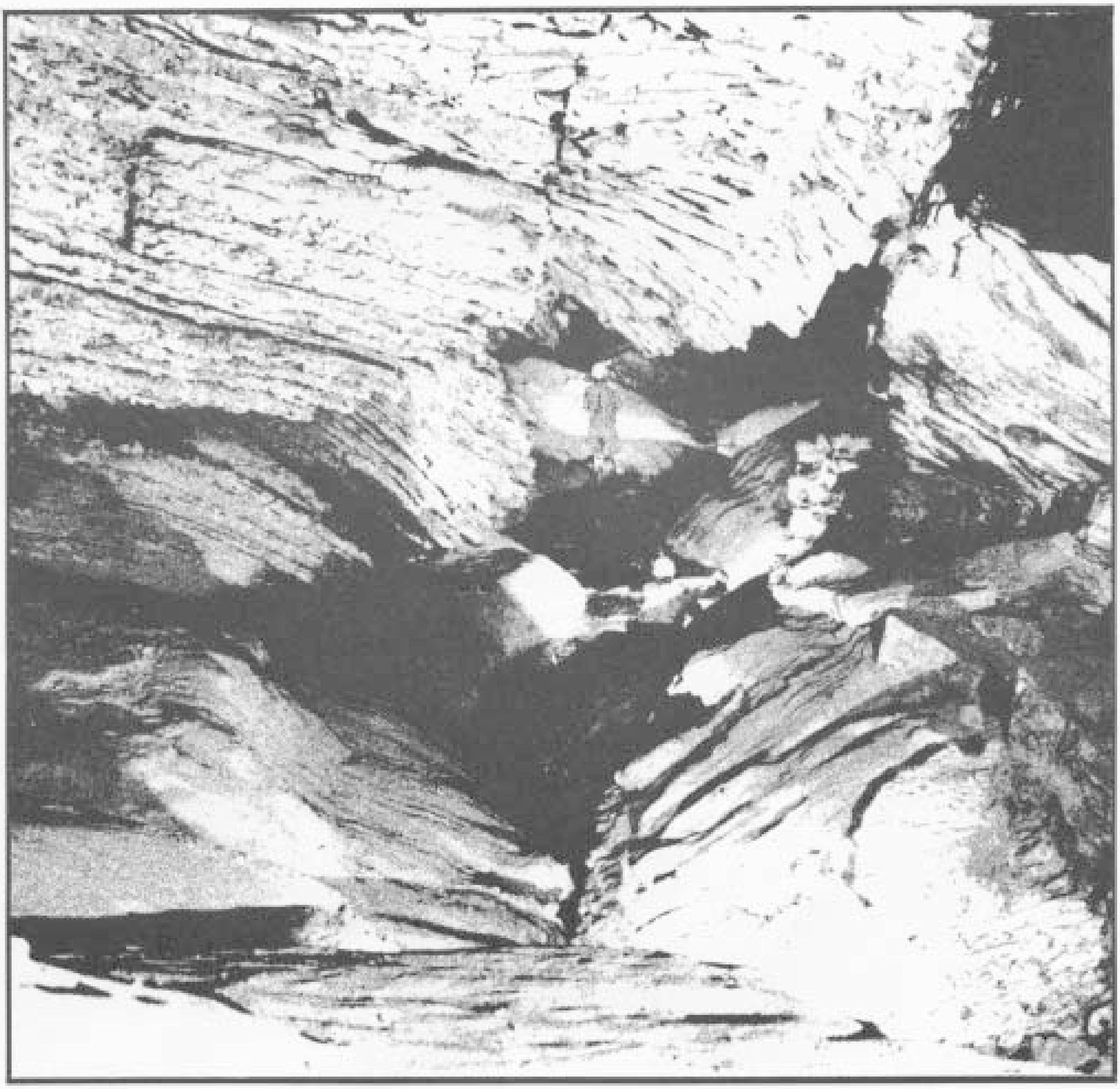
# pholeos

the wittenberg university speleological society

vol. 2, no. 1 • dec. '81



The Wittenberg University Speleological Society is a chartered internal organization of the National Speleological Society, Inc. The Grotto received its charter in May 1980 and is dedicated to the advancement of speleology, to cave conservation and preservation, and to the safety of all persons entering the spelean domain.

Cover: Tawney's Cave, Giles County, Virginia (photo by Hobbs).

# pholeos

Grotto Address
c/o H.H. Hobbs III
Dept. of Biology
Wittenberg University
Springfield, Ohio 45501
513/327-7029

Editor
Lynn Morrill
641 N. Wittenberg Ave.
Springfield, Ohio 45501

Subscription Rates
One volume: $3.00 (two issues)
Single issue: $1.50
Send to Grotto address.

Exchanges
Exchanges with other grottos and caving groups are invited. Please mail inquiries to Grotto address.

Meetings
Second Wednesday each month, 7:00 p.m., Room 206, Science Building, Wittenberg University, Springfield, Ohio.

Grotto Officers
Jane Bush, Chairman
633 Woodlawn Ave.
Springfield, Ohio 45501

Lynn Morrill, Vice Chairman
641 N. Wittenberg Ave.
Springfield, Ohio 45501

Terry Madigan, Secretary
901 Woodlawn Ave.
Springfield, Ohio 45501

Bill Simpson, Treasurer
222 Deardorff Ave.
Springfield, Ohio 45503

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# Editor's Letter

Welcome to the first issue of our second volume of Pholeos. Wittenberg's Speleological Society has compiled an interesting variety of literature and art work for your reading and studying pleasure.

Thanks to the efforts of Horton H. Hobbs III, we have a continuation of our survey of Ohio caves. The five described in this publication are in Adams and Ross counties. A second article on cave ecology provides an excellent overview of the zonation of caves and their flora and fauna. Other major articles include a completed map of Laurel Cave and an update on the survey of the caves of Carter County, Kentucky.

The caving club has had an active season pursuing the ongoing surveys of caves of Ohio and Carter County, Kentucky. Several trips to Freeland's Cave, Adams County, and one to Bat Cave, in Carter Caves State Park, were the primary projects fall term. Other activities of the club included surveying and mapping sessions, and an afternoon of rapelling off the rock ledges in Cliff Park.

Our spring publication will contain further investigations of both Ohio and Carter County caves including the intriguing studies of Freeland's Cave, one of the longest caves in the state. There will also be a report of tropical caves on San Salvador Island, the Bahamas.

I would like to offer my sincere thanks to everyone who contributed to this issue and its publication. I would also like to extend my thanks to the reader, who through his purchase of Pholeos has helped to support this grotto.

