprengel	*
Collema polycarpon Hoffm.	*

Species	Status (*, +, o)
Diploschistes scruposus (Schreber) Norman	o
Imshaugia aleurites (Ach.) S. F. Meyer	*
Lecanora badia (Hoffm.) Ach.	+
Lecanora christoi W. Weber	+
Lecanora chrysoleuca (Sm.) Ach.	*
Lecanora garovaglii (Körber) Zahlbr.	*
Lecanora melanophthalma (DC in Lam. & DC) Ramond	+
Lecanora muralis (Schreber) Rabenh.	+
Lecanora novomexicana (B. de Lesd.) Zahlbr.	+
Lecanora peltata (Ramond) Steudel	+
Lecanora rupicola (L.) Zahlbr.	*
Lecanora varia (Hoffm.) Ach.	+
Lecidea aglaea Sommerf.	+
Lecidea atrobrunnea (Ramond *in* Lam. & DC) Schaerer	o
Lecidea lithophilla (Ach.) Ach.	+
Lecidea lyngei Degel.	o
Lecidea macrocarpa (DC. *in* Lam. & DC.) Steudel	+
Lecidea stigmatea Ach.	o
Lecidea tesselata Flörke	*
Lepraria lesdainii (Hue) R. C. Harris	*
Microthelia aterrima (Krempelh. ex Anzi) Zahlbr.	o
Neofuscelia subhosseana (Essl.) Essl.	*
Physcia adscendens (Fr.) H. Olivier	o
Physcia biziana (Massal.) Zahlbr.	*
Physcia caesia (Hoffm.) Fürnr.	*

Species	Status (*, +, o)
Physcia dubia (Hoffm.) Lettau	*
Physcia millegrana Degel.	o
Physcia phaea (Tuck.) Thomson	*
Physcia subtilis Degel.	*
Rhizocarpon disporum (Naeg. ex Hepp) Müll. Arg.	*
Staurothele clopima (Wahlenb. ex Ach.) Th. Fr.	+
Umbilicaria krascheninnikovii(Savicz) Zahlbr.	*
Verrucaria glaucovirens Grumm.	+
Xanthoria elegans (Link) Th. Fr.	*
Mosses	
Aulacomnium androgynum (Hedw.) Schwaegr.	*
Bryoerythrophyllum recurvirostre (Hedw.) Chen	*
Dicranoweisia crispula (Hedw.) Mild.	*
Dicranum tauricum Saphin	*
Grimmia apocarpa Hedw.	*
Phascum cuspidatum L. ex Hedw.	*
Tortula mucronifolia Schwagr.	*
Bacteria	
Leptothrix ochracea Kützing	*

Table 6. Alternate names for lichen species.

Name in Table 1	Alternate Name
Aspicilia calcarea	*Lecanora calcarea*
Aspicilia cinerea	*Lecanora cinerea*
Aspicilia desertorum	*Lecanora desertorum*
Aspicilia quartzitica	*Lecanora morioides*
Caloplaca arenaria	*Caloplaca lamprocheila*
Caloplaca tominii	*Fulgensia desertorum*
Caloplaca trachyphylla	*Xanthoria elegans var. trachyphylla*
Imshaugia aleurites	*Parmeliopsis aleurites* or *Parmelia aleurites*
Lecanora badia	*Protoparmelia badia*
Lecanora chrysoleuca	*Rhizoplaca chrysoleuca*
Lecanora melanophthalma	*Rhizoplaca melanophthalma*
Lecanora peltata	*Rhizoplaca peltata*
Lecidea aglaea	*Tephromela aglaea*
Lecidea macrocarpa	*Porpidia macrocarpa*
Lecidea stigmatea	*Lecidella stigmatea*
Microthelia aterrima	*Lichenothelia scopularia*
Neofuscelia subhosseana	*Parmelia subhosseana*
Xanthoria elegans	*Caloplaca elegans*

Table 7. Percent cover of lichens and mosses in Crystal Pit and Snow Cone caves at Craters of the Moon National Monument. Species names are abbreviated by the first three letters of the generic name and the first three letters of specific name. Ab = abundant, P = present, Tr = trace.

	Crystal Pit					Snow Cone						
	Depth (m.)					Depth (m.)						
Species	Above Entry	0-0.6	0.6-3	40	80	Above Entry	0-0.3	0.6-1.2	1.5-2.1	12	15	24
LEPLES	0	Tr	10	30	65	0	Tr	Tr	20	35	65	25
ACAAMR	P					P						
ACACHL	1					Ab					Ab	
ACASCH	20					P	P					
ACAFUS	1					Ab	P				P	
ACASTR	1						P			Ab		
ASPCAL	10					Ab	Ab	Ab	Ab			
ASPCIN											P	
ASPDES										Ab		
ASPQUA	2					Ab	Ab					
CALARE	1	P										
CALSAX	5	2				15	Ab	Ab				
CALTRA	2	1				5	Ab	P				
XANELE	2	2				2	P					
CANAUR	2					Ab					Ab	
CANROS	5					5	P	Ab				
CANVIT	2					1	P	P				
CATLAC	Tr					Ab				Ab		
CLACHL		2		5								
COLPOL	Tr	P										
DIPSCR	Tr	P						P				
IMSALU									5			
LECBAD	P	P	P				P					
LECCHI	20	P					P					
LECCHY	1											
LECGAR	5	P	P				P	P				

	Crystal Pit					Snow Cone						
	Depth (m.)					Depth (m.)						
Species	Above Entry	0-0.6	0.6-3	40	80	Above Entry	0-0.3	0.6-1.2	1.5-2.1	12	15	24
LECMEL	Tr											
LECMUR	25					Ab	P					
LECNOV	10						P					
LECPEL	P											
LECRUP	Ab	Ab				Ab	Ab					
LCDLIT	P						Ab					
LCDLYN	P											
LCDMAC	P											
LCDSTG	P											
LCDTES	2					Ab	Ab					
MICATR	P											
NEOFUS	Ab											
PHYBIZ	P					Ab	P					
PHYCAE	P											
PHYDUB	Ab	P										
PHYPHA	P					Ab						
PHYSUB	Ab	P				Ab						
RHZDIS	Ab					Ab	P					
STACLO	Ab	P										
UMBKRA	Ab											
VERGLA	Ab											

Table 8. Relation of cover of lichens and mosses relative to exposure and depth in Snow Cone cave at Craters of the Moon National Monument; the depth values indicated in the table heading are for October 7 and their exact locations were different from those of September 30. Species names are abbreviated by the first three letters of the generic name and the first three letters of the specific name. Ab = abundant, P = known to be present at that location, may or may not be abundant, Tr = present in trace amount, - = no record for that species at that location, may or may not be present.

Aspect:	SOUTH					EAST							WEST				NORTH			
	Depth (m)					Depth (m)							Depth (m)				Depth (m)			
Species	0.6	1.5	3	3.7	4.6	+0.6	0.3	1.8	3	4	4.9	7.3	0	0.6	2.1	3	0	1.5	3	4.9
LEPLES	0	Tr	P	P	P	0	0	5	Tr	P	15	25	0	P	P	P	20	Ab	Ab	Ab
ACAAMR	-	-	-	-	-	Ab	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ACACHL	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	25	-	-	-
ACASCH	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-
ACAFUS	-	-	-	-	-	5	5	-	-	-	-	-	5	-	-	-	-	-	-	-
ACASTR	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total ACA	Ab	-	Ab	P	Ab	5	20	-	P	P	-	-	Ab	-	Ab	-	Ab	-	Ab	Ab
ASPCAL	P	-	Ab	Ab	P	Ab	-	-	-	Ab	-	-	-	-	Ab	-	P	-	-	P
ASPCIN	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ASPDES	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ASPQUA	P	-	Ab	Ab	-	-	-	-	-	Ab	-	-	-	-	Ab	-	P	Ab	P	P
Total ASP	Ab	P	35	20	10	85	60	20	10	25	Ab	0	P	40	45	35	Ab	15	15	P
CALSAX	-	P	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Tr	-
CALTOM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	-	-	30	-
CALTRA	-	25	-	P	-	-	-	-	-	-	-	-	-	-	-	Ab	-	-	-	-
XANELE	-	P	5	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-
Total CAL+XAN	-	35	Ab	30	-	-	Tr	5	5	5	-	-	-	5	-	20	3	-	-	-

