H. H. Hobbs III

BULLETIN

OF THE

NATIONAL SPELEOLOGICAL SOCIETY

VOLUME 31 NUMBER 3

Contents

JULY 1969

Information for Contributors To the Bulletin

Papers in any discipline of speleology are considered for publication in the BULLETIN. The upper limit for length is about 10,000 words or approximately 40 pages of manuscript, typed double-spaced. At least one copy but preferably two copies of the manuscript (typed, double-spaced) should be submitted to the Editor, Jerry D. Vineyard, Missouri Geological Survey, Box 250, Rolla, Missouri 65401. Photographs and line drawings, if required, should be submitted with the manuscript. In general, prints and line drawings will be photo-reduced to the size necessary for use in the BULLETIN.

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The Paradise Ice Caves, Washington: An Extensive Glacier Cave System

By Charles H. Anderson and William R. Halliday

INTRODUCTION

The existence of caves in glaciers has long been known. The specific cave system discussed in this report has been a tourist attraction for decades (fig. 1). One of us has discussed briefly pseudokarstic surface features of glaciers (Halliday, 1960, p. 112), and these are mentioned in at least one standard text (Cotton, 1945). Further, in deglaciated areas, long sinuous ridges of gravel and silt *(eskers)* have long been interpreted as deposits in extensive subglacial watercourses; in retrospect it seems surprising that little consideration has been given to their potential speleological implication with

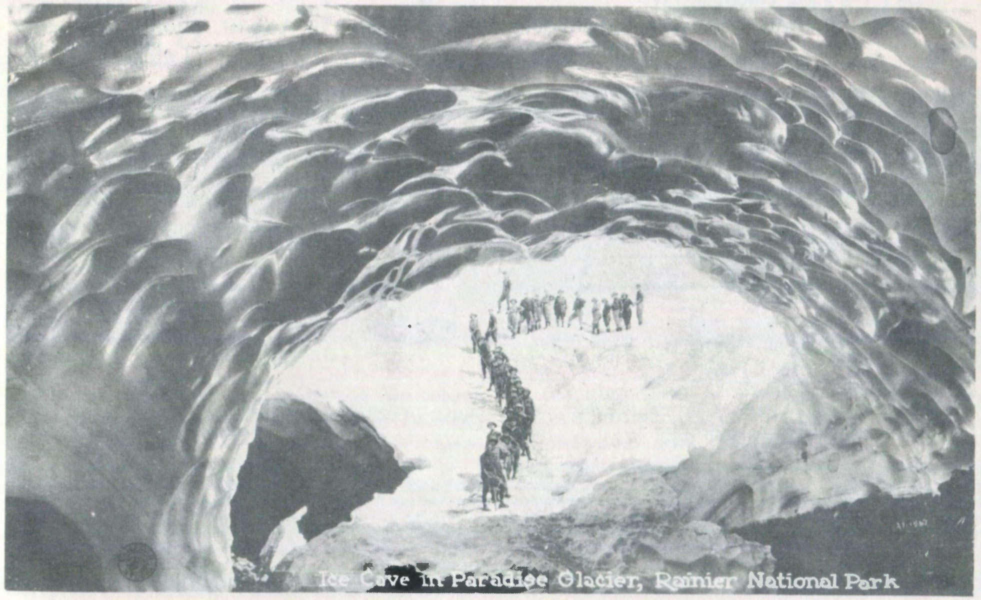


Figure 1.
Old postcard view of Paradise Ice Cave tour party during 1920s, showing entrance to Pillar Passage and Water Passage at that time. The cave system has retreated about 100 feet in this area since that time.

Figure 2.

The Water Passage at moderately high water in August, 1967. Photo by Dave Mischke.

Figure 3.

Snout of Paradise lobe of the Stevens Glacier in late August, 1968. The large entrances at left formed after July, 1967.

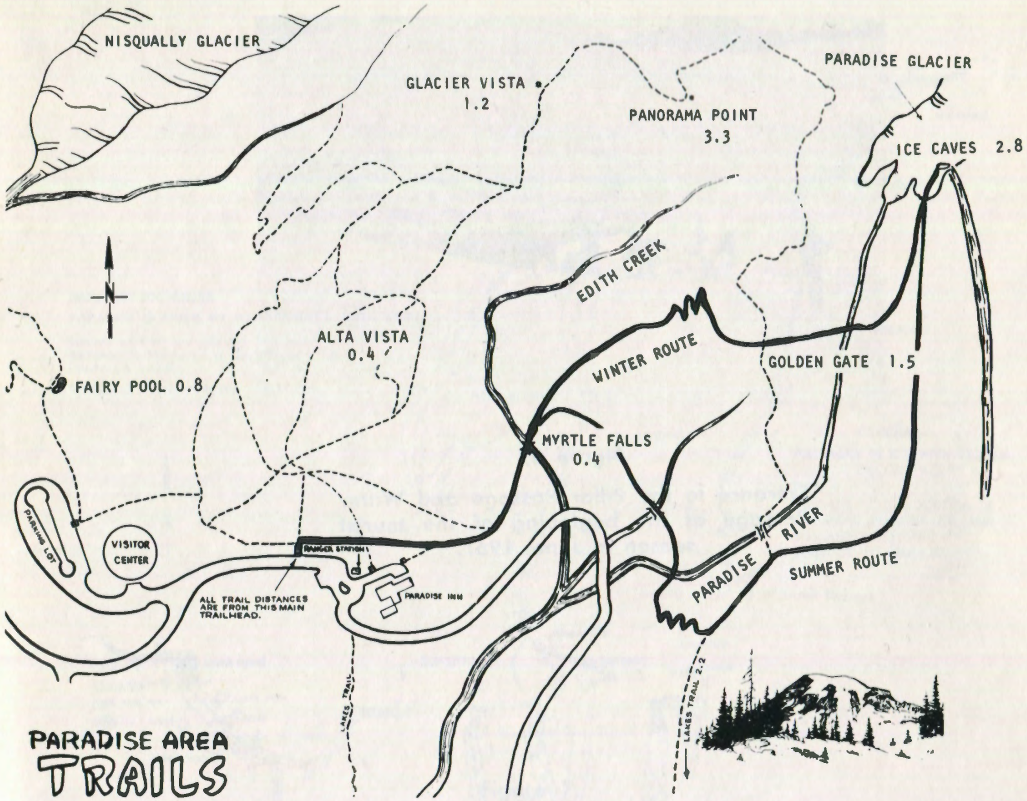


Figure 4.

Trails and roads in the Paradise Ice Caves area.

some exceptions (*i.e.,* Russell, 1893). In general, it has been assumed that glacier caves are simple structures of insignificant length and content. It has been believed that these form as small caverns melted annually within glacier snouts, largely or entirely closing in winter as a result of glacial flow.

Recent studies by the Cascade Grotto of the National Speleological Society indicate that this is not true for the Paradise Ice Cave system of Mt. Rainier, Washington.

Project Format

The "tourist section" of the Paradise Ice Caves was visited by the Cascade Grotto as early as 1961. Only in preliminary studies during the autumn of 1967, however, did the extent and complexity of the caves become apparent. Participating repeatedly in the project were Charles Anderson, Edith Anderson, Dave Mischke, Eric Nelson, Bill Petty, Ronald Pflum, Rick Rigg and Ken Severa. Jerry Frahm periodically maintained base communications at the Paradise Valley roadhead.

With subglacial torrents stilled by winter, exploration and study were found easier than in summer, once the caves were reached. By midwinter of 1967-68, almost 1¼-mile of passage had been mapped. The existence of recurrent seasonal speleothems had been discovered, and new concepts of glaciospeleogenesis were fast evolving. Although access was hazardous (Halliday, 1968). the Cascade Grotto did much of its work during that winter. The winter of 1968-69 saw record snow depths, forcing the project to halt temporarily. The longest single passage in the cave is still unmapped because of the volume of streamflow in summer (fig. 2).

Figure 5.

Entrance to the Pillar Passage and Water Passage at the beginning of the tourist season in June, 1967.