# Book Review

--by T.J. Madigan

A Geological Guide to Mammoth Cave National Park (Palmer, Zephyrus Press, 1981) 210 pp.

A Geological Guide to Mammoth Cave National Park is an excellent manual to the Flint-Mammoth Cave system. The author, having over 25 years of caving experience, does a thorough job of describing this system. He reviews in detail the geology of the region and how caves and cave formations come about. He then applies this information to the Flint-Mammoth Cave system. In the course of the book he answers the following questions: 1) How did the system form? 2) How old is it? 3) Why does it look the way it does? and 4) What do the rocks tell us? Palmer utilizes geologic rock formations and time scales to present the material in a precise yet nonscientific, manner.

The final section of the book introduces the reader to the cave tours that the United States Park System offers in the cave system.

The book contains over 100 maps and photographs, thus forming an excellent text of the park as well as one applicable to many other caves in the world.

# Erratum

In Vol. 1, No. 1 & 2, appeared a map on page 20 of Frost Cave, Pike County, Ohio. The scale was incorrectly indicated to be in kilometers. It should be in meters.

# bat cave

--by Donna D'Angelo and Kathy Crowley

(Editor's Note: One of the primary expeditions of the fall term was a weekend trip to Bat Cave in Carter County, Kentucky. During the trip several new members of Wittenberg's Caving Club acquired first-hand experience in surveying and mapping this relatively uncharted cave. The two surveying teams mapped the entire length of both levels of the cavern. This entailed wading through the stream, creeping up, around, and over rock formations, investigating tangent passages, and even crawling along on their stomachs in areas where the height was only 0.3-0.4 meters.

The grotto is now working on putting together all the information obtained. However, a return trip to complete the preliminary data may be delayed until spring since the cave is inaccessible during the winter months while the Indiana bat is in hibernation. The following letter provides a brief overview of what one might expect to find upon entering Bat Cave.)

Hi! My name is Herman, the friendly bat that lives in Bat Cave. Located in Carter County, Kentucky, Bat Cave has recently been declared a natural preserve for an endangered species of Indiana bats, of which I'm a member. The front entrance to my home is barred off to prevent the free passage of people who might irritate or disrupt my night life. Once past the front entrance, one finds oneself in a spacious, airy cavern. Continuing down the main passage one is faced with the difficult decision of whether to take the high road or the low road.

The upper tier is undoubtedly the drier of the two passages. Along the way crystalline formations, rimstone dams, stalagmites, stalactites, columns and domes can be found. The domes, which are found mainly in the larger caverns, provide such perfect

accomodations that we often congregate within them. Caution is advised for all non-flying species, for an occasional pit can be discovered leading down to the lower tier.

If by chance you decide to venture into the lower tunnels, be prepared for a case of wet feet. A meandering stream flows through the majority of the passage forming occasional pools and puddles. While displaying a variety of formations, such as flowstone, rimstone dams, and stalactites, not to mention breakdown, none were so impressive as those found in the upper passageway. However, several unique rooms appear to house a majority of my bat friends and provide the perfect bat "hangout." Moving along, one will eventually come upon the exit, or back entrance, which is also barred to protect us furry little guys and gals.

I hope you enjoyed the tour through my home--Bat Cave--and found it interesting. Keep in touch, for there are many cracks and crevices yet to be explored. ■

# 5 ohio caves

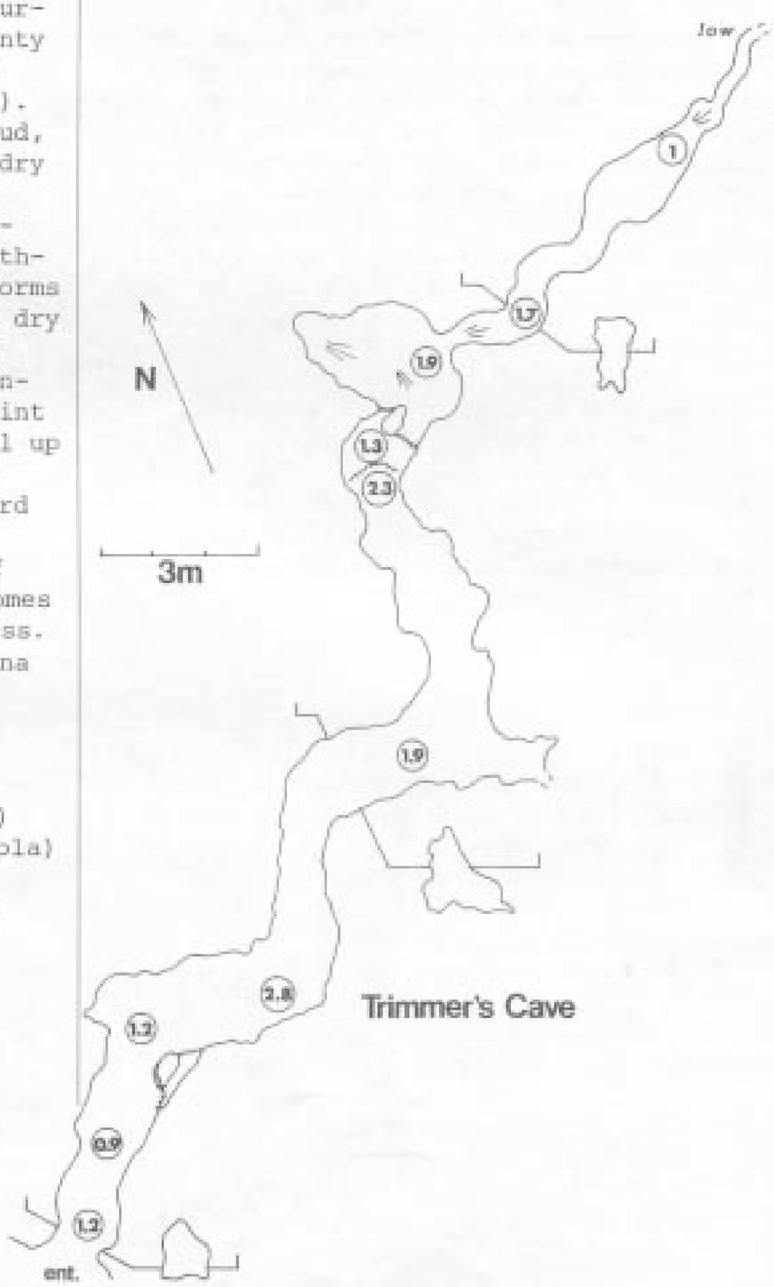
--by H.H. Hobbs III and Michael Flynn*

Trimmer's Cave (also Fisher's or Lyndon Cave) is a small (38m THC) joint-controlled cave which has formed in limestone only a few meters below the surface near the top of a hill in Ross County overlooking a tributary ravine to Paint Creek at an elevation of 206m (680 feet). The passage is sinuous, is floored by mud, and the walls are partially covered by dry flowstone.