Aspect:	SOUTH					EAST							WEST				NORTH			
	Depth (m)					Depth (m)							Depth (m)				Depth (m)			
Species	0.6	1.5	3	3.7	4.6	+0.6	0.3	1.8	3	4	4.9	7.3	0	0.6	2.1	3	0	1.5	3	4.9
CANROS	Ab	Ab	Ab	-	0	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-
CANVIT	P	P	P	1	0	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-
Total CAN	P	P	Ab	P	0	-	-	Ab	-	-	-	-	10	-	-	-	-	-	-	-
COLPOL	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LECBAD	P	-	-	-	-	-	-	-	-	-	-	-	-	-	Ab	-	-	-	-	-
LECCHI	-	-	-	-	Ab	-	-	-	-	-	-	-	-	-	10	-	30	-	-	-
LECGAR	-	-	1	-	2	-	15	5	-	10	-	-	5	-	-	2	-	30	-	5
LECMEL	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LECMUR	-	-	-	Ab	-	-	-	Ab	-	-	-	-	Ab	-	P	-	-	-	-	-
LECRUP	Ab	-	-	Ab	-	-	-	Ab	P	Ab	-	-	-	-	Ab	-	-	-	-	-
Total LEC	Ab	-	-	20	-	-	15	15	-	15	Ab	-	-	-	Ab	-	Ab	-	-	-
LCDLIT	P	-	-	-	-	-	-	-	-	-	-	-	-	Ab	-	-	-	-	-	-
LCDTES	-	-	-	P	-	-	-	-	-	15	-	-	40	-	-	-	-	-	-	-
Total LCD	Ab	-	-	20	-	-	10	-	-	20	Ab	-	45	-	-	-	-	-	-	-
PHYBIZ	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PHYPHA	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PHYSUB	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total PHY	Tr	60	20	-	70	-	-	-	Tr	-	10	-	-	-	-	20	-	-	5	45
RHZDIS	P	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UMBKRA	-	-	-	-	-	2	-	-	Tr	-	-	-	-	-	-	-	-	-	-	-

Aspect:	SOUTH					EAST							WEST				NORTH			
	Depth (m)					Depth (m)							Depth (m)				Depth (m)			
Species	0.6	1.5	3	3.7	4.6	+0.6	0.3	1.8	3	4	4.9	7.3	0	0.6	2.1	3	0	1.5	3	4.9
Total Lichen																				
Oct. 7	75	98	98	98	95	99	99	45	35	70	65	25	65	30	85	80	80	60	70	70
Sept. 30	70	35			30	10	80	15		35			40	70	70	35	15	20	30	0

Fig. 1 (Overleaf). A map of Crystal Pit at Craters of the Moon National Monument.

Crystal Pit Spatter Cone

Craters of the Moon National Monument

Surveyed 9/9/95 through 10/7/95
Total Length 75.93m Total Depth 29.75m

Surveyed by:

Jeff Baldwin
April Earl
Scott Earl
Dean Killian
Marshall Neeck
Vicki Snitzler-Neeck

Copyright 1995 Idaho Cave Survey

0 5 10 15 20
Scale: meters

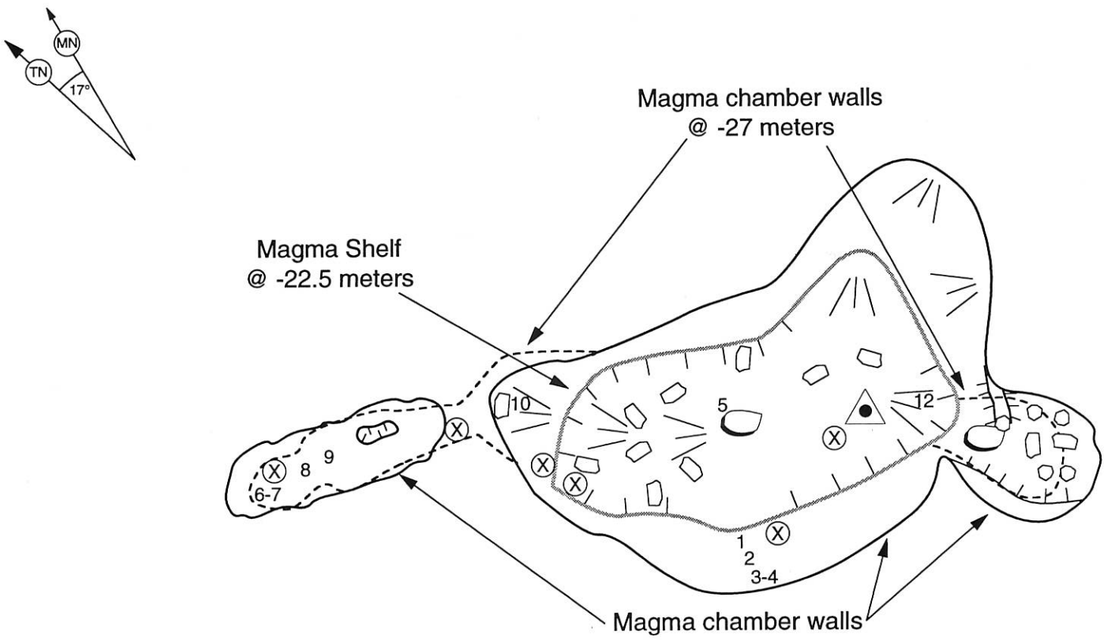
Legend

- Center of the Drop
- Cave Walls
- Breakdown Rocks
- Floor Slope
- Vertical Drop
- Faunal trap locations

1995 Mineral Samples

1 = natrojarosite/gypsum
2 = thenardite
3 = thenardite
4 = gypsum
5 = gypsum
6 = gypsum
7 = thenardite/gypsum
8 = natrojarosite
9 = natrojarosite/gypsum
10 = natrojarosite/gypsum
12 = gypsum

Note that the thenardite samples may have actually been mirabilite before removal from the cave.



PLAN VIEW

PROFILE VIEW
(FACING SOUTHWEST)