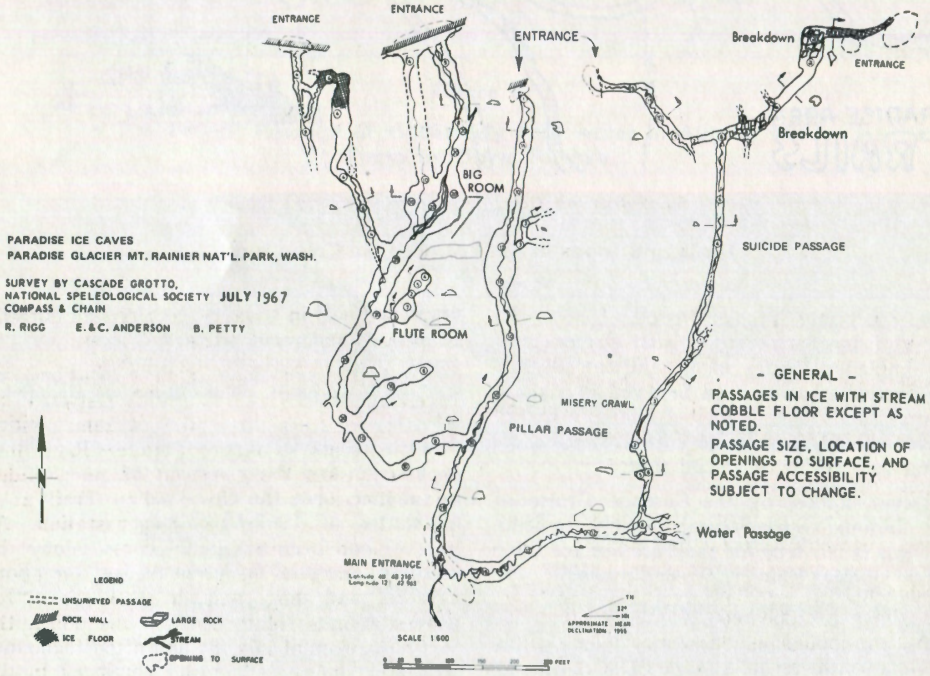


Figure 6.

The Paradise Ice Cave system in July, 1967.

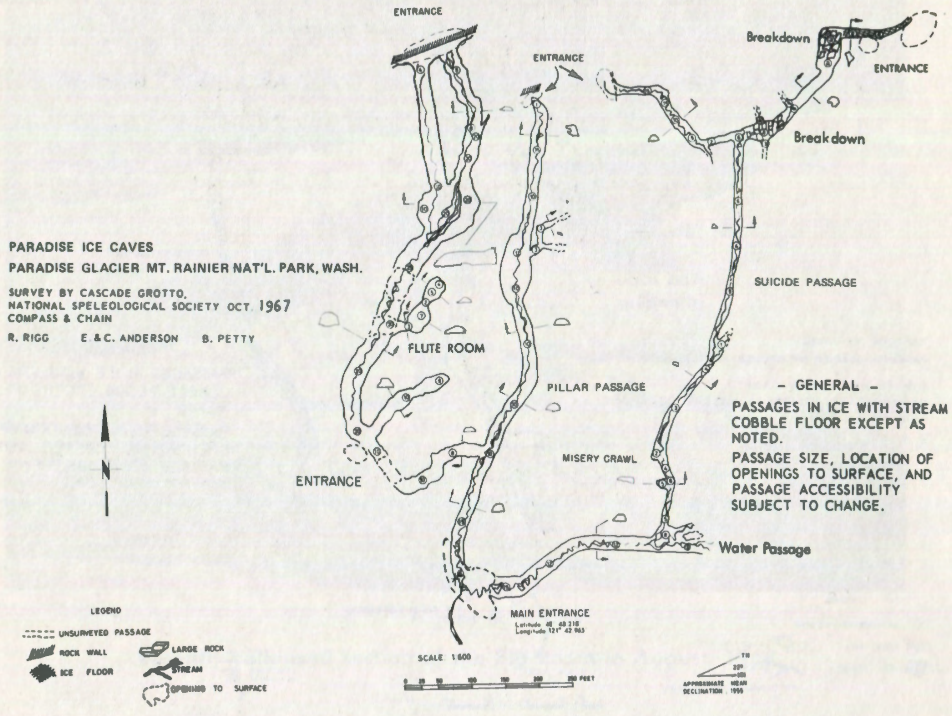


Figure 7.

The Paradise Ice Cave system in October, 1967.

Location

The Paradise Ice Caves are in the Paradise-Stevens Glacier on the southeast side of Mt. Rainier, a dormant 14,410-foot volcano in the Cascade Mountains of Washington (fig. 3). The altitude of the caves is approximately 6,500 to 6,900 feet.

A few decades ago, the Paradise and Stevens Glaciers were distinct entities with a common source. The Paradise Glacier has receded rapidly, however, and some consider it to have disappeared entirely so that the caves now should be considered to lie entirely within a southwest lobe of the Stevens Glacier.

The caves are approached from the Paradise Valley visitor center roadhead (fig. 4). The summer route requires no special arrangements if only tourist areas are to be visited, otherwise the chief park ranger should be contacted well in advance, to ascertain current conditions and regulations.

From the Paradise Ranger Station, an excellent trail leads ½-mile eastward to Myrtle Falls. Thence, the Mazama Ridge trail continues across the Paradise River just below Sluiskin Falls and up Mazama Ridge to a junction with the Skyline Trail at a point 1½-mile from the ranger station. At this junction, visitors proceed left along the Skyline Trail, up Mazama Ridge, for about ½-mile. At this point, a rustic sign "Ice Caves" points right. Beyond this point, the route is informal (fig. 5) and often fogbound. In early summer, flags are emplaced in the snow to mark the route.

The winter route requires special permission and parties must sign in and out at the ranger station. It involves a more direct but much steeper ascent on snow to and across

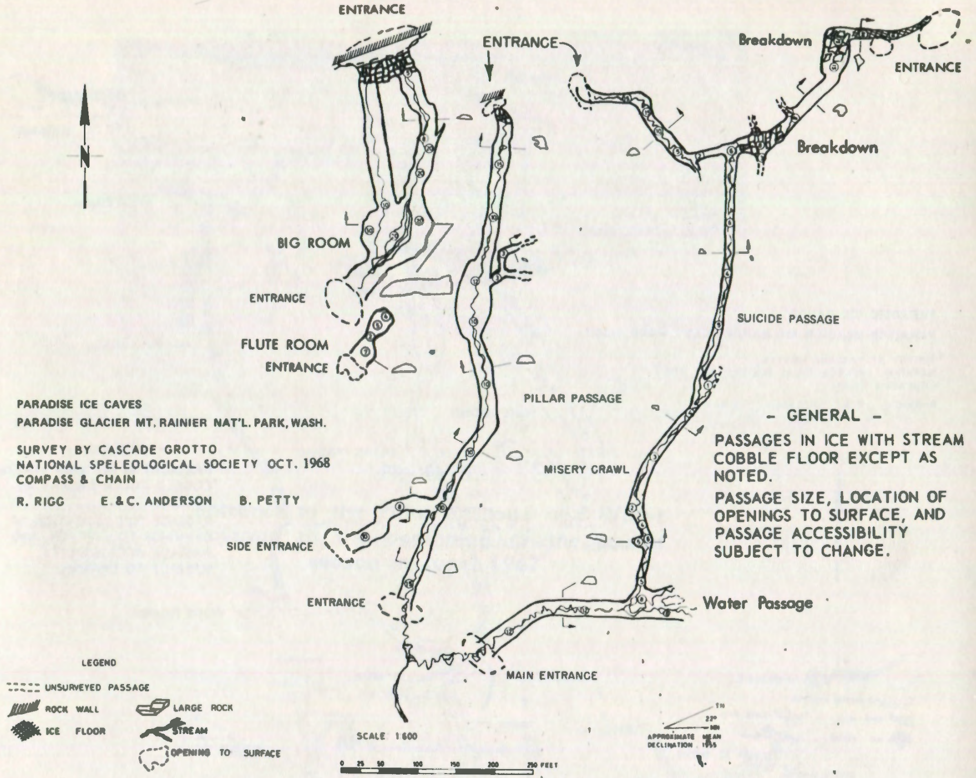


Figure 8.

The Paradise Ice Cave system in October, 1968.

the Skyline Trail via the "Golden Gate" above Myrtle Falls, thence down the steep wall of Paradise Canyon a few hundred yards from the caves. Travel is routinely by compass in thick fog and blowing snow.

Description

As presently known, the Paradise Ice Caves include at least 12,000 feet of passage in a branchwork pattern. Passages totalling about 7,500 feet have been mapped to date, with most of the remainder in the Water Passage (figs. 6, 7 and 8). Collapse has segmented the system during the course of this study (figs. 9 and 10). While some parts of the caves are little more than crawlways, most consist of glorious corridors a dozen or more feet in diameter (fig. 11). Locally, the width and height are much more (fig. 12).

Strong air currents are perceptible in many areas, especially where constricted, but no air flow studies have been made. Rudimentary temperature studies have been made at three points: 100 feet inside the cave in the Water Passage, at the Great Pillar and in Suicide Passage near its confluence with the Water Passage. Recorded air and water temperatures have varied seasonally from 32°F to 36°F, with water temperatures one or two degrees higer than air temperatures except near the entrance on October 7, 1967, when the water and air temperatures respectively were 36°F and 32°F. Only one water temperature reading of 32°F has been obtained.

Streams of various sizes are present in most of the passages in summer (fig.2). Marked variation of streamflow occurs, with some active freezing within the cave, but at no time has all streamflow been found halted. Atypical eskers-in-development are present in the stream beds; most include large stream

Figure 9.