The cave is entered as a hands-and-knees crawlway. This extends to the northeast for 4m where an enlarged passage forms a small, elongated room 2.8m high; some dry flowstone is present on the south wall. This leads to a narrow passage which continues in a northeast direction to a point where the passage constricts and a crawl up through a "window" leads one to a small room. The floor of the room slopes upward to the ceiling, but a narrow passage extends in an easterly direction out of this chamber for 8m. Here the cave becomes too low and narrow for continued progress.

The following is a list of the fauna known to occur in Trimmer's Cave:

Hyloniscus riparius (Isopoda)
Sinella cavernarum (Collembola)
Hypogastrura denticulata (Collembola)
Onychiurus pseudofimetarius (Collembola)
Ceuthophilus brevipes (Orthoptera)
Ceuthophilus gracilipes (Orthoptera)
Hesperochernes sp. (Arachnida)
Leiobunum bicolor (Phalangida)
Meta menardi (Araneae)
Peromyscus leucopus (Rodentia)



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*Present address: Department of Biology, P.O. Box 42451, University of Southwestern Louisiana, Lafayette, Louisiana 70504.

The Preston Caves (I, II, and III) are developed in the dolomitic limestone of Adams County, Ohio. The caves are fairly small, the largest being Preston Cave III with 43m total horizontal cave. Total horizontal length for Preston Caves I and II is 14m and 15m, respectively. All the caves are characterized as joint-controlled passages (see maps).

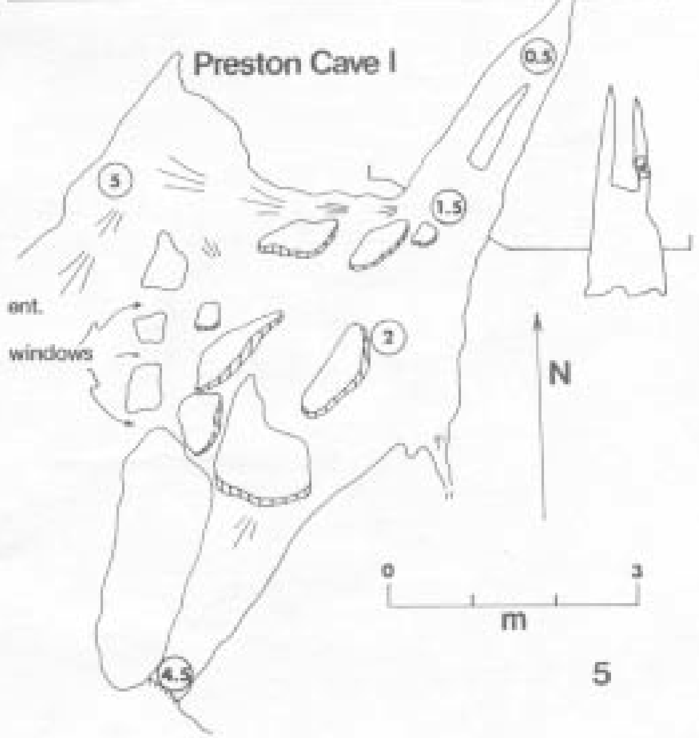
Entrances to the caves are situated approximately 24m (80 feet) below the crest of a cliff running east-west along a ridge lobe overlooking the distant Ohio River (see photograph). Each of the entrances consists of an inclined passage in a crevice on the cliff face followed by a fairly level main passage trending perpendicular (NNE) to the cliff. Preston Cave I is the westernmost one, with an entrance located 53.5m west of the entrance to Preston Cave II. The entrance to Preston Cave II is located 20m west of Preston Cave III. All the entrances occur at an elevation of approximately 242m (800 feet). The Preston Caves are dry with some development of speleothems, the most notable occurring in Preston Cave III; this cave has considerable drip input approximately 20m into the passage.

Preston Cave I consists of a room entered from the west by a walk-up entrance and from the SSW by an entrance elevated 6.5m from the base of the cliff. A short crawlway passage extends from the room in a NNE direction. Three "windows" overlook the walk-up entrance from the east side of the room. Some popcorn and a little flowstone is seen in the room and the passage.

Preston Cave II consists of a single passage extending approximately 13m from the entrance. Entry into the cave is the most difficult of the three due to the very steep, narrow crevice at the entrance. A small pool containing mosquito larvae and collembola is seen in a solution pocket on the right (SE) side of the passage approximately five meters from the entrance. Very limited development of flowstone and popcorn occur in the cave. Skeletal remains of the Turkey Vulture (*Carthartes aura*) were found one meter beyond the pool and at the rear of the cave, suggesting possible habitation of the cave by this bird.

Preston Cave III is the largest of the caves, with a main passage extending approximately 32m from the entrance before becoming too narrow for further progress. Approximately 17m from the entrance the passage slopes downward somewhat. At the bottom of this slope a large accumulation of guano, presumably of the cave rat (*Neotoma floridana*), has built up in the main passage and in a small side passage to the right (SE). Immediately beyond this is an area of extensive soda straw development. The soil character of the cave changes distinctly from mud to a very dry floor 28m from the entrance. At this point a small side passage extends for a short distance to the right (SE) from the main passage before becoming too narrow to negotiate. Fifteen meters from the entrance a passage extends to the left (NW) of the main passage for approximately four meters. At this point the cave slopes

(continued)



upward to another room. However, a flowstone extension from the wall prevents entry into this passage. In addition to soda straws and flowstone, some development of popcorn is observed.

A recent article (24 April 1980) in "The People's Defender" (West Union, Ohio) describes an event in which two men being held for burglary escaped from the Adams County Jail and were eventually apprehended when officers noticed smoke issuing from the entrance of one of the Preston Caves in which the two men had been hiding.

The following is a list of the fauna known to occur in the caves.