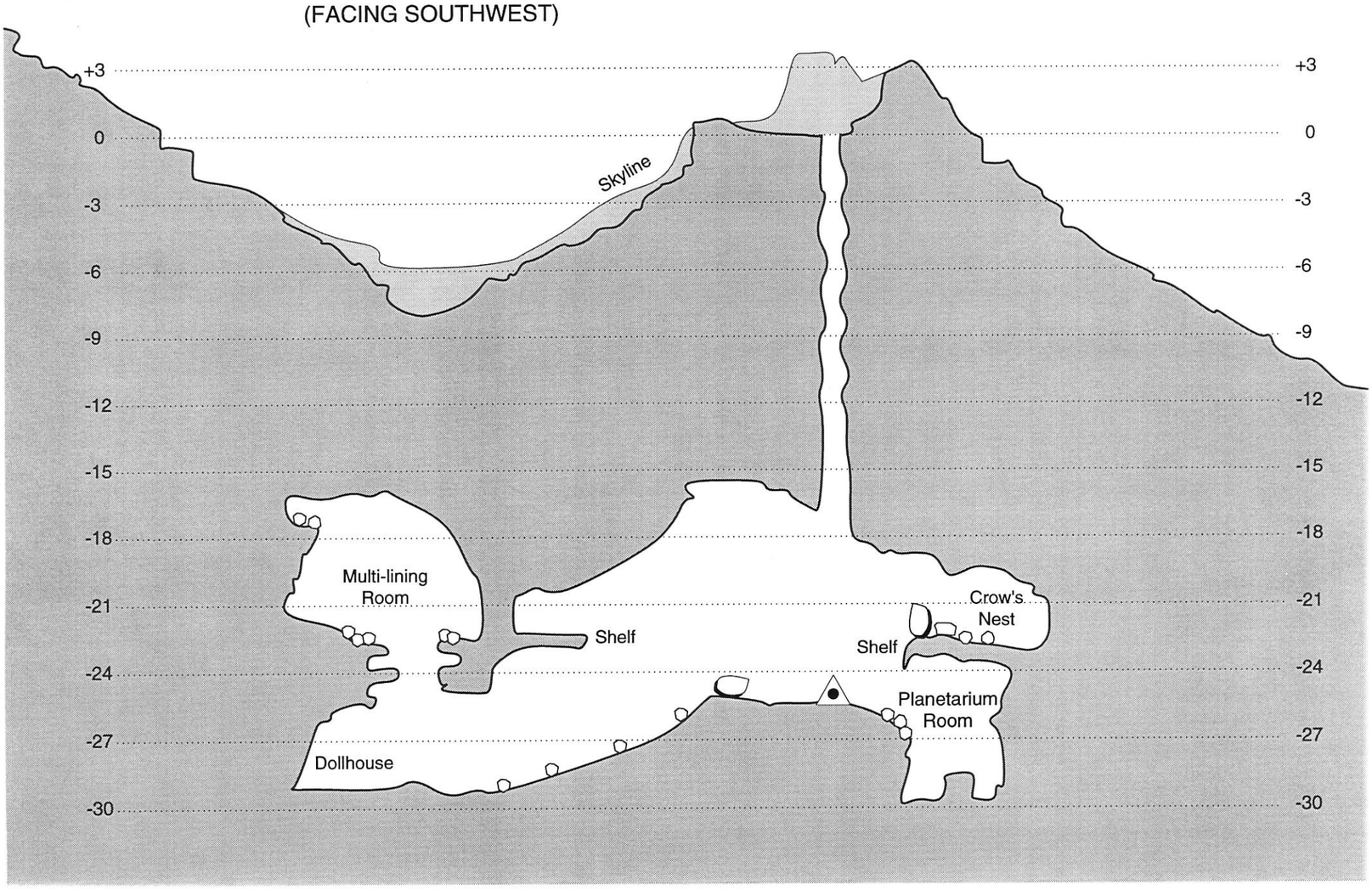


Fig. 2 (Overleaf). Map of Snow Cone in Craters of the Moon National Monument.

Snow Cone Spatter Cone

Craters of the Moon National Monument

Surveyed 9/24/94 through 11/20/94
Total Length 121.58m Total Depth 36.39m

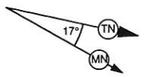
Surveyed by:

Jeff Baldwin	Eirik Fowler	Scott Nelson
April Earl	Chris Jensen	Scott Ryan
Scott Earl	Dean Killian	

Copyright 1994 Idaho Cave Survey

0 5 10 15 20 25

Scale: meters



Mineral Samples

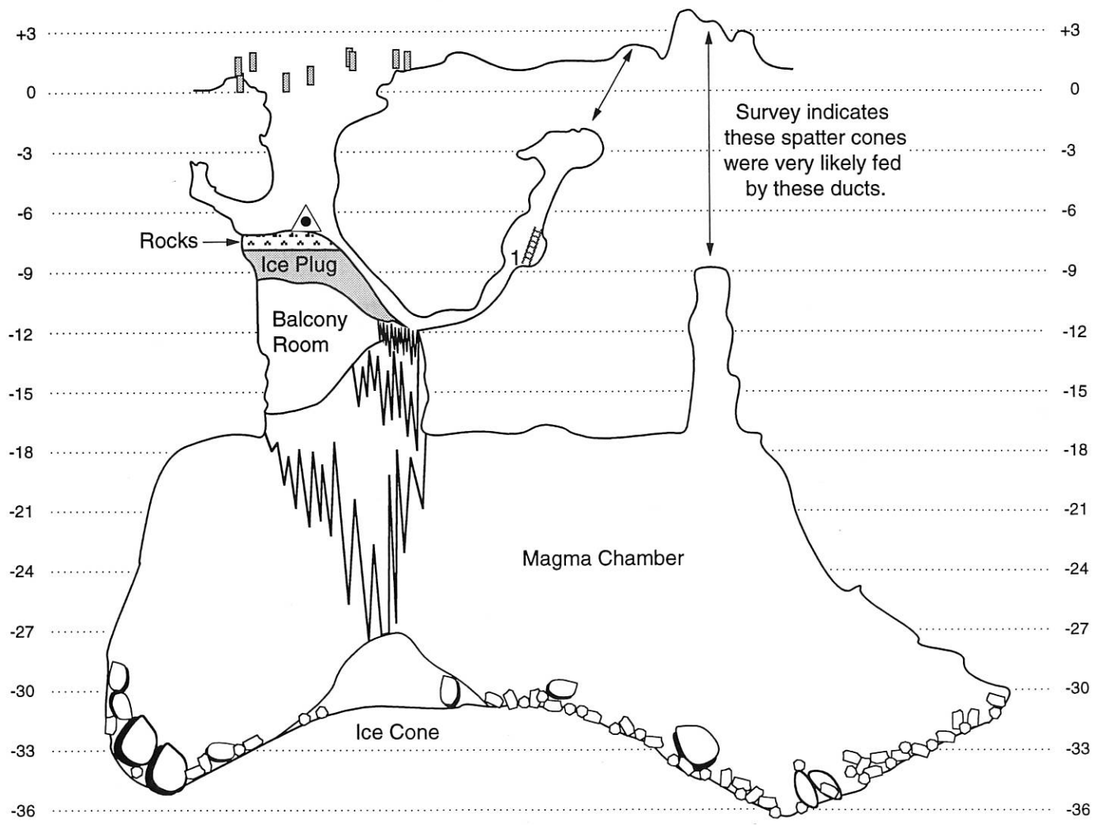
1 = Gypsum/Thenardite
2 = Gypsum/Thenardite
3 = Gypsum
4 = Gypsum
5 = Thenardite
6 = Gypsum/Thenardite
7 = Thenardite/Gypsum
8 = Thenardite
9 = Gypsum/Thenardite
10 = Thenardite

Legends

- Fence Pillars
- Alignment references for Center of Snow Cone
- Cave Walls
- Breakdown Rocks
- Icicles and Ice Columns
- Ⓒ Major Mineral areas
- Floor Slope
- Ⓧ Bait Tray locations

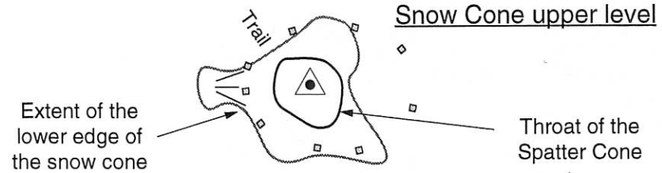
PROFILE VIEW

(LOOKING WEST)