Recently collapsed section of the Big Room in August, 1968.

Figure 10.

Now-collapsed section between the Flute Room and the entrance of the Pillar Passage in October, 1967 at an intermediate stage of segmental collapse.

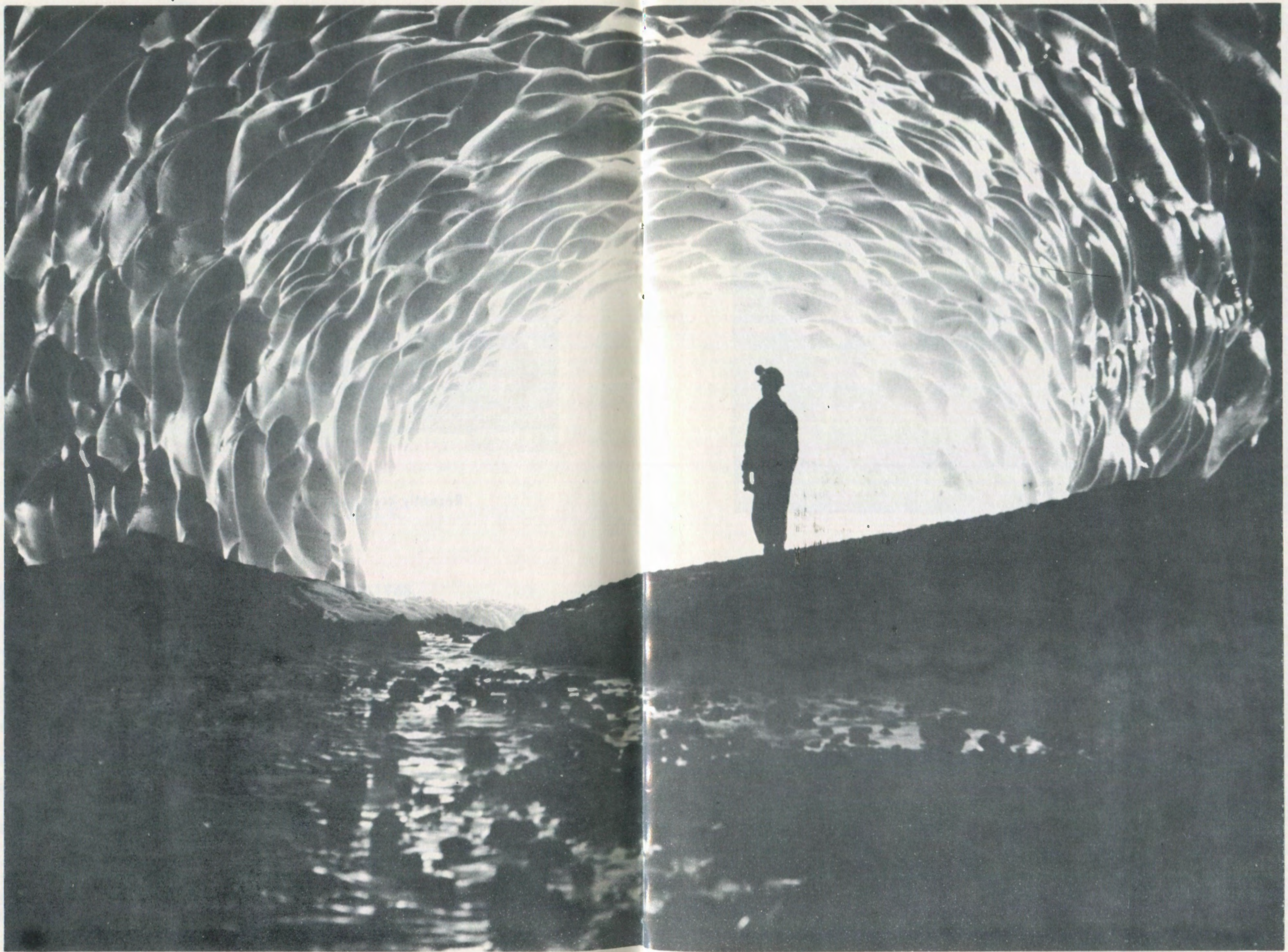


Figure 11.
Scalloped walls and ceiling in the Pillar Passage.

Figure 12.

The Big Room in July, 1967.

boulders and cobbles in addition to finer sediments (figs. 13 and 14).

Most of the system occurs beneath the glacier but some sections are floored by glacial ice. Although far from homogeneous, the glacier ice is largely glistening white or blue-white. Bedding and some impurities (fig. 15) can be observed. Speleogens and speleothems are well developed. These features and the effects of local illumination through the glacier render the caves entrancingly beautiful. The play of color and light on the scalloped ice walls ranges from delicate green to deep ultramarine. The most prominent speleogens are large scallops or flutes (figs. 1, 2, 11, 12, 13 and 14), often more than a meter in width. Superficially resembling on a grand scale the stream flutes of limestone caverns, they are probably aerogenic. Locally but not universally, their shape and size appear modified by impurities or intraglacial bedding and related features.

Figure 13.

Misery Crawl area. Note banding of ice. Stream cobbles form a small island.

Figure 14.

Boulders and drifted snow near rear entrance of the Big Room in midsummer 1967.

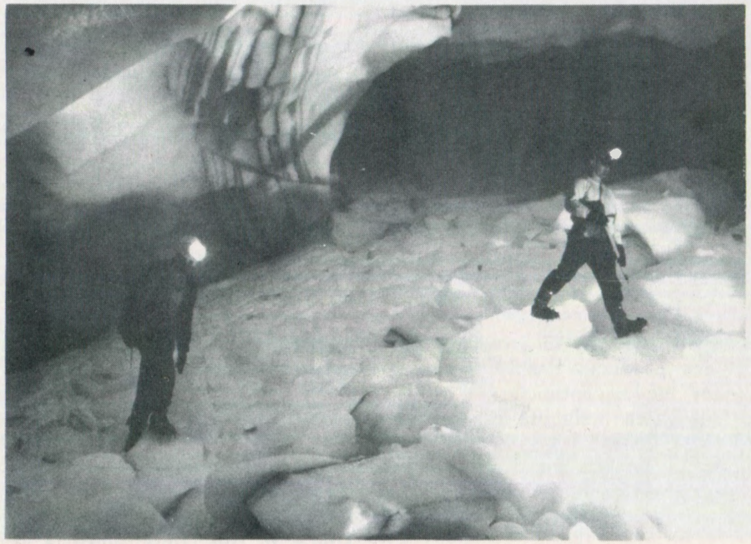


Figure 15.

Fallen flakes at rear of Big Room in April 1968. Note banding (impurities) in ice at left rear.

Figure 16.

Medium-sized flake (right) near complex column in the Big Room. The snow in the foreground drifted into the cave from the lower entrance. Another flake shows in the center distance. A small frozen waterfall can be seen along the surface of the complex column near the left edge of the picture.

Coalescence of scallops in irregular patterns sometimes produces deeply undercut, hanging "flakes" of ice centimeters or meters long (fig. 16), often weighing many tons. Collapse of these flakes is a specific hazard of exploration; some cannot be discerned until one has passed beyond them and relatively minor vibrations sometimes cause them to fall.

Entrances to these caves are located at the snout of the ice lobe and also in the bergschrund (figs. 17, 18 and 19). Three other types of orifices connect the caves and the surface of the glacier. Several of the rounded, domepit-like swallets termed *moulins* intersect the caves (fig. 20) A crevasse about 4 feet wide and an estimated 500 feet long intersects the Water Passage. As indicated, newly-formed collapse sinks have separated the system into multiple caves during the course of this study; most occurred between August 19 and Spetember 30, 1967.

Large columns of glare ice form seasonally at the base of active moulins, and below

Figure 17.

Entrance to the Pillar Passage in August 1968. Entrance to the Water Passage is also visible on the extreme right. Some upper entrances are present in the bergschrund at the upper left.

Figure 18.

Entrance to the Water Passage in early September 1967. The Tatoosh Range is in the middle distance and Mt. Adams in the background.