Preston Cave I:

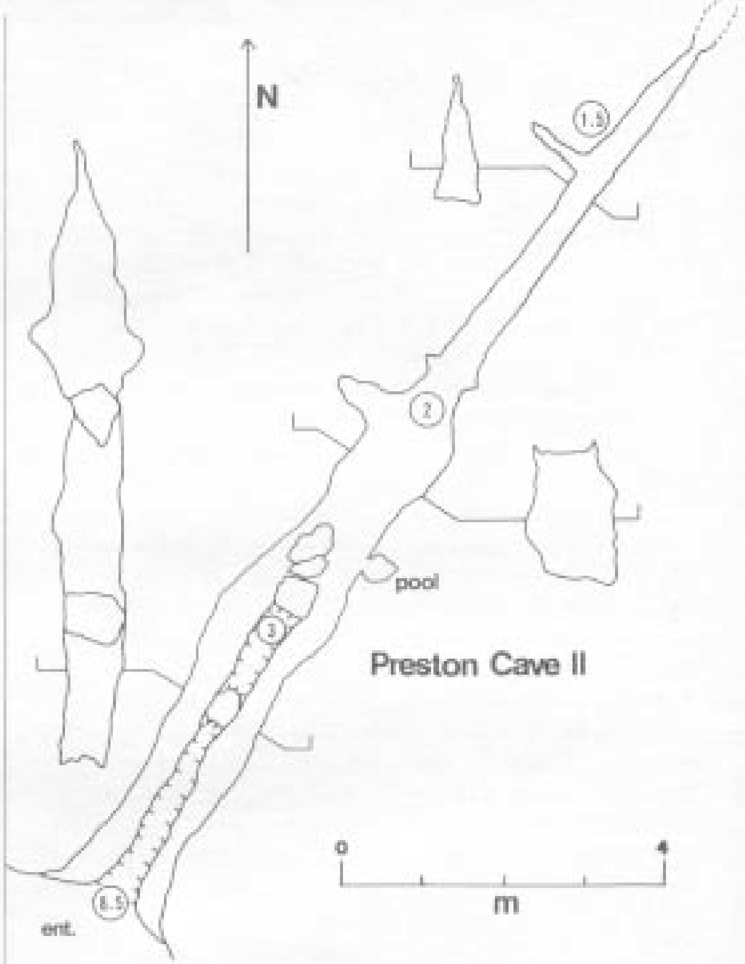
- Tomocerus flavescens (Collembola)
- Coleoptera (unidentified beetle)
- Diptera (unidentified fly)
- Leiobunum bicolor (Opilionida)
- Pedentontus sp. (Thysanura)
- Ceuthophilus gracilipes (Cricket)
- Sozibius pennsylvanicus (Centipede)
- Armadillidium nasatum (Terrestrial isopod)
- Meta menardi (Spider)

Preston Cave II:

- Pedetontus sp. (Thysanura)
- Tomocera flavescnens (Collembola)
- Diptera (unidentified fly)
- Coleoptera (unidentified beetle)
- Leiobunum bicolor (Opilionida)
- Pseudotremia sp. (Millipede)
- Ceuthophilus gracilipes (Cricket)
- Porcellio scaber (Terrestrial isopod)
- Carthartes aura (Turkey Vulture)

Preston Cave III:

- Tomocera flavescens (Collembola)
- Diptera (unidentified fly)
- Coleoptera (unidentified beetle)
- Pedetontus sp. (Thysanura)
- Leiobunum bicolor (Opilionida)
- Pseudotremia sp. (Millipede)
- Ceuthophious gracilipes (Cricket)
- Pipistrellis subflavus
- Neotoma floridana (?)



Preston Cave II

Preston Cave III

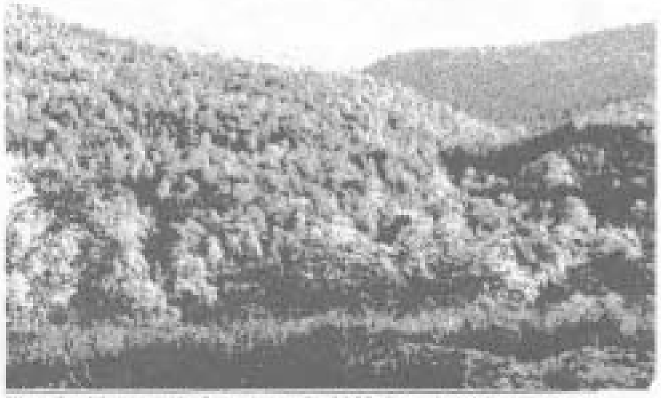
Devil's Den Cave is developed in the dolomitic limestone of southeastern Adams County, Ohio. The cave is small yet complex, and a total of nine entrances open on to the south face of Devil's Den Bluff overlooking the Ohio River. The cave has a total of 130m (429 feet) of passage and demonstrates an extreme joint-controlled pattern.

The eastern and westernmost entrances are 44m (144 feet) apart and lie approximately ten meters (33 feet) beneath the top of the ridge. The passages are "honeycombed" and intersect one another at right angles, being generally oriented NE-SW and NW-SE. They are floored by dry, sandy sediments.

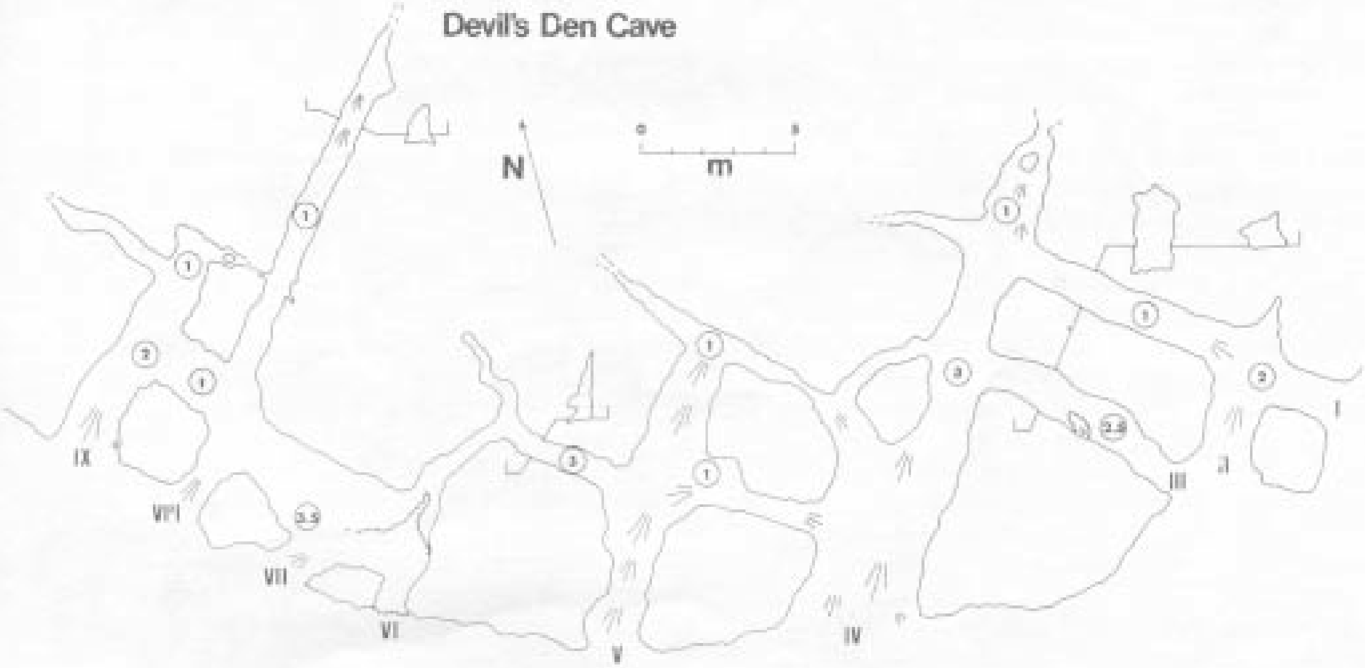
It is rumored by local residents that one passage formerly extended beneath Devil's Den Bluff and could be traversed to the north side of the ridge. The passages extending from entrances IV and VIII (see map) continue, but considerable digging is required to penetrate further into the cave.