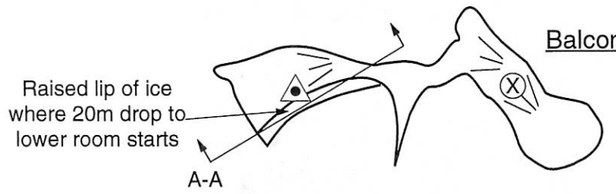


PLAN VIEWS

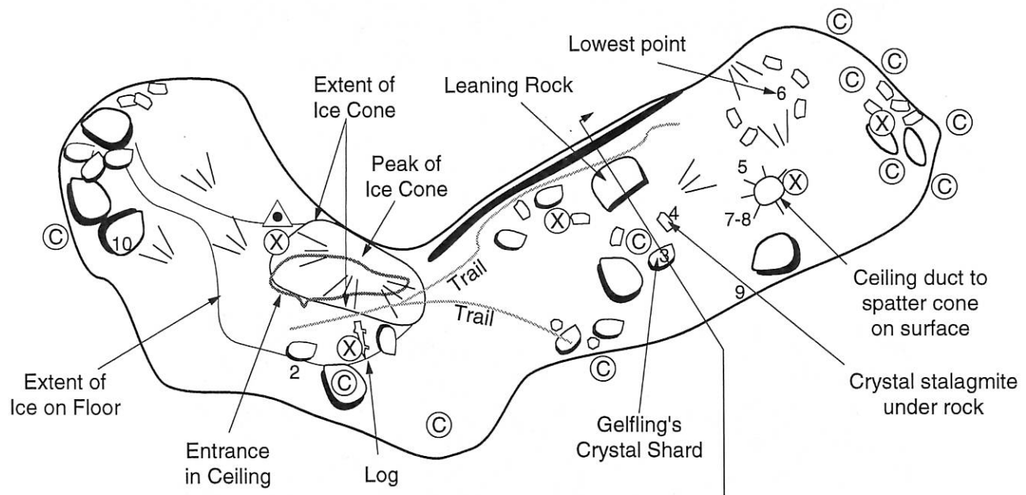
Snow Cone upper level



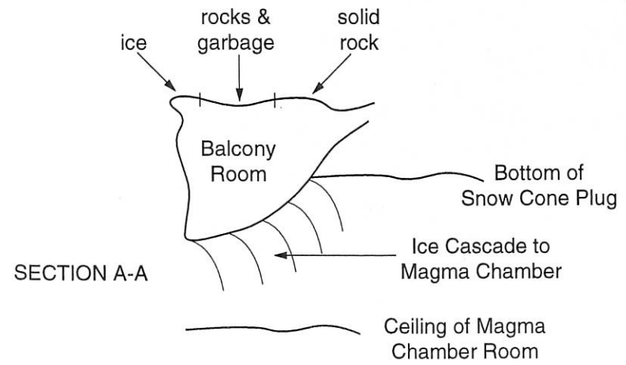
Balcony Room & Ladder Room



Magma Chamber Room



SECTION VIEWS



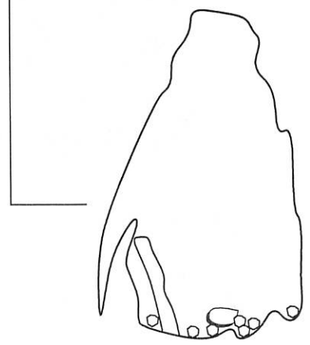




Fig. 3. An 11-cm bait tray used in sampling fauna in Crystal Pit and Snow Cone. Each such plate was "baited" with a 8 - 16 cm^3 piece of (a) honey-soaked dry dog pellets, (b) ripe pear, (c) decaying pork liver, (d) decaying beef, and (e) decaying chicken.



Fig. 4. The micro-Berlese apparatus used to extract micro-arthropods from a small sample of wood from the Ladder Room in Snow Cone. The wood sample (in the funnel) was gradually dried with a 25-W incandescent bulb, and mites in the sample dropped into a container of 70% alcohol as the wood sample dried.



Fig. 5. A profile of Crystal Pit and adjacent spatter cones. The view is facing southwest.



Fig. 6. Crystal Pit spatter cone taken from the adjacent spatter cone. Note the collapse depression in the bottom center of the photograph.



Fig. 7. The tripod and gate at the entrance to Crystal Pit.



Fig. 8. Looking into the Crystal Pit entrance.

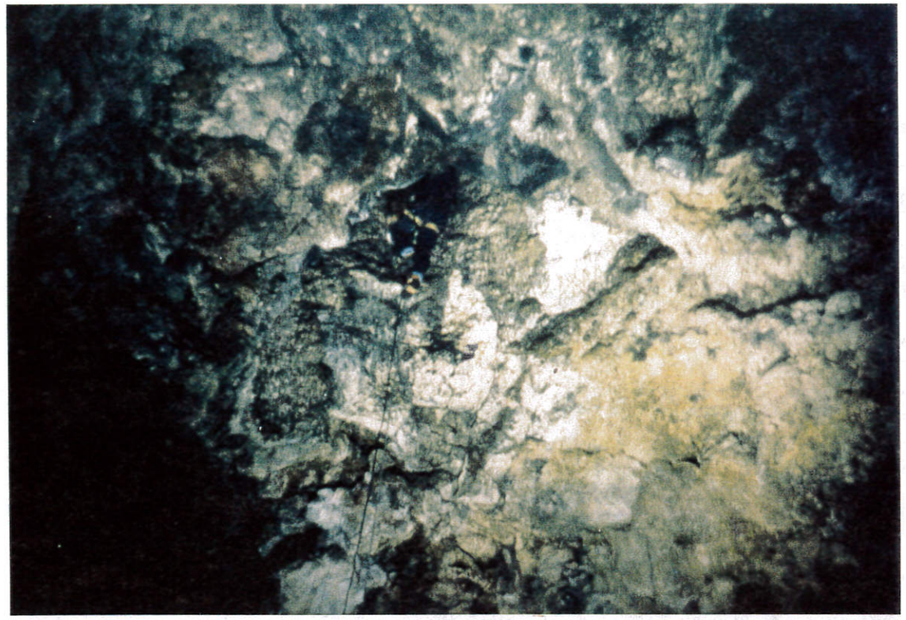


Fig. 9. Ceiling of the Crystal Pit magma chamber. Note the caver ascending therope into the throat of the cave.



Fig. 10. The main magma chamber of Crystal Pit facing southeast. A second flash lights the Planetarium Room.

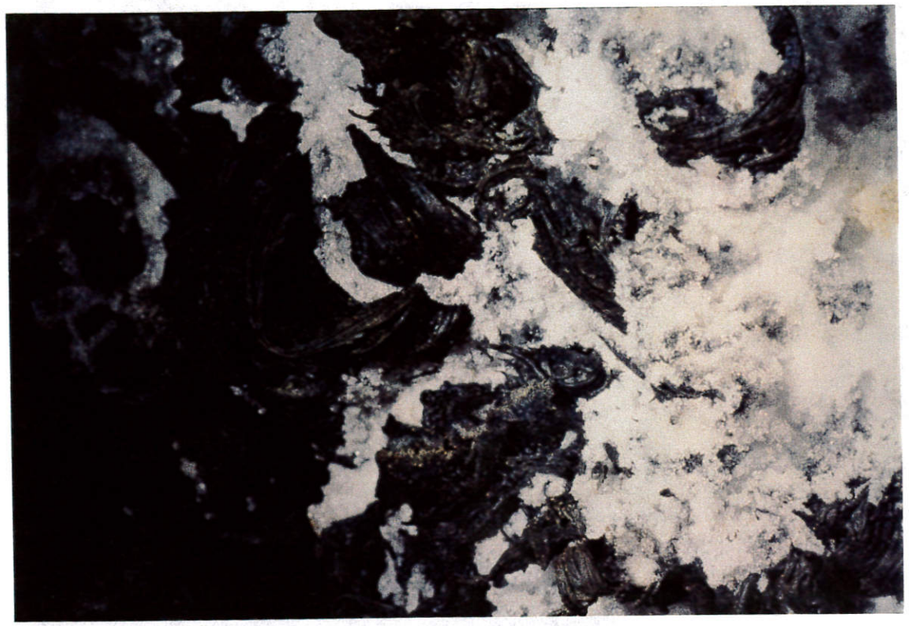


Fig. 11. Lava taffy coated with gypsum crystals. This feature is on the right (west) wall of the Planetarium Room.



Fig. 12. An apparent drip erosion hole in a thick thenardite crust at the upper left entrance to the Planetarium Room. The hole is 10 cm in diameter.



Fig. 13. Gypsum crystals underlying a broken away crust of thenardite on the upper right entrance to the Planetarium Room.

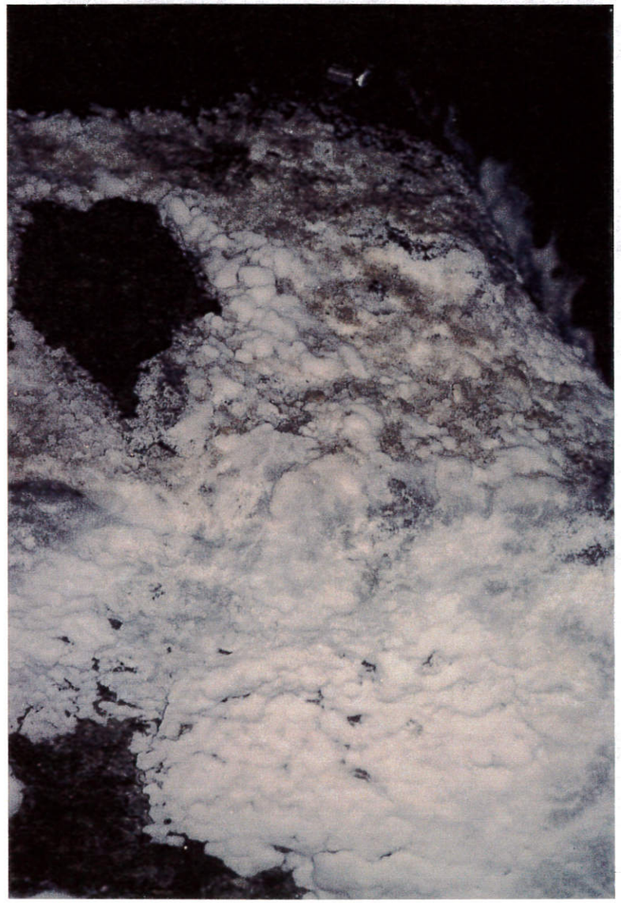


Fig. 14. A thick coating of thenardite on a large rock at the entrance to the Crow's Nest Room. A nine volt battery and LED survery station light are included (top center) for scale.