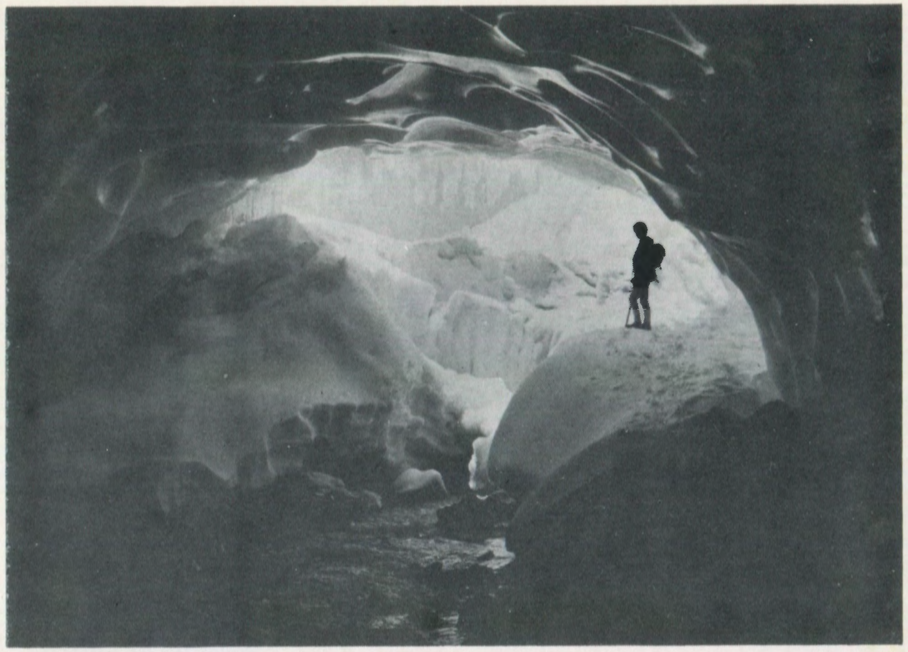


Figure 19.

Same view as Figure 18, but in early March 1968.

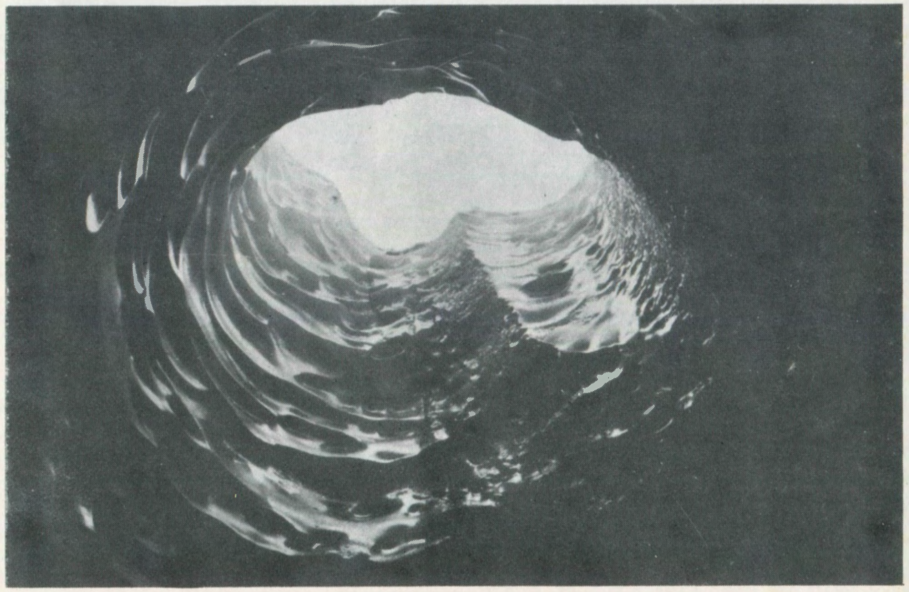


Figure 20.

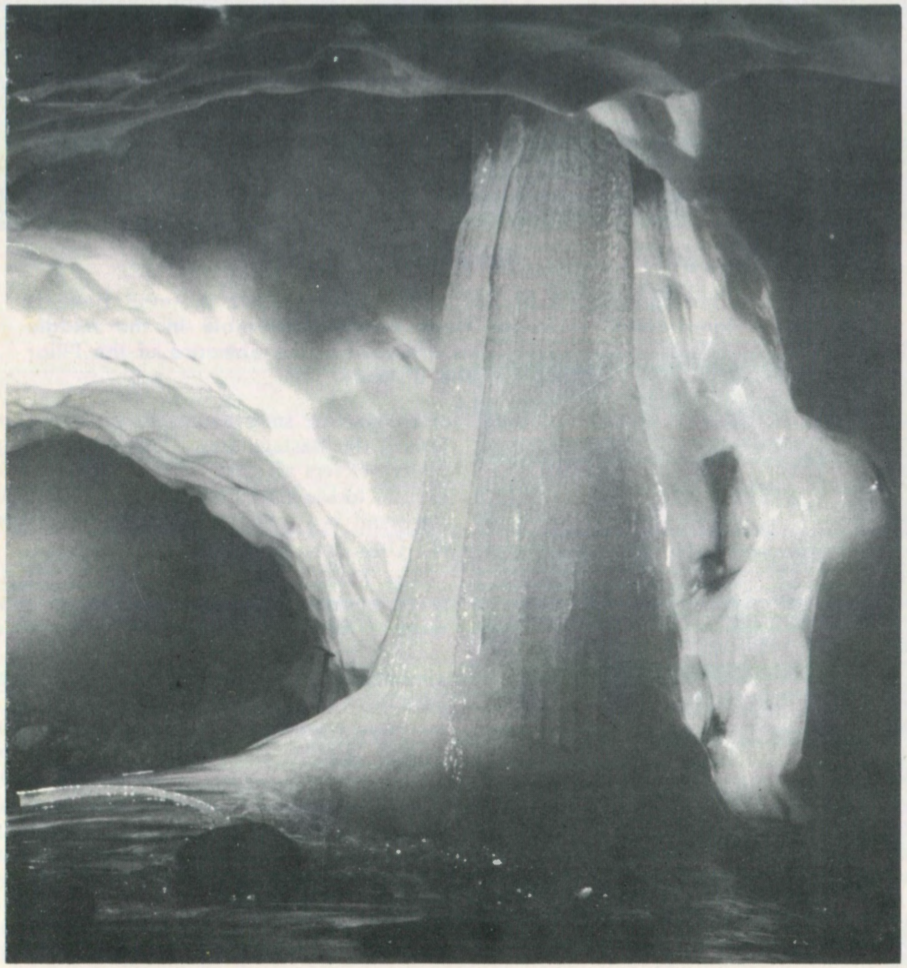
Looking up a moulin above the Great Pillar. The glacier is about 20 feet thick at this point.

Figure 21.

The Great Pillar in winter, with drifted snow at the base.

Figure 22.

The Great Pillar in late June.



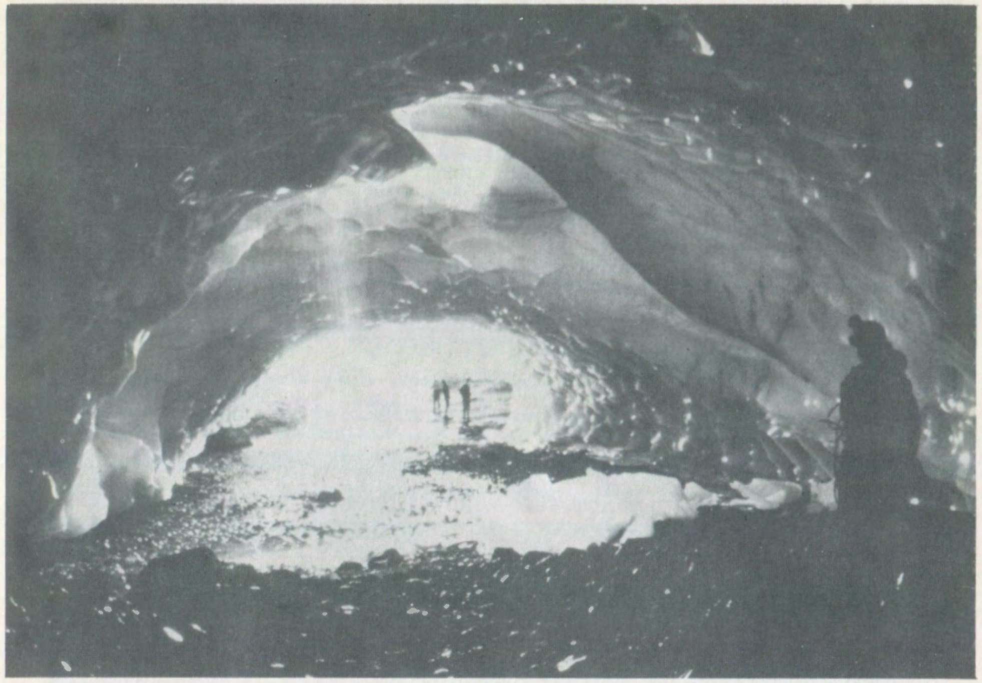


Figure 23.

Water dripping through moulin at site of the Great Pillar. A small flake is visible in the foreground. A larger flake barely discernible in the middle distance is about 300 feet long. Tourists are seen in the entrance of the Pillar Passage in the distance.

other drip points to a lesser degree. Most are largely or entirely melted by mid-June of most years (figs. 21, 22, 23, 24). Tapered stalactites are fairly common, and participate in column formation. Tubular stalactites have been observed in the Water Passage. Ribbon draperies form locally but are quite transient. Curious ice helictites are even more evanescent. They have been observed only at the lower entrance of the Water Passage (fig. 25) and on the surface of one column.