The following is a list of fauna known to occur in Devil's Den Cave:

- *Porcellio scaber* (Terrestrial isopod)
- Diptera (an unidentified fly)
- Coleoptera (an unidentified beetle)
- *Ceuthophilus gracilipes* (Cricket)
- *Meta menardi* (Spider)
- *Sayornis phoebe* (Phoebe nest) ■



View looking south from top of cliff face in which Preston Caves are located (photo by Hobbs).



# cavefish threatened

(Editor's Note: The following newspaper article is reprinted to stress to the reader just how susceptible the cave and its denizens really are to the irresponsible activities of man. This appeared in the St. Louis Globe-Democrat on December 2, 1981.)

The St. Louis Zoo is sheltering rarely found cavefish, cave crayfish and grotto salamanders which were taken from Maramec Spring after toxic ammonium nitrate fertilizer leaked from a pipeline and left the spring nearly devoid of oxygen.

The chemical spill is potentially an ecological disaster for the spring near St. James, Mo., Dr. James Whitely said Tuesday. Whitely is superintendent of fisheries for the Missouri Department of Conservation.

By late Monday night, conservation agents had removed an estimated 70,000 small rainbow and brown trout from hatcheries fed by the spring, which is about 80 miles southwest of St. Louis.

The trout were moved to Montauk State Park in Dent County, about 70 miles south of St. James.

Charles H. Hoessle, deputy zoo director, said two dozen cavefish, two dozen grotto salamanders and about 100 cave crayfish were brought to the zoo in an effort to save the species. The crayfish, identified as Salem cave crayfish, are on the state's rare and endangered species list. The fish, salamanders and crayfish are white, but are not true albinos, he said.

Other survivors were taken to aquariums at Bennett Springs State Park near Lebanon, Mo.

The fish, believed to be southern cavefish, are about 2 inches long. They live in several underwater caves in Missouri but are not believed to inhabit the Meramec River basin until the spill depleted the oxygen in the spring and caused the stressed fish to rise to the surface, Hoessle said Tuesday.

Hoessle said the creatures, which are born without eyes, have a "good" to "excellent" chance of surviving and will be re-introduced to the spring as soon as the oxygen level is safe.

But Whitely and Ronald Crunkilton, a state water biologist at Columbia, said Tuesday that damage to other fragile organisms like fresh water shrimp, a fish food item in the spring, may be so extensive that the species may never be able to return to the spring.

Joel Vance, conservation department spokesman, said his department does not know the extent of the spill, which took place about 12 miles southwest of Maramec Spring and was reported Nov. 14.

The leak was traced to the pipeline operated by the Williams Pipeline Co., of Tulsa, Okla., Vance said. The pipeline extends from Tulsa through Missouri into Illinois and Indiana. It carries liquid ammonium nitrate and urea for fertilizer. Several chemical spills and fish kills have resulted from leaks in the pipeline in Missouri since 1977, Vance said.

Officials from Williams Pipeline reported that about 2,000 to 3,000 gallons of ammonium nitrate leaked into the ground, but others contend the spill may have been as high as 100,000 gallons, conservation officials said.

In 1978, the company paid Missouri

and two counties $23,453 in fines and expenses to the state for three spills, officials said.

Roy Wilkens, vice president of Williams Pipeline, said, "We're assuming responsibility for the spill."

Wilkens said the pipeline could not have been leaking for more than six days and said company officials are removing fertilizer left in the Dry Fork River near the pipeline.

Vance said the ammonia compounds are apparently oxidizing in the spring, robbing the water of oxygen and causing organisms to suffocate.

Cold-water fish, like trout, require about 8 parts per million of oxygen in water to survive. By Monday, the oxygen level in the spring had dropped to less than .2 parts per million, officials said.

Conservation agents said they have no idea how many fish were killed because most sunk to the bottom.

As an emergency step, conservation agents began pumping oxygenated water into the spring to bring oxygen levels back up.

State Conservation Agent Eldred Gallagher, who operates the fish hatchery at Maramec Spring, said the water in the stream below the spring appears to have normal oxygen levels and the winter trout fishing season should open there on Dec. 12.

Maramec Spring is operated jointly by the state and the James Foundation, a trust from an old mining family.

A large number of mottled sculpins and darters, small fish found in Ozark streams, were also killed by the leak.

Crunkilton said it could take years for the chemicals to be removed from ground water in the area.

"This is the most extensive underground example of pollution in Missouri," Crunkilton said. ■

# laurel cave

--by Nathan Pfeffer, T.J. Madigan,
and H.H. Hobbs III

Laurel Cave, one of many karst features located within the boundaries of Carter Caves State Park, Carter County, Kentucky, is a small (total horizontal cave: 1091m, or 3600 feet), bilevel subterranean conduit which receives considerable quantities of storm waters from Horn Hollow to the north. Horn Hollow is a perched karst valley and is a tributary to Cave Branch, a small stream that disappears underground and reappears three times prior to its confluence with Tygarts Creek, the only major surface stream in the area. The largest of the three entrances to Laurel Cave is located adjacent to the east bank of Cave Branch, approximately 100m downstream (south) from the entrance to $H_2O$ Cave at an elevation of 230m (760 feet). The passages are developed primarily in the Ste. Genevieve limestones of Mississippian age. Since this cave is located on State property, written permission must be obtained from the park office prior to entering.