Fig. 15. Apparent drip erosion holes in the thenardite crust on the floor of the Crow's Nest Room.



Fig. 16. The main magma chamber of Crystal Pit facing northwest. A second flash lights the Dollhouse Room.

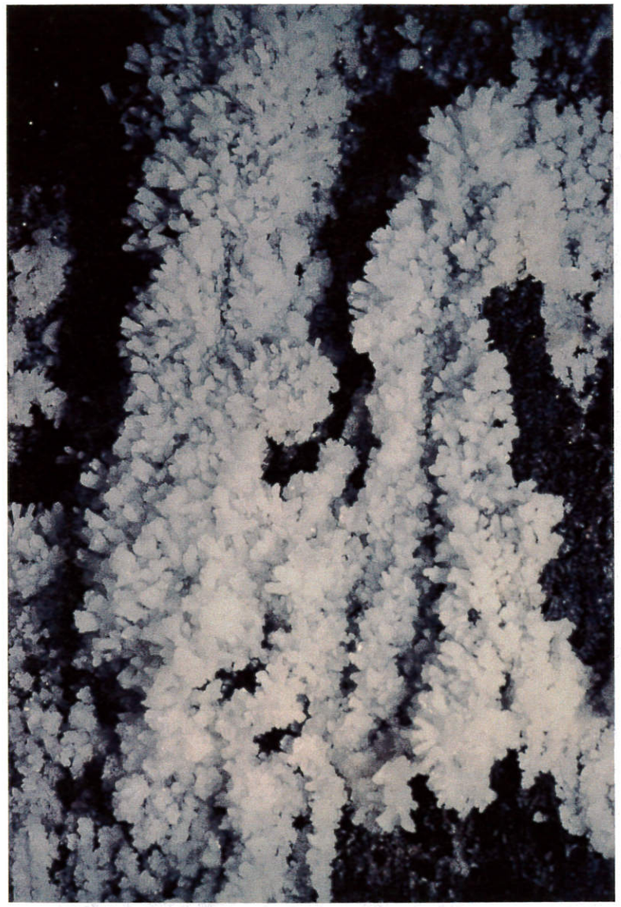


Fig. 17. Mineral coating on the lower right (northeast) wall of Crystal Pit's Dollhouse Room near the entrance.

Fig. 18. Mineral coating on the lower left (southwest) wall of Crystal Pit's Dollhouse Room near the entrance.

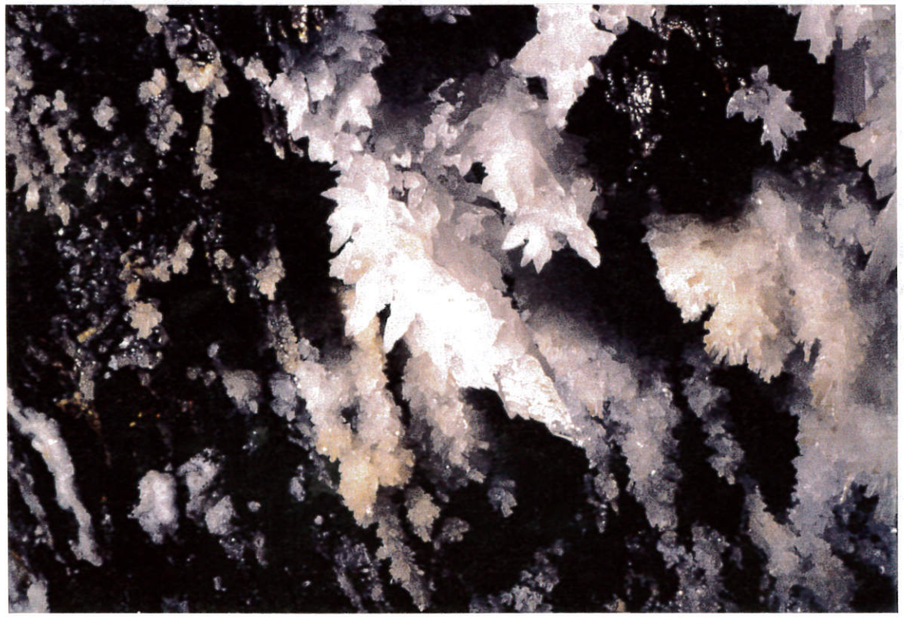




Fig. 19. Mineral coating on the floor of the Dollhouse Room of Crystal Pit.

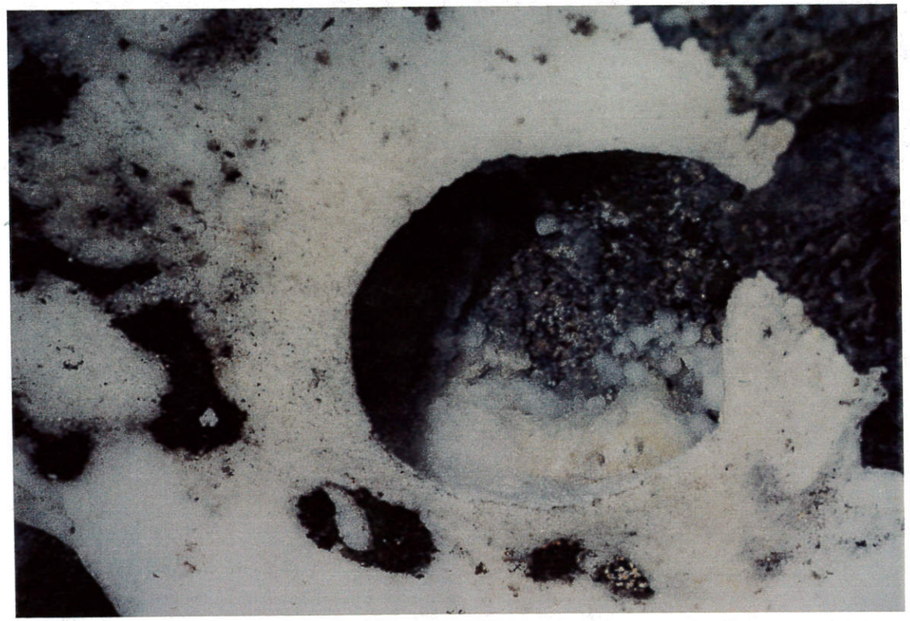


Fig. 20. An apparent drip erosion hole on the floor of the Dollhouse Room in Crystal Pit.