Glaciospeleogenesis

Whether a glacier advances, retreats or remains stationary depends on increases or decreases in snowfall in the area of accumulation, with regional temperature changes also a factor.

Unless virtually all the snow cover melts from the surface of the glacier (in which case the glacier will soon disappear), the weight of compacting snow causes slow plastic flow toward the wastage area. This process eventually delivers all parts of the glacier and its cavities to the glacier's melting snout whether the snout is advancing, retreating or stationary (fig. 26).

The Paradise lobe of the Stevens Glacier is in a state of old age, and is in rapid retreat. Almost all the seasonal snow which mantles it melts annually. The firn limit is almost at the upper end of the glacier. Comparatively little glacial flow thus appears to be present to counteract two forces which enlarge glacier caves: stream action and circulation of warm air.

As in the case of many limestone caves, the size of the cavern passages appears disproportionate to the present streams on their floors, and some are presently stream-free. Some major passages show no evidence of stream action on the ice walls, while others show typical vadose speleogens. Despite

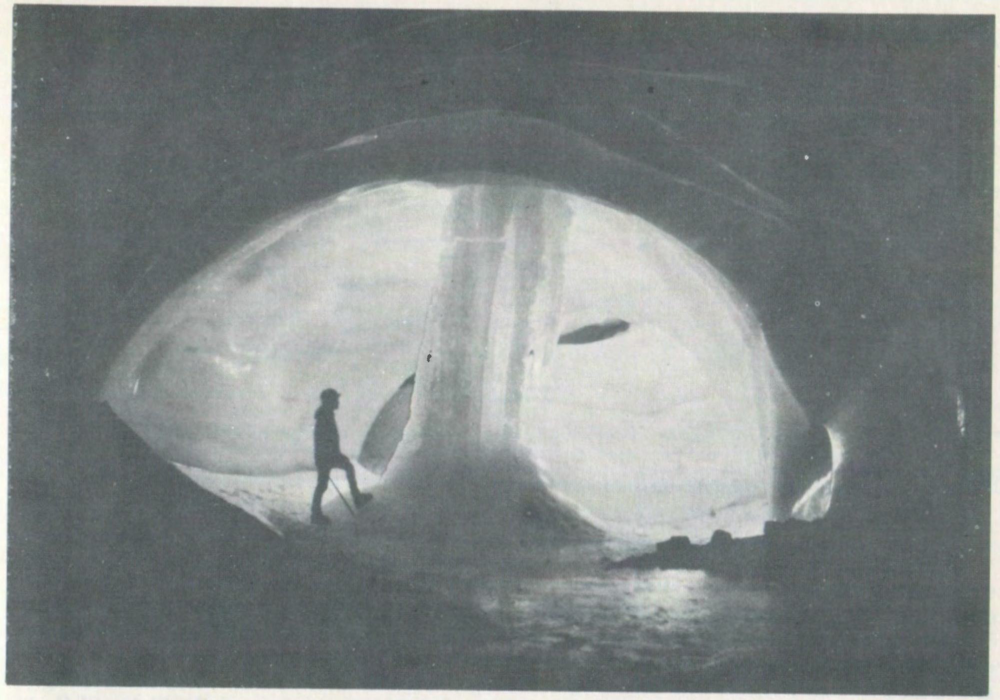


Figure 24.

Column in the Flute Room in March 1968.

Figure 25.

Transient helictites in the Water Passage entrance in April 1968.

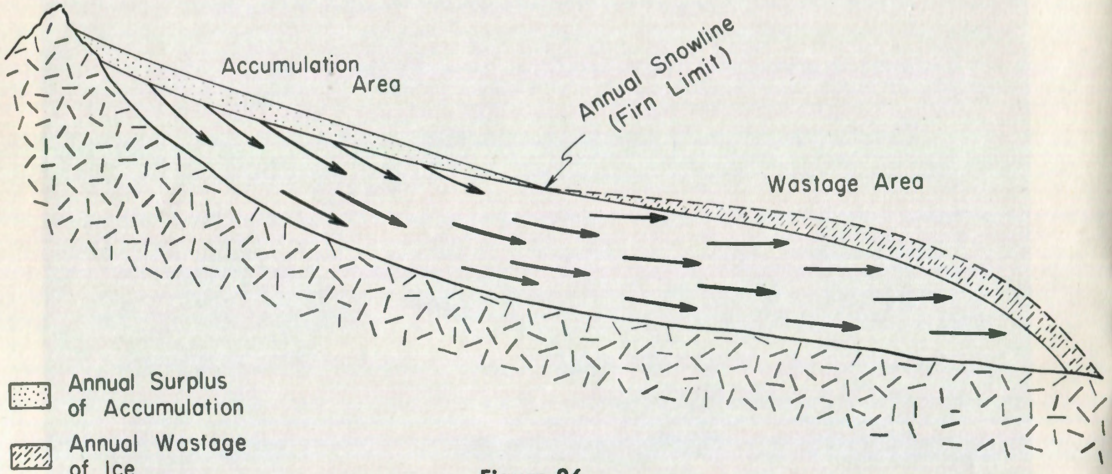


Figure 26.

Diagrammatic side view of glacier.

noteworthy fluctuations in streamflow, it seems doubtful that the larger passages could be filled either by present floodwater invasion or by greater past runoff — or by flow when the passage was largely filled with esker. Rather, it appears that each passage was initiated by running water, but that initial streamways admitted enough circulating air to cause melting which produced most of the present volume of the cave. Some warming of circulating air by heat transfer from subglacial streams may be a significant factor, but tentatively it is felt that most of the heat transfer results from ingress of seasonal air above the freezing point.

Photographs of the past few decades indicate that retreat of the glacier has caused loss of considerable length of the cave. Plastic flow also probably serves to reduce the size of the caves. Yet direct observation during this study suggests that collapse from over-enlargement is currently more important in destruction of the caves.

ACKNOWLEDGMENTS

This study was possible only because of special permission and assistance rendered by the National Park Service and especially the staff of Mt. Rainier National Park. Particular thanks are due to Superintendent John A. Townsley, Chief Park Naturalist Norman Bishop and Chief Ranger Joseph L. Orr. We also wish to express our inestimable obligation to all the members of the National Park Service, Mountain Rescue Council, Cascade Grotto of the National Speleological Society and others who assisted during the 1968 rescue operation near the "Golden Gate."

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Microecosystems in Lehman Cave, Nevada

By N. Stark

ABSTRACT

Over 70 species of plants and animals have been found and most of these identified from Lehman Cave near Baker in eastern Nevada. These organisms play parts in 12 microecosystems, some of which are "pseudo" or lacking producer organisms, and "terminal" or destined to cease to exist once the organic food supply left by former trogloxenes is exhausted. The microecosystems differ in degree of moistness, dept of "soil" development, the presence or absence of light, and the numbers and types of organisms they support. A strong controlling factor in an otherwise quite stable environment is the extremes of temperature, air relative humidity, air movement, and the drying power of the air caused by turning lights on or off in various reflecting positions. Lights boxed on three or four sides produce conditions too severe at 0.1 m distance for plant growth, but deep reflectored or open bulbs (100 w) produce cool, moist conditions, favoring moss while shallow reflectored bulbs favor algae on moist sites at 0.1 m.

INTRODUCTION

Simple ecosystems are prized by ecologists because they are easy to study and still retain many of the factors and forces at work in more complex ecosystems. Lehman Cave in eastern Nevada at the base of Wheeler Peak (13,063 ft.) is a limestone cave complex with a variety of simple microecosystems. The Cave is 10 miles west of Baker, Nevada at about 6,800 ft. elevation (Lat. 39° N., Long. 114° 50' W.). These caves are particularly interesting because they have vestiges of earlier microecosystems which were active before Lehman Cave was lighted, and a different group of organisms which exist because of the lights. The flora and fauna of the Cave is not considered to be typical of caves in general and there are no troglobites, but it has a potpourri of organisms normally living elsewhere and generally showing no specific adaptations to caves (Mohr and Poulson, 1966). This paper describes the types of microecosystems which exist in Lehman Cave and some of the microclimatic factors which govern their existence. The influence of the more than 50,000 visitors to this National Monument each year cannot be overlooked.

The Cave extends into the base of Wheeler Peak for a lateral distance under one mile (fig. 1, Mohr and Sloane, 1955). The vegetation consists of Pinyon-Juniper, sagebrush *(Artemisia tridentata)*, rabbitbrush *(Chrysothamnus nauseosus)*, and a few abundant herbs such as *Penstemon palmeri* and grasses.