The largest (main) entrance (5m high by 26m wide) is quite picturesque and is floored by large slabs of breakdown. Approximately 50m into the cave the main passage turns strongly to the left. This passage becomes a high canyon with a dry, upper level intersecting at this point from the southeast. The lower main passage continues for approximately 240m in a northerly direction to a sinkhole entrance where storm waters enter from Horn Hollow. This passage, for most of its length, is a high, narrow, meandering canyon (see map) with a small stream flowing over the scoured bedrock. Along the stream course are a number of small, shallow pools, and the water disappears (during "normal" flow) approximately 65m from the main entrance. During periods of heavy rain, this small trickle becomes a raging torrent, and thus the lower levels of the cave should not be entered if rain is forecast.

The northern sinkhole entrance leads south to the main passage as well as to a series of low, muddy passages and rooms to the north and east. Presumably it is this portion of the cave that Jillison (1924: 28) referred to as having "a small

lake." During late January 1981, when the cave was mapped by WUSS, water levels were low, yet a number of extensive pools floored much of these passages. During the spring months, much of this area probably contains deep water.

Three isolated upper levels can be reached from the main canyon passage: 1) the previously mentioned one 50m from the main entrance (see below); 2) one approximately 110m upstream from the main entrance consisting of a short intermediate level passage which terminates in breakdown (surface downcut) and an upper, somewhat more extensive series of domes, rooms, and crawlways that are sporadically well-decorated with speleothems, and that overlook the lower and intermediate levels in three places; and 3) a dome with breakdown and small crawlways that can be reached from the main canyon passage approximately 30m dowstream from the northern entrance.

The largest upper level is a relatively extensive (approximately 280m) tubular passage, having a number of crawlways and loops and many speleothems (rimstone, cave pearls, stalactites, stalagmites, flowstone). Access is gained to this level by a climb (4.5m) up a large log that has been wedged into the canyon bedrock. The passage extends only 15m to the west where it terminates in breakdown, a result of surface erosion (downcutting of Cave Branch). By traversing approximately 200m in the opposite direction (southeast) the third entrance (1m high by 4m wide) is encountered, overlooking a small ravine in the cliff above Cave Branch (downstream from the main entrance).

Additional information concerning Laurel Cave, as well as other caves and scenic features of Carter Caves State Park, can be found in Jillison (1924), McFarlan (1958), and McGrain (1966). ■

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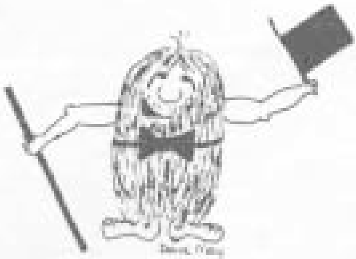
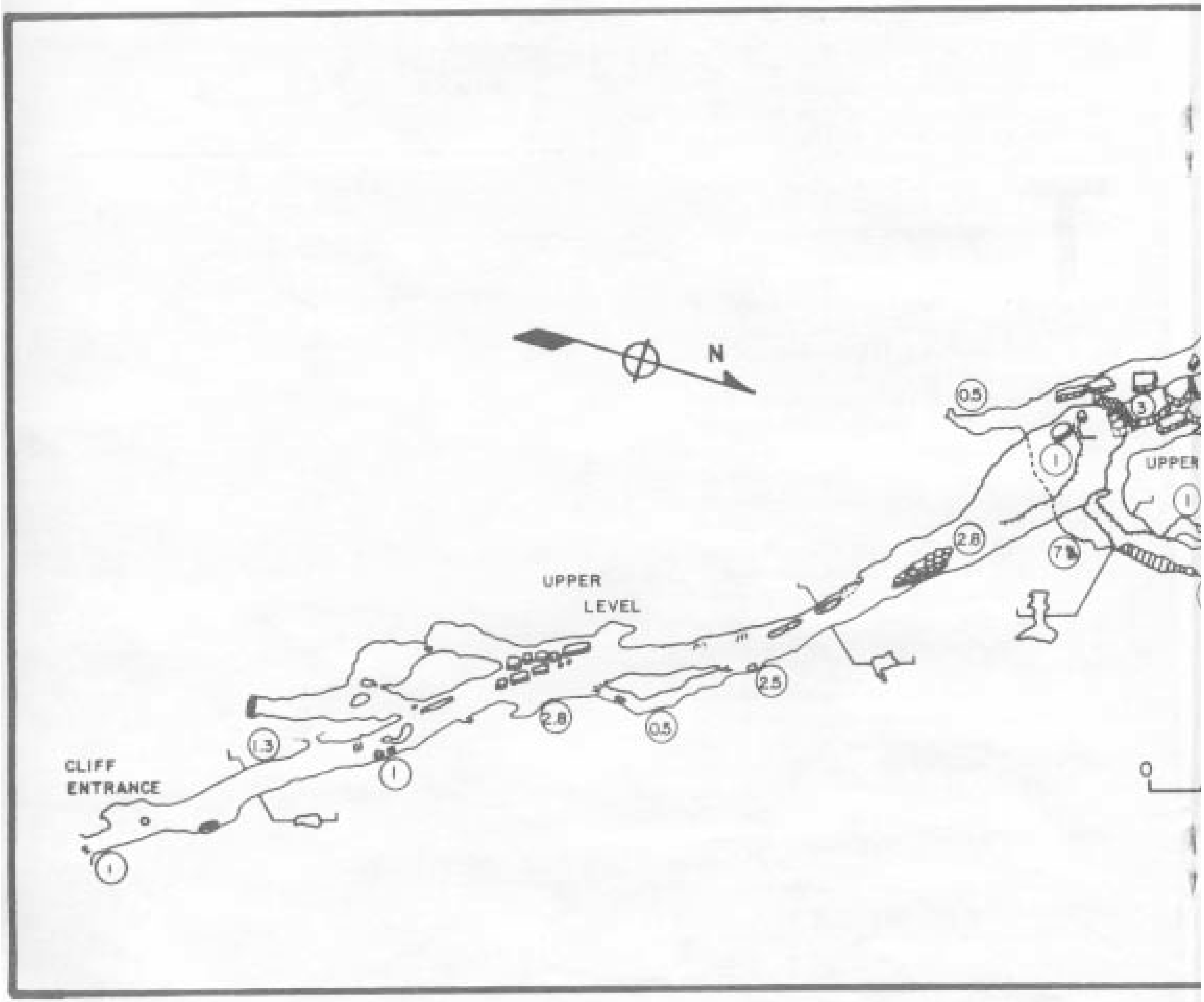
Jillison, Willard Rouse. 1924. Kentucky State Parks. Kent. Geol. Surv., Frankfort, Ky., 92 pp.
McFarlan, Arthur C. 1958. Behind the scenery in Kentucky. Kentucky Geol. Surv., ser. 9, Spec. Pub., 10:1-144.
McGrain, Preston. 1966. Geology of the Carter and Cascade Caves area. Kentucky Geol. Surv., ser. 10, Spec. Pub., 12:1-32.