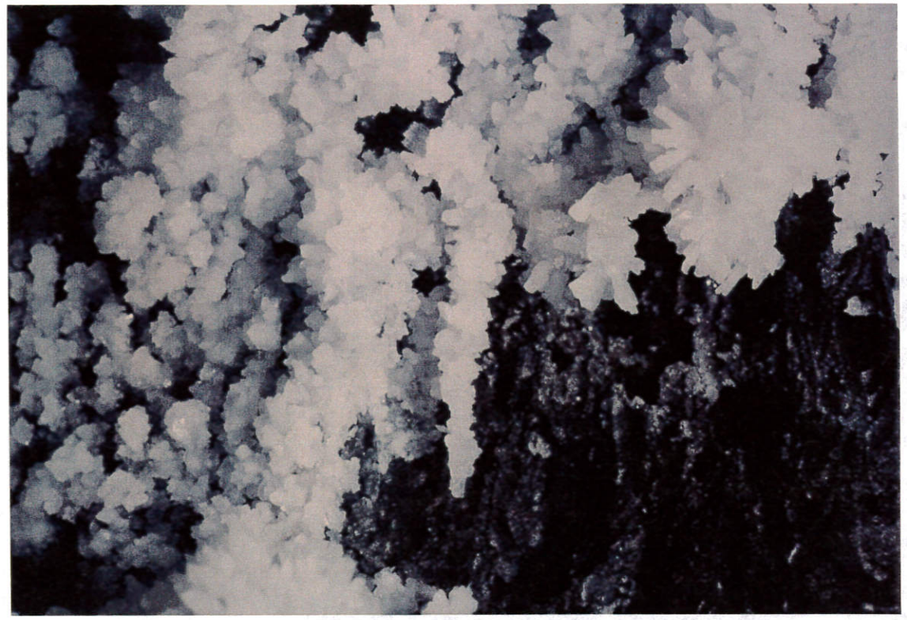


Fig. 21. Minerals on the right (northeast) wall of the Dollhouse Room in Crystal Pit.



Fig. 22. In the Multi-Lining Room of Crystal Pit looking down through the mini-shelf area. The caver at the lower center is on an extension ladder in the ceiling of the Dollhouse Room.



Fig. 23. The upper portion of Crystal Pit's Multi-Lining Room facing southeast.

Fig. 24. The Multi-Lining Room in Crystal Pit facing northwest.





Fig. 25. The Multi-Lining Room in Crystal Pit showing the innermost black lining (lower right), the red lining, and the exposed clotted lava behind the linings.



Fig. 26. Crystal Pit's Multi-Lining Room looking straight up at the ceiling.



Fig. 27. Stretched lava projections beneath the shelf in the main magma chamber of Crystal Pit.



Fig. 28. Mineral coated lava projections beneath the shelf in the main magma chamber of Crystal Pit.



Fig. 29. Mineral coated stretched lava projections beneath the shelf in the main magma chamber of Crystal Pit.

Fig. 30. At the entrance to Snow Cone. Snow Cone spatter cone is heavily visited and visitors are restrained form falling into the 7 m deep pit by a series of stone pillars connected with cables.





Fig. 31. The throat of Snow Cone. The upper portion of the spatter cone is hourglass-shaped so that the area of the rubble covered floor is about the same as the area contained within the stone pillars on the surface.



Fig. 32. Discovery Hole in Snow Cone. The passage shown here opened up during the summer of 1994, allowing access down the north slope of the ice cap.



Fig. 33. The entrance to the Ladder Room in Snow Cone. Apparently, the Ladder Room entrance experienced a brief surge of orange, frothy lava after the prior lining had cooled.



Fig. 34. The ladder in the Ladder Room appears quite sturdy on initial inspection, but is actually decomposed and fragile. Its surface is black; the white in the photo is light reflected from water droplets. Note the ultimate ceiling of the Ladder Room in the upper right corner of the photograph, 8 m above the floor.



Fig. 35. The entrance to Snow Cone's Balcony Room. The caver in the photograph is descending an ice slope from the Ladder Room entrance into the Balcony Room.



Fig. 36. The floor of the Balcony Room in Snow Cone. A low dike of ice and fallen rock separates the floor of the Balcony Room from the 20 m drop into the Magma Chamber Room. The photograph was taken facing south by a caver hanging under the north edge of the ice cap.

Fig. 37. The top portion of the Surprise Ice Cascade in the Balcony Room of Snow Cone. In 1995 the ice in this room appeared little changed from the previous year.

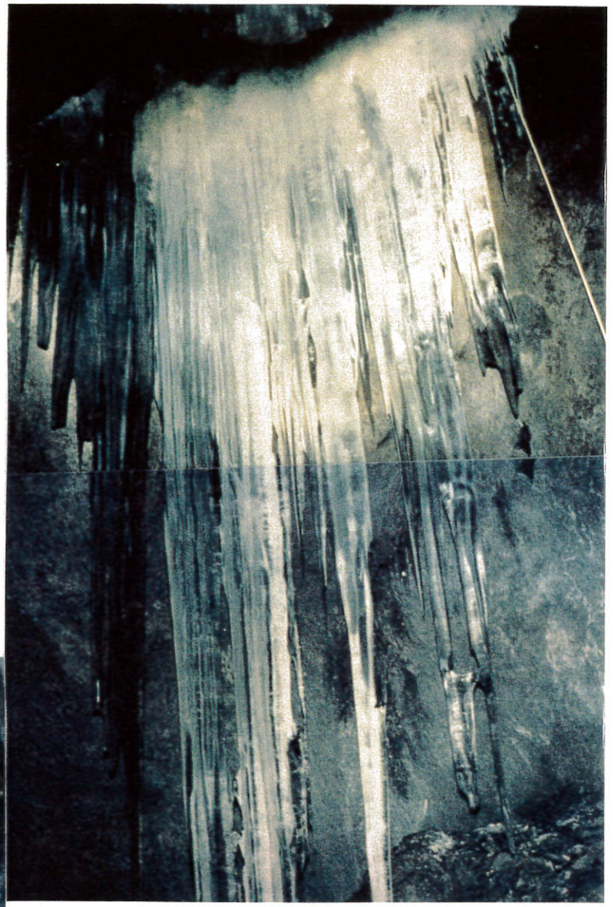




Fig. 38. The ceiling and upper southwest wall of the balcony room showing the underside of the ice plug in Snow Cone. Note the rubble and the stick in the ceiling where a prior opening may have existed and later filled with rock and ice.



Fig. 39. The underside of Snow Cone's ice plug taken from the Balcony Room.



Fig. 40. The upper portion of Surprise Ice Cascade in Snow Cone. Note the ice crystals on the ceiling in the upper right hand corner of the photograph.