ACKNOWLEDGMENTS

I thank the National Park Service at Lehman Cave for supporting this research. I am grateful to Dr. Harold Humm of the University of South Florida for verification of algal identifications, and to Dr. L. E. Anderson of Duke University for moss identifications. Drs. George C. and Jeanette Wheeler identified the animals. The work was conducted from the mobile laboratories (Went, 1968) of the Desert Research Institute which made it possible to live near the problem in the field.

Methods

Careful observations 'and collections of living material for identification were made at 200 of the existing lights along the trails. Dark areas were also studied. The survey of lights included:

a) light wattage, position, and reflectance

b) algae, mosses, ferns, other plants and their conditions

c) visible evidence of fungi

d) flies, other insects, larvae, spiders, Annelids, mammals (signs)

e) the nature of the substrates *i. e.,* part or all rock, soil, wood, dung

f) the relative moistness of the substratum

g) the minimum and maximum distance from the lights to plant life

h) debris brought in by man.

Data were compiled to show what percentage of the lights had various organisms and conditions. Tentative food chains were diagrammed for the various microecosystems.

Five different representative light positions were studied for microclimate with the lights on and off to better understand the effect of microclimate on the organisms. Air temperatures, relative humidity, the evaporative power of the air, air movement, and light intensity were studied at different distances with lights on and off.

Species and Environment

Of the 200 lights studied, 77.5% had algae, 20.5% had mosses, 75.0% had visible evidence of fungi, 30.5% had Collembola, and 31.5% had various types of dead or live flies (Table 1). A material which I called "flow dust" (fig. 2) appears as rivulets of mud or dust on moist or dry stalagmites. Flow dust on moist lighted sites was composed of diatoms, minerals and organic debris, and was found at 24.0% of the lights. This material is not identical to the vermiculations described by Parenzan (1960) but the original clay deposits may have formed in the same manner as clayish-slimy vermiculations. An oligochaete worm which appears to feed on the diatoms occurred at only 10% of the lights. Many ecological niches are not occupied in the Cave after over 28 years. Ninety-eight percent of the lights had rock as a part of the substrate, while soil occurred at 25.0% and organic debris at 58.0% of the lights. The substrates were graded objectively as wet to moist (48.0%), slightly moist (32.0%) and dry to damp (20.0%).

The Cave was divided into the entrance area which is dry to damp with the least algae, few mosses, no flow dust, and the most old dung; the mid-section which has the most moisture and dripping, abundant algae and mosses; and the final section which has less dripping, few mosses or algae, and the least recent animal signs (Table 1, fig. 1).

The entrance area is dry because the inflow of cold, relatively dry air during winter makes part of the entrance a variable temperature zone. The middle section is protected from dry air movement and has the most active dripping and the best development of microecosystems. These first two sections were lighted in 1939-40 and have the healthiest plant life. The last section (Talus Room) was lighted in 1960. The amount of plant life which has become established in eight years is so small that most visitors are not aware that there are any plants there. Collembola are scarce in the Talus Room because they require an area of concentrated plant life of about 4 x 4 cm. They do occur where there are fungi and no green plants.

Dark areas with dust and lint, support fungi, and occasionally Protozoans. Plant life in this Cave is likely to remain in small areas near lights. In 28 years, the largest plant to invade the Cave and stay is a smalll fern *(Cystopteris fragilis* var. *fragilis).* Limited amounts of soil, low light intensity, and possibly a deficiency of nitrogen and other elements is preventing the establishment of higher plants near lights. The energy level for the Cave ecosystem as a whole is extremely low. This may, in part, explain why the permanent organisms in the Cave are so small. All plants living in the Cave are dispersed by spores probably brought in by water and moved about on the feet of tourists and trogloxenes. The repeated visits of transient mammals bringing in seeds has not resulted in the establishment of any higher plants, possibly because the shortage of food during the spring when young mammals are born causes all usable food to be eaten.

Table 1. Summary or organisms and conditions adjacent to 200 lights and 25 dark areas in Lehman Caves, November, 1968.

Sec. No.	No. Lights	Algae	Moss	3 Fungi	Collembola	1 Flies	Flow Dust	Annelids	Dung New	Dung Old	Substrate Rock	Soil	Organic	Mositure M	Sl.	2 D
1-No.	35	16	9	31	10	11	0	0	8	23	31	9	31	2	16	17
%	—	45.7	25.7	88.5	28.6	31.4	0	0	22.8	65.7	88.5	25.7	88.5	5.7	45.7	48.5
2a-No.	35	33	16	25	14	19	19	7	13	1	35	14	17	24	7	7
%	—	94.2	45.7	71.4	40.0	54.3	54.3	20.6	37.1	2.9	100.0	40.0	48.5	68.6	20.6	14.2
2b-No.	35	27	8	23	8	7	11	5	14	1	35	20	18	18	12	5
%	—	77.1	22.8	65.7	28.8	20.6	31.4	14.2	40.0	2.9	100.0	57.2	51.4	51.4	34.3	14.2
3a-No.	35	33	1	22	13	12	12	4	33	2	35	4	21	33	1	1
%	—	94.2	2.9	62.8	37.1	34.2	34.2	11.4	94.2	5.7	100.0	11.4	60.0	4.2	2.9	2.9
3b-No.	37	28	3	28	9	10	5	1	23	4	37	2	21	18	12	7
%	—	75.7	8.1	75.7	24.3	27.0	13.5	2.7	62.2	10.8	100.0	5.4	56.7	48.6	32.4	18.9
3c-No.	23	18	4	21	7	4	1	3	6	3	23	2	8	2	16	5
%	—	78.3	17.4	91.3	30.4	17.4	4.3	13.0	26.0	13.0	100.0	8.7	34.8	8.7	69.6	21.7
Totals	200	155	41	150	61	63	48	20	97	34	196	51	116	97	64	40
Averages		77.5	20.5	75.0	30.5	31.5	24.0	10.0	48.5	17.0	98.5	25.0	58.0	48.6	32.0	20.0
Dark No.	25	0	0	25	3	2	6	0	0	14	17	5	15	10	12	3
%	—	0	0	100.0	12.0	8.0	24.0	0	0	56.0	68.0	20.0	60.0	40.0	48.0	12.0

1 Dead and live flies.
2 M = moist, sl. = slightly moist, no standing water sheen, D = dry or slightly damp.
3 Fungi refer to areas with hyphal material visible with the naked eye. Areas visibly lacking fungi almost certainly have small growth of fungi. Section 1 refers to points 1-6 on Fig. 1. Section 2a extends from beyond point 6 to beyond point 8, Section 2b extends from beyond point 8 to a few yards beyond point 10, Section 3a extends from beyond point 10 to near point 13a, Section 3b extends from 13a to 16, and Section 3c from point 16 to 19 Fig. 1.

Organisms From Lehman Cave

A. Producers-Autotrophs synthesizing carbohydrates from CO_2 using light energy.

Algae

Class Myxophyceae - blue green algae

Anacystis montana (Lightfoot) Drouet and Daily forma *montana* (Drouet and Daily)

Schizothrix calcicola (C. Agardh) Komont

Oscillatoria Vaucher sp.

Anabaena Bory sp.

Coccochloris Sprengel sp.

Class Chlorophyceae - green algae

Mugeotiopsis calospora Palla

Chlorococcum humicola (Nageli) Rabenhorst

Protococcum viridis Agardh

Nannochloris Naumann sp.

Roya anglica G. S. West

Tentative identification

Cosmarium corda sp.

Chlorella vulgaris Beijerinck

Coccomyxa dispar Schmidle

Palmella miniata Liebl.

Class Bacillariophyceae

Navicula - 6 species of naviculoid diatoms

Coscinodiscus Ehr. sp.

Mosses

Physcomitrium sp.

Campylium chrysophyllum (Bird) J. Lange

Pohlia wahlenbergii (Web & Mohr) Andr.

Amblystegium serpens (Hedw.) BSG

3 others unidentified, moss species had to be determined on vegetative characters since no sporophytes were present, and capsules are rarely formed.

Liverwort - 1 species

Ferns

Cystopteris fragilis (L.) Benth. var. *fragilis*

Asplenium sp.

B. Producers - Chemotrophs - derive energy from chemical reactions in the absence of light. *Leptothrix* sp. - iron bacteria.

C. Primary Consumers - utilize plant food for energy

Members of the Phyla Flagellata, Sarcodina, Ciliophora, Rotifera, Annelida, and Arthropoda were identified by the Drs. Wheeler. Oribatid mites, Collembola (three species *Entomobrya marginata* Tullberg, det. D. L. Wray, USNM; and two others unidentified), three species of flies (*Bradysia* sp. det. R. J. Gagne, USNM; *Megaselia* sp. det. W. W. Wirth USNM; *Psychoda* sp.), and one beetle were identified. A Psyllipsocidae, *Psyllipisocus ramburii* Selys-Longchamps (det. E. L. Mockford, Ill.) is from a family of known cave-dwellers which feeds on fungi, pollen and dead insects. Of the larger trogloxenes. only *Peromyscus maniculatus* (deer mouse) and *Eutamias* sp. (chipmunks) were seen (G. Ralston).