A complete map of Laurel Cave can be found on the following pages.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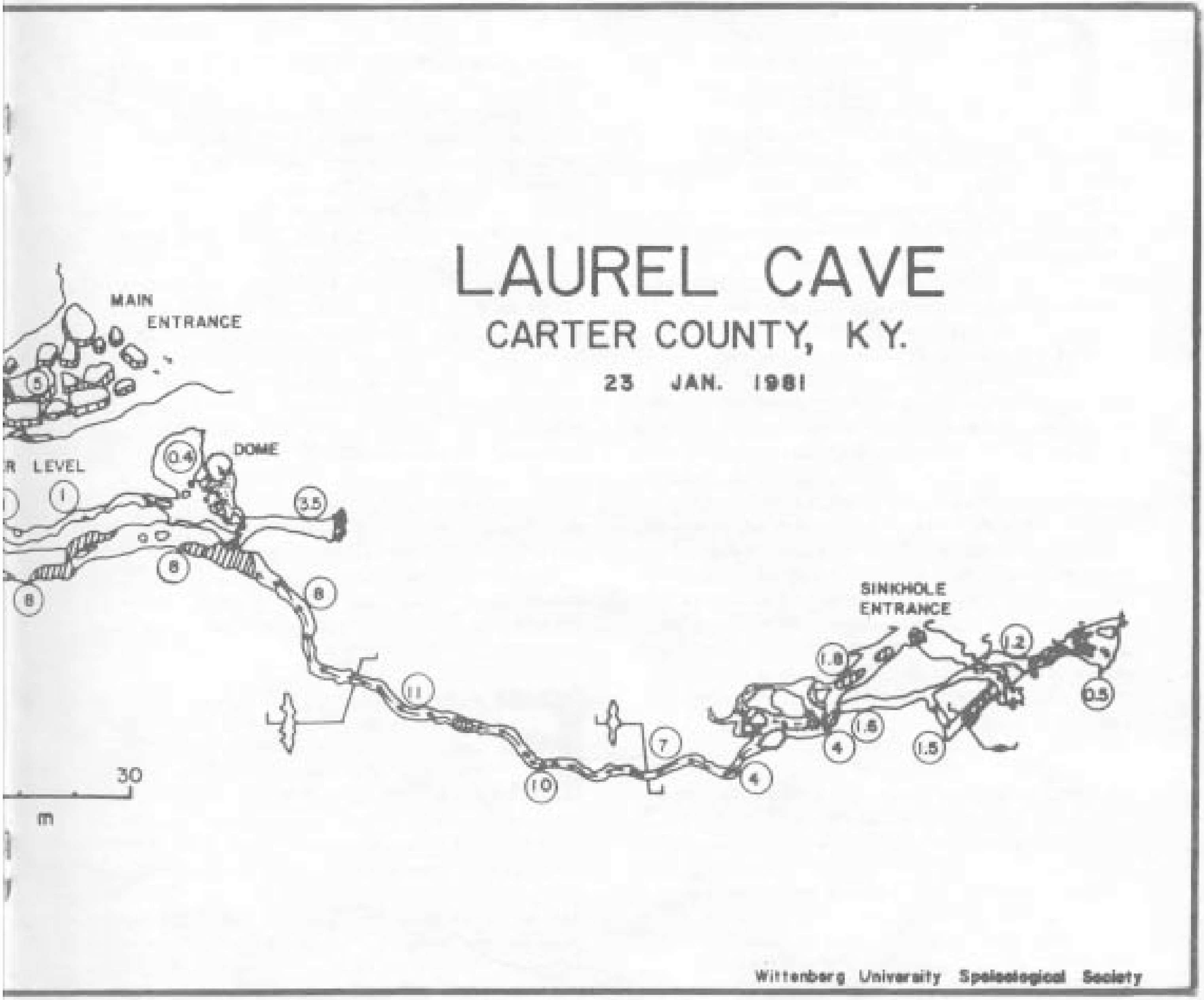
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Wittenberg University Speleological Society

# ecology of caves

--by H. H. Hobbs III

There are very few areas on the thin crustal veneer of the earth's surface that do not support life. Although caves are never exposed to the energetic rays of the sun, virtually all support varying forms of plants and animals. These life forms, functioning primarily as heterotrophs (consumers) depending ultimately on the surface for energy, have complex life histories, demonstrate intricate community dynamics, exhibit highly specialized adaptations for spelean existance, and are represented by numerous endemic species.

"In addition to 1) an absence of light, the physical environment of a cave is characterized by 2) comparative silence; 3) nearly constant temperature; and 4) in 'wet caves,' an unusually high humidity which, except near entrances, makes for an exceptionally low rate of evaporation. The degree of constancy, rate of change, and faunal abundance are dependent upon how much the cave is subject to epigean influence. This depends upon number and size of streams (input and output), size, number, and exposure of entrances, and configuration of entrance passages ..." (Hobbs and Burdsall, 1972:2). Many of these same conditions (particularly lack of light and food limitation) are characteristic of deep ocean systems, and because of these similarities analogy has been made for these two environments (see Poulson, 1971). In addition, it has been suggested by various authors (see Culver, 1970, 1971) that caves have similarities with islands (e.g. both are discontinuous habitats, both contain highly modified organisms, and both contain relatively low numbers of species).

This short discussion of cave ecology will present some of the physical and chemical aspects of the cave environment, define the ecological zones of caves, examine representative types of cavernicoles (cave-dwellers), and cave community energetics will be treated briefly.

In employing "community" there is an obvious misconception of the term as used in association with caves. Specifically, communities consist of organisms (producers, consumers, and decomposers) that exist in some state of dynamic equilibrium. Cave "communities" lack the external solar energy source and therefore, in fact, are lacking the producer trophic level (see below for a discussion of the minor role played by a few autotrophic bacteria). Thus, the majority of organisms living in caves are heterotrophic and are in reality only part of a larger, more complex community originating on the surface where light energy is available. That light energy is converted to chemical energy and is stored in plant biomass through complex biochemical processes collectively called photosynthesis. Green plants directly or indirectly contribute energy to the "cave community" as organic matter is brought into the cave environment. Hence, with appropriate reservation, the somewhat ingrained term "cave community" will undoubtedly continue to appear in the literature and will be used throughout this paper.