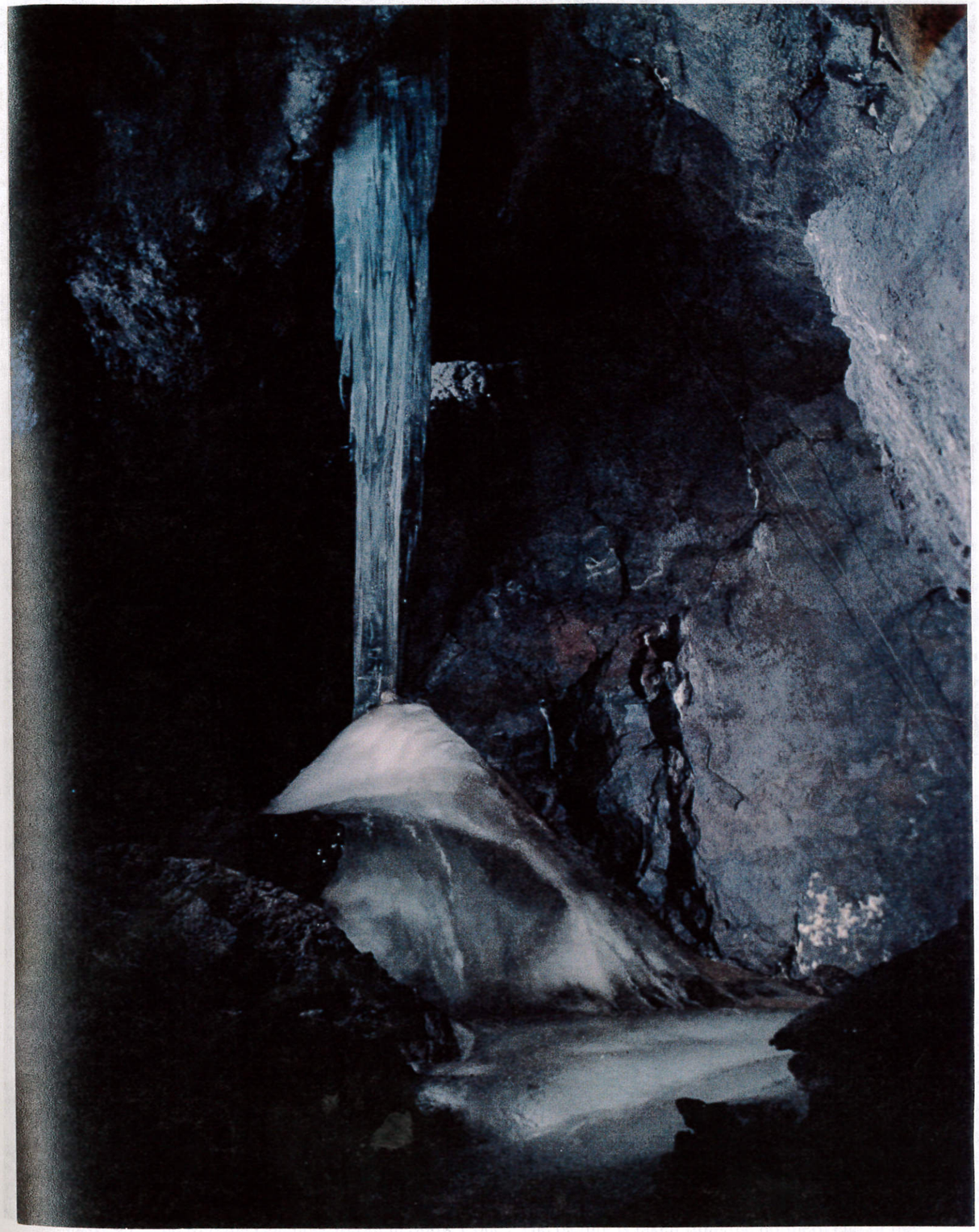


Fig. 41. The ice cone at the bottom of Surprise Ice Cascade in Snow Cone.

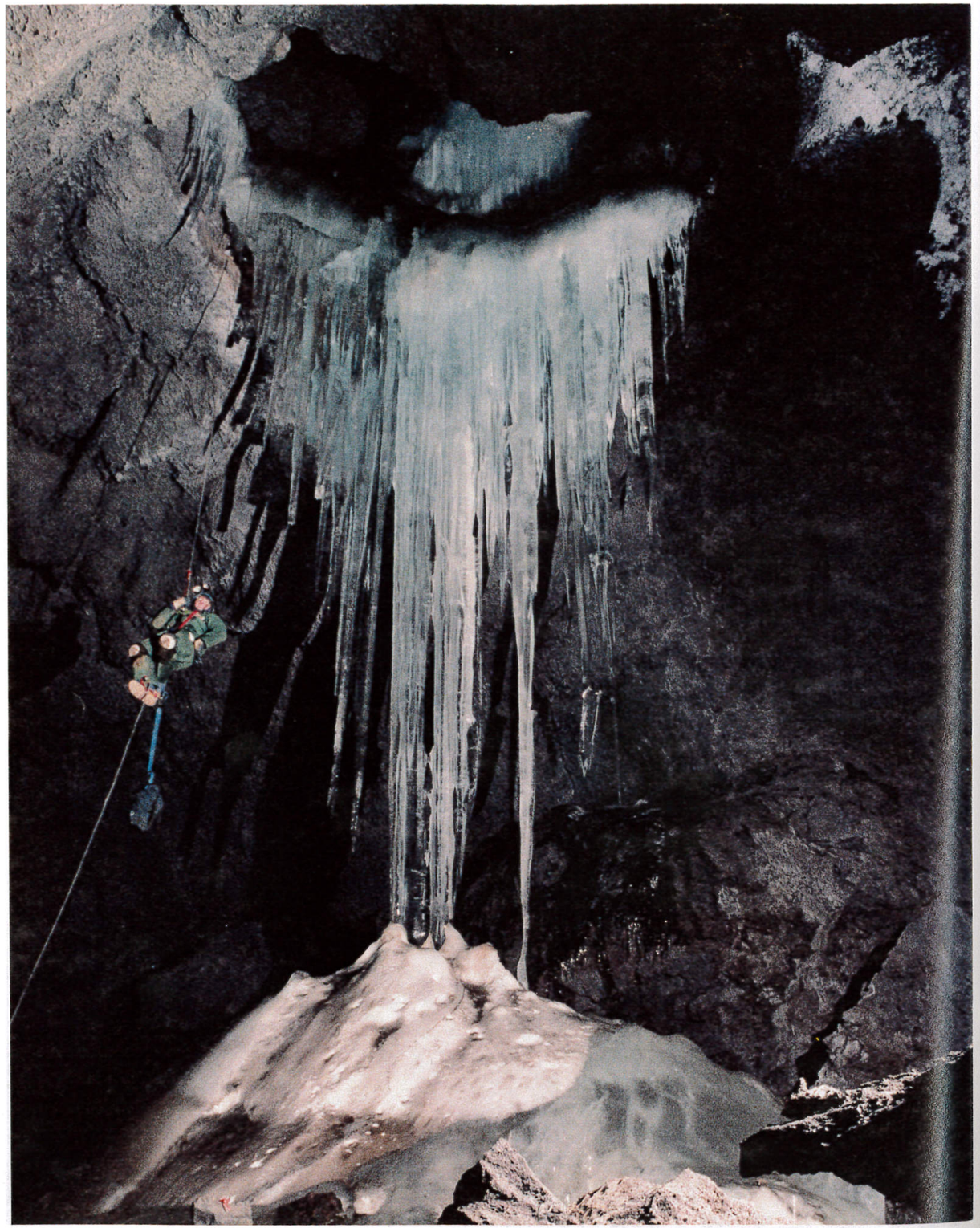


Fig. 42. Surprise Ice Cascade in Snow Cone. At the top of the cascade is the Balcony Room.