D. Secondary Consumers - eat herbivores

Sixteen species of protozoans were tentatively identified, but many of these are also primary consumers. The pseudoscorpion *Microcreagris grandis* (det. R. R. Bridgeman) and four species of spiders belong to the carnivores. Of the insects, there were fleas (Dolichophysillidae), bat flies (Streblidae), and *Culicoides* sp. (det. W. W. Wirth USNM). A moth of the family Tineidae, probably *Amydria* sp. (det. D. R. Davis, USNM) of uncertain food habit was fairly abundant. Bats were scarce and thought to be mainly insect eaters.

E. Reducers - Large numbers of fungi occur throughout the Cave on moist walls, dead organic matter, dead flies and on stalactites. Bacteria were common in the pools which dry during winter. The slime bacterium *Dictyostelium* sp. occurs on walls and *Stemonites* sp. the slime mold is common on wood. Chytrids live on dead algae and pollen.

Pack rats were once common in the Caves before the lights were installed. Deposits of pack rat dung over a foot deep remain as evidence of their importance in the Caves in the past. Beetle galleries and frass are common under old dung and another type burrows into the pellets, but no beetles are known to be active in the dung of the Caves today.

During the early solution stage when flowing water was eroding the Caves, plant

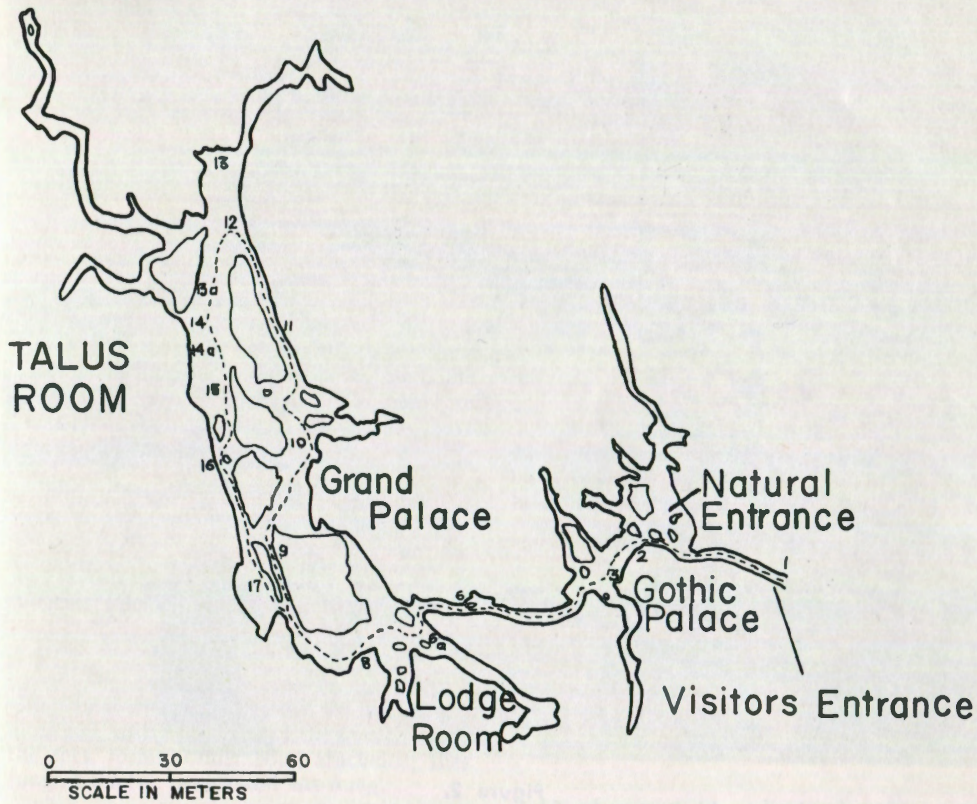


Figure 1.

Map of Lehman Cave. The entrance section (1) extended from numbtrs 1-6 Section 2 (2a, 2b) extends from beyond point 6 to beyond point 10 and Section 3 (3a, 3b, 3c) extends beyond point 10 to a few yards beyond point 19 (see Table 1).

and animal life may have been transported through the Cave. If fish lived in the Cave at earlier times, no evidence of their past has been found and no fish live there today, probably because the low energy level of the entire system is inadequate to support fish. As the Cave became drier, pack rats, bats and other organisms spent part of their lives there. After the lights were introduced, the slow colonization by plants and microscopic animals from spores began. The pack rats left, and the present trogloxenes do not concentrate their dung.

Today there are 12 types of microecosystems known to exist in Lehman Cave. These are called "microecosystems" because they are small in areal extent. Some are also "terminal" such as the dung ecosystems since no new dung is being added. Once the dung has no food supply left to support organisms, the dung microecosystems will cease to exist. Others are "pseudo" because they depend on food brought in from the outside and lack any producers to perpetuate food production within the Cave (dung). Even the true microecosystems are not permanent since two or three weeks with the lights left off or herbicide treatment would damage the green plants and create unsightly brown patches.

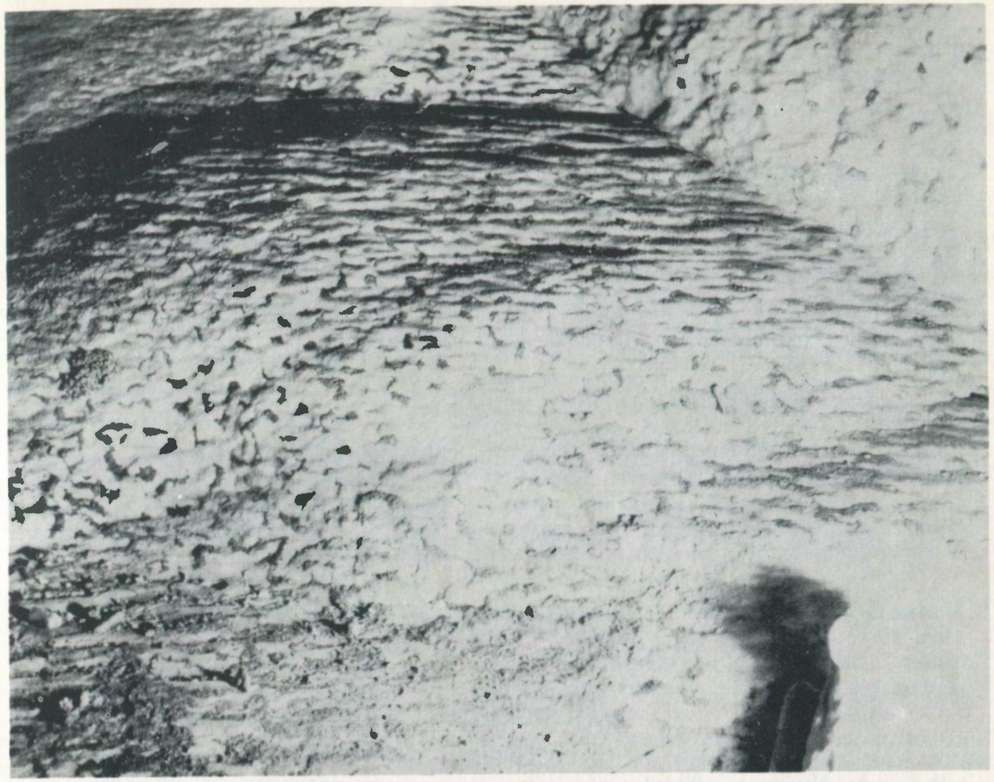
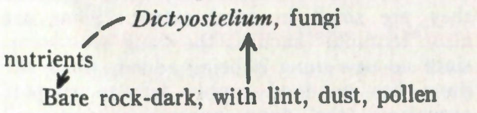


Figure 2.

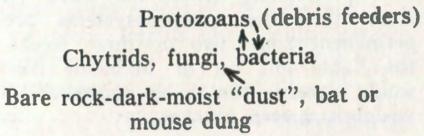
"Flow dust," a material composed mostly of diatoms with bits of soil may be dry and no longer active, brown and moist (dead), or green and alive. Oligochaete worms live within the flow dust and presumably eat diatoms.

The microecosystems of Lehman Caves are:

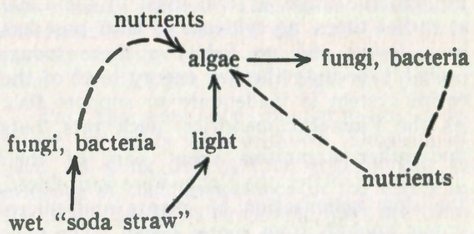
1. Bare rock, slightly moist, in the dark with fungi, bacteria, living and dead insects, lint, pollen, dust. This is the habitat of *Dictyostelium* sp.



2. Moist rock in dark with fungi, Protozoans, bacteria, living on moist dust of dead insects, pollen, lint, bat and mouse dung.

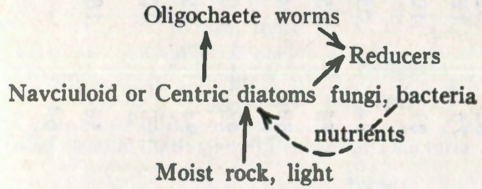


3. "Soda straws," wet, with fungi, bacteria, or if in lighted areas there may be algae, some energy may come from organic or inorganic compounds in the water.

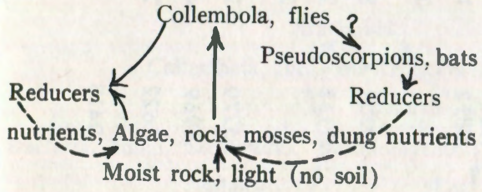


4. Moist rock in light with brown (dead) and green (live) flow dust containing minute

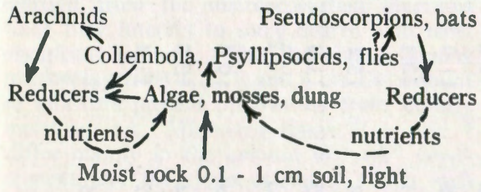
naviculoid diatoms as the producers and Oligochaete worms as consumers with bacteria and fungi as reducers.



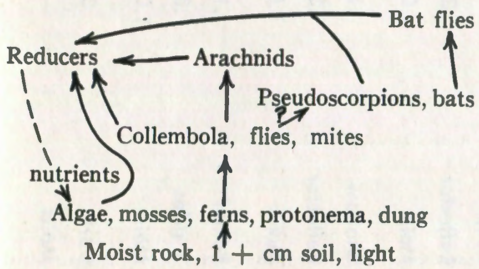
5. Moist rock in light with algae, some diatoms, no flow dust. Collembola, fungi, and bacteria are usually present with mouse or bat dung (small amounts). Rock may have mosses and liverworts.



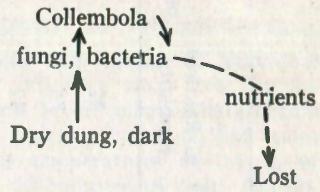
6. Moist rock in light with 0.1 to 1 cm or more soil, with algae, any of the mosses except the rock forms, Collembola, arachnids, flies, fungi, bacteria, mouse and bat dung.



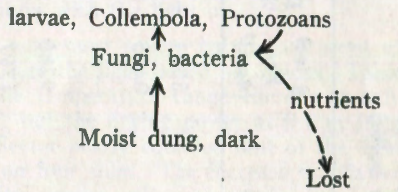
7. Moist rock in light with soil 1 to many centimeters deep, with algae, mosses. and ferns. Collembola, arachnids, flies, fungi, bacteria, dung (recent).



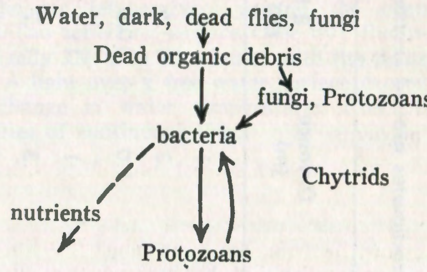
8. Dry dung (moisture under 8%) in dark with fungi and bacteria (beetle galleries and frass may no longer be active), terminal and "pseudo."



9. Moist dung in dark (moisture 12%+), with larvae and Protozoans feeding on fungi, bacteria — terminal and "pseudo," Collembola may be present.



10. Aquatic habitats in the dark with dead flies supporting fungi and chytrids, floating on water surfaces, dead organic matter settles to the bottom and provides food for bacteria, Protozoans, chemotrophic iron bacteria are often present (not terminal as long as organic debris is added).

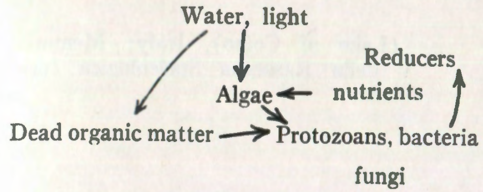


11. Aquatic habitats (pH 7.0-8.2) in light with algae, dead organic matter such as flies,

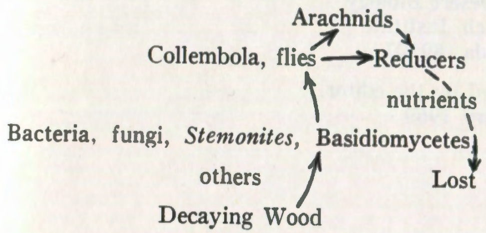
Table 2. Microclimates around Lehman Cave lights (100 watt bulbs)

Light Type	Distance (m)	Temperature °C 8 hrs. Off	On	10 min. Range	g lost hr/ (4cm)²	Drying Power % Water loss, 4 hrs.	Light f. c.	% Relative Humidity	Wind m/sec.	Moisture %
Open	.1	10.6	13.5	2.9	.3051	75.5	200	82	.10	—
Moist	.3	10.6	11.3	0.7	.0425	86.7	100	75	.10	7.4
	1.0	10.6	10.1	-0.5	—	36.2	20	82	.10	—
Boxed	.1	11,2	22.5	11.3	.9280	89.9	360	78	.38	—
4 Sides	.3	11.2	11.3	0.1	.1797	42.7	280	55	.22	5.0
Moist	1.0	11.1	10.6	-0.5	.1622	34.5	18	47	.08	—
Deep	.1	10.6	10.2	-0.4	.0391	7.4	200	82	.08	—
Reflector	.3	10.6	11.0	0.4	.0812	18.9	340	75	.12	6.0
Moist	1.0	10.1	10.1	-0.6	—	36.4	20	81	.10	—
Shallow	.1	10.4	15.1	4.7	.2731	80.0	180	94	.05	Moist
Reflector	.3	10.5	11.8	1.3	.1158	22.6	600	75	.05	Rock
Moist	1.0	10.5	10.2	-0.3	—	36.6	150	88	.04	—
Boxed	.1	11.4	19.6	8.2	.5270	79.9	340	96	.10	—
3 sides	.3	11.4	13.8	2.4	.1969	40.1	170	94	.05	5.1
Moist	1.0	11.2	11.4	0.2	.1622	26.3	22	100	.10	—
Dark	0	10.6	—	—	.0413	9.9	—	58-	.18	6.6
Moist	—	—	—	—	—	—	—	64	—	—

bats, wood, algae, dung providing food for Protozoans, bacteria, fungi, chytrids. May have iron bacteria.



12. Decaying wood (moist) in dark or light with a variety of Basidiomycetes including *Marasmius* sp., slime molds (*Stemonites* sp.), flies, Collembola, bacteria, arachnids. Fruiting bodies have Diptera larvae (terminal).



Most transients (mice, chipmunks) are omitted from the microecosystem diagrams since they interact to some degree with most organisms present. The differences among microecosystems 1, 2, 3, and 4 are the amount of moisture present progressing from slightly moist to wet. Microecosystems 5, 6, and 7 differ mainly in the amount of "soil" development and the types of plants which each can support. Microecosystems 8 and 9 differ in their moisture content while 10 and 11 differ in the presence or absence of light. Collembola occur wherever it is moist and there are fungi, algae, or mosses of sufficient extent and concentration (4x4 cm) to support them. They are most abundant 30 to 70 cm from the lights and rarely occur on steep, wet flowstone.

Microclimates Around Lights

The positioning and wattage of individual lights strongly influence what lives in the Caves. The most severe microclimate occurs around a light which is boxed on four sides resulting in air temperatures at 0.1 m of 22.5° C after 10 minutes of light (an increase of 11.3° C in 10 minutes), with a loss of 89.9% of surface moisture in four hours or 0.928g/hr. (Table 2). No plant life occurs at this light because of the sudden temperature and humidity fluctuations and the drying power of the air when the lights are turned on. The relative humidity around the boxed light dropped from 98 to 58% in 30 minutes with the light on.

The next most severe habitat occurred at 0.1 m from the light boxed on 3 sides (Table 2). The temperature range there was only 8.2° C, but the drying power at 0.1 m from the reflector nearly equalled that of the light boxed on four sides. The increase in relative humidity occurs when slow air flow and heating allows rapid evaporation.

All other light positions studied had lower temperature ranges, less evaporation and considerable plant life at 0.1 m to 2 m distance. The cool temperatures (10.2 - 11.0°C) produced at the deep reflectored light were ideal for moss growth, while the warmer temperatures (15.1°C) and fast drip rate at the shallow reflectored light favored algae.

The air temperatures around the open light (no reflecting surface close by) fluctuated only 2.9°C in 10 minutes with the lights on. A light over a free water surface caused no change in water temperatures after 30 minutes of continuous light.

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