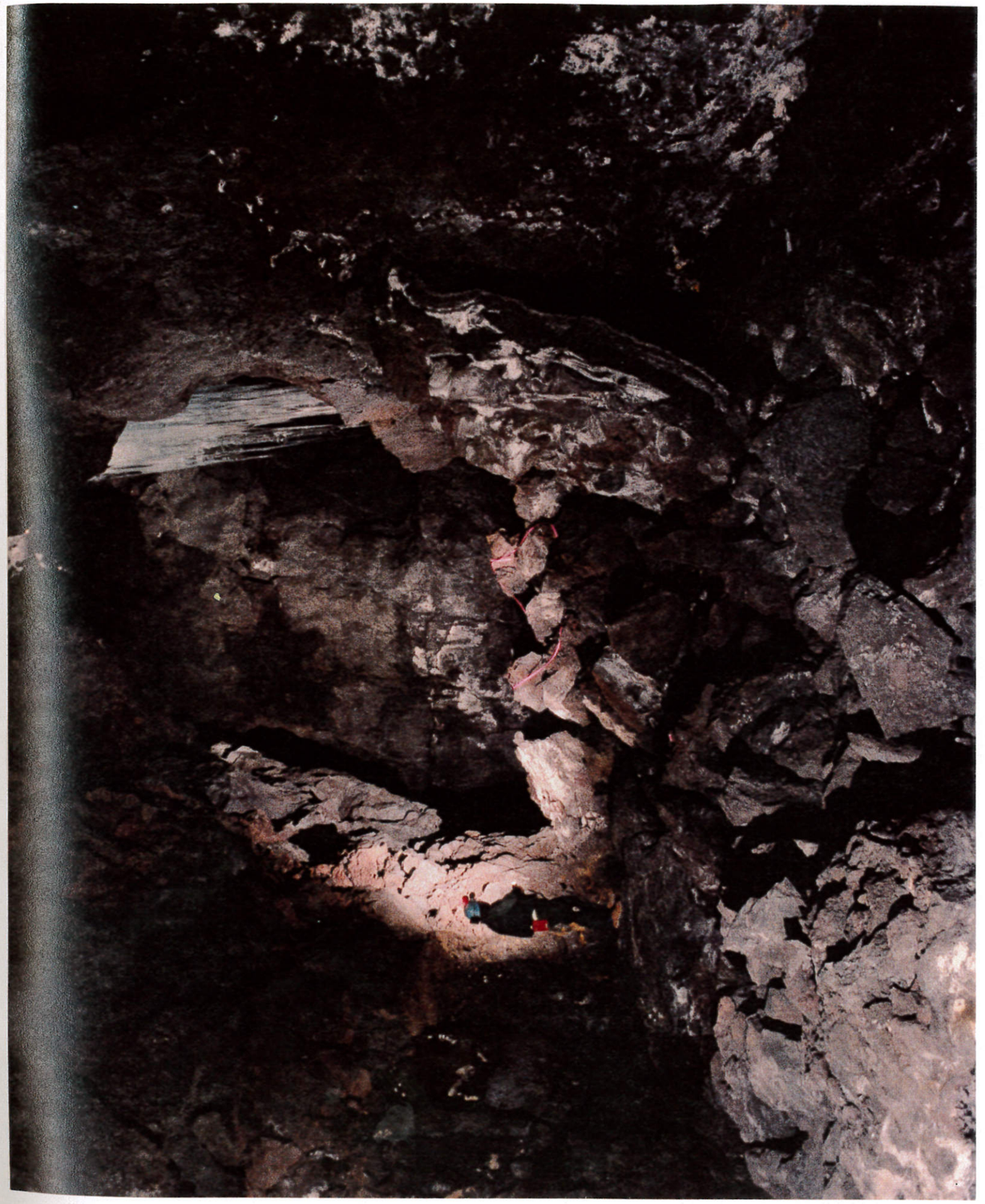


Fig. 43. The Magma Chamber Room in Snow Cone. The picture is taken from the northern end of the room. The ribboned-off area contains Gelflling's Crystal Shard. Surprise Ice Cascade in background.



Fig. 44. Stretched lava projections and extensive secondary mineralization in the southeast wall of the southern extension of the Magma Chamber Room in Snow Cone. The longest lavacicle is about 30 cm long. The white strips are reflective markers.



Fig. 45. Gelfling's Crystal Shard in Snow Cone. This 2 cm tall gypsum crystal is on a large breakdown boulder 6 m north of the base of the lower ice mound.

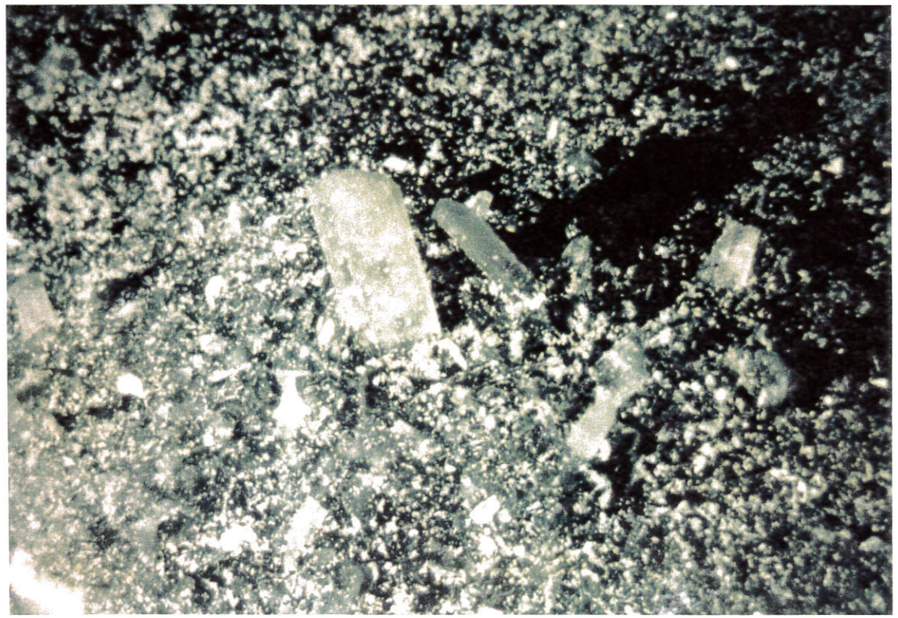


Fig. 46. Gelfling's Crystal Shard in Snow Cone is surrounded by several similar, but smaller, crystals.

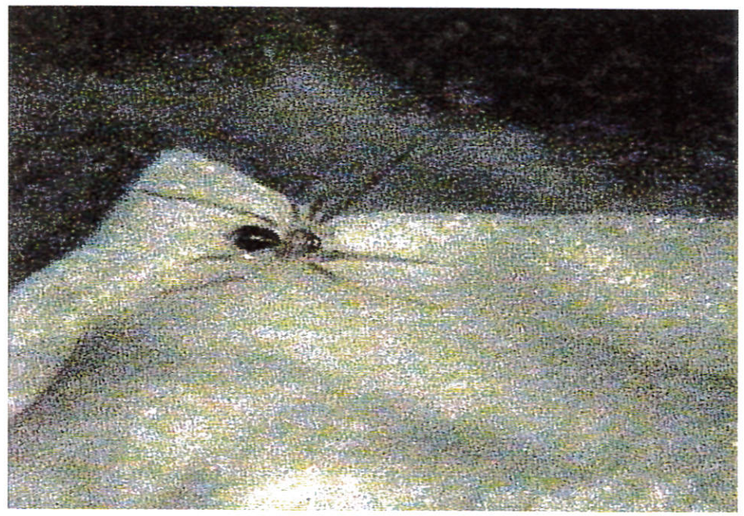
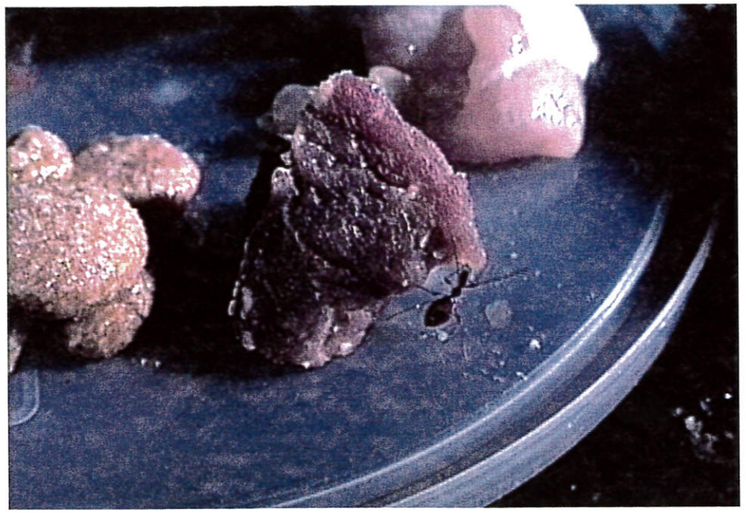


Fig. 47. A small (3 mm) cave spider (Araneida: Leptonetidae) found under a rock on the floor of Crystal Pit at the base of the entrance throat.



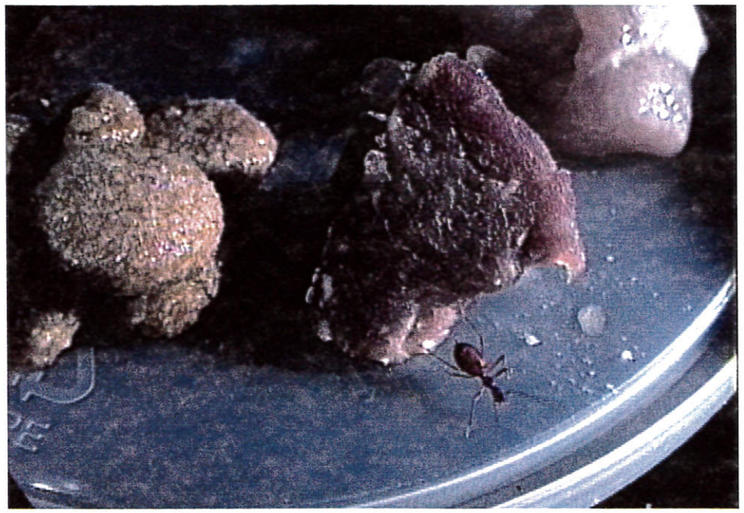


Fig. 48. A 6 mm specimen of the blind cave beetle *Glacicavicola bathyscoides* Westcott found sampling bait on one of the trays at the north end of Crystal Pit, 7 October 1995. The specimen wandered from the tray and could not be found within 10 minutes after taking the photograph, making its collection impossible. No other specimens of this unusual and enigmatic insect were seen during our expeditions into either cave.