Ecological Zonation Caves can be separated into a series of zones, each of which is represented by a distinct set of chemical, physical, and biological characteristics: the threshold (Entrance and Twilight) and the dark (Variable-Temperature and Constant-Temperature) zones. The threshold zone (sometimes called the "Pro-epigean domain" or the "light zone"--Jefferson, 1976) extends from the surface opening of the cave to the furthest point to which daylight can penetrate. It is an area of the cave where physical factors are relatively variable. The environment in the entrance area is controlled by prevailing local climatic and meterological conditions and exhibits characteristics of both epigean systems (surface) and the cave interior (hypogean). Muchmore (1976) discussed the effects of cave entrances on the distribution of cavernicolous terrestrial arthropods (see also Ives, 1927 and Culver and Pouson, 1970). Progressing from the entrance, light intensity diminishes rapidly to the twilight zone; light obviously varies with time of day and with external conditions. Other parameters such as humidity and temperature are also similarly variable. Relative humidity increases and may vary from 10% to 100%, yet it is generally far more constant than that of the surface. Temperatures may range from -10 to +30°C in the entrance and from 0 to +20°C in the twilight zone of temperate caves. Even though these fluctuations occur, the threshold is considerably less variable than the exterior environment. The biota of these regions is the most diverse of any area of the cave. Both green plants and animals inhabit the threshold zone, and Poulson and White (1969) reported that the entrance area typically supports 100-300 species with a diversity index of 1.5 and a biomass (gram/hectare) of 1,000,000, whereas the twilight zone has up to 50 species, with a diversity index of 0.5 and a biomass of 300. These values are considerably higher than those of Ohio caves.

The variable-temperature dark zone is much more constant than the preceding zones. Darkness is undoubtedly the most important feature ecologically. The relative humidity is increased and varies from 30% to 100%, and temperatures commonly vary from 3° to 15°C. Barr (1967a) suggests that is is the evaporation rate and not the variation in temperature which is the most significant environmental parameter in this zone. Furhter discussion concerning variations and effects of temperature change may be found in Cropley (1965). The biota shows a great decrease in both numbers and individuals and species. The number of species is typically reduced to 10 with 0.2 diversity index and biomass ranges from 100 to 5000 g/ha (Poulson and White, 1969). This lower biomass reflects the scarcity of organisms as well as their small size.

The constant-temperature dark zone is characterized by relatively stable temperatures (air temperatures rarely vary more than 1°C throughout the year at any one place) which approximate the mean annual surface temperatures for the area, being largely dependent on latitude and altitude. Water temperatures are generally not as stable, being subject to change as a result of ice and snow melt and can be altered as flood waters flow through underground aquifers; fluctuations of 5°C or more may occur. The relative humidity is continuously high, ranging normally from 80% to 100%. Evaporation rates are consequently low, yet the air is not stagnant, as most caves generally ventilate continuously. The composition of air is usually similar to that in the epigean environment, although the concentration of carbon dioxide may sometimes be higher. In areas of caves isolated from moving water, elevated levels of carbon dioxide are occasionally found associated with clay beds; it may also accumulate at bases of shafts and in passages where there is little air movement and where there are deposits of organic debris.

It should be noted that the horizontal zonation described herein also can be applied to the vertical scale, however not so well defined: specific zonation, particularly within the threshold area, occurs as one passes down from the pit entrance into the cave below. Senger (1980) discusses the relationships between cave morphology and cave climate.

The characteristics of water in limestone-dolomite caves are quite variable. The waters of pools can be quite distinct from those of underground streams and in those waters supplied by the sinking of surface streams, both the chemical and physical features will be affected to some extent by surface conditions. Such streams

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generally contain higher concentrations of organic matter (allochthonous, CPOM, FPOM, and DOM), most of which is transported in from the surface, both as living organisms and as detritus which can provide a source of nutrients for cave-dwellers. Most cave waters tend to be alkaline (pH ranging from 7 to 8+) and have a high alkaline hardness. The biochemical oxygen demand is generally low, and, even in static pools, oxygen is at or near saturation values. Conductivity ($\mu$mho$\cdot$cm$^{-1}$) varies with temperature change but generally ranges from 50-600 $\mu$mho$\cdot$cm$^{-1}$ at 25°C. High values of phosphorous ($>50 \mu g\ PO_4-P\cdot l^{-1}$) and nitrate ($>100 \mu g\ NO_3-N\cdot l^{-1}$) usually indicate contamination by sewage or excessive use of fertilizers. Expected values of solutes in "unpolluted waters" in limestone areas are presented in Table I (see Bray 1969, Jacobson and Langmuir 1970, Langmuir 1971, Shuster and White 1971, Barr and Kuehne 1971, Jones 1973, and Vineyard and Feder 1974, for additional chemical data of karst waters).

Table I: Values of Selected Solutes in Unpolluted Waters in Limestone Areas (from Picknett, et al., 1976)

| Solute | Mean Values | Extreme Values | Units |
|---|---|---|---|
| Total hardness | 15-300 | 10-400 | mg $l^{-1}$ $CaCO_3$ |
| Alkaline hardness | 5-250 | 0-350 | " " |
| Magnesium Hardness | 10- 30 | 2- 60 | $10^{-3}$M $Mg^{2+}$ |
| Silica | 5 | 3- 15 | mg $l^{-1}$ $SiO_2$ |
| Potassium | 2 | 0.1- 15 | mg $l^{-1}$ K |
| Iron | 0.05 | 0.01-0.4 | mg $l^{-1}$ Fe |
| Oxygen demand (4 hours) | 0.5- 4 | 0- 10 | mg $l^{-1}$ $O_2$ |

**Cave Biota** Organisms occurring in caves not only are represented by a wide range of different systematic groups, but they also are customarily classified as to length of life history spent in caves and to degree of specialized adaptations exhibited. Some species are found only in underground habitats, while others which occur there are also found in various other environmental situations.

**Cave Flora** Plants occupying caves are generally considered to be representative of those epigean species of the area that demonstrate some degree of shade tolerance, many of which have developed remarkable characteristics of their own (Tomaselli, 1951:67). Transects of plant species taken horizontally or vertically from the entrance into the cave interior indicate that the more advanced species (tracheophytes--ferns and flowering plants) occupy the entrance areas but quickly disappear as the light diminishes. Bryophytes (mosses and liverworts) are found farther into the threshold zone, but the thallophytes (algae) are the most resistant to decreasing light and thus penetrate farther into the cave than any other green plants (Tomaselli, 1947 and Dalby, 1966). See Kofoid (1900), Scott (1909), and Barr (1967b: 178-184) for additional information concerning algae in caves.

Light reduction has been shown to initiate structural changes in tissues of green plants (Dalby, 1966). For example, low light intensity restricts vegetative growth (mitosis), thus reducing the maximum potential size of the plant (e.g., liverwort). Dalby (1966) has shown that the photosynthetic area of leaves is often increased (e.g., moss) as light intensity falls. The effects of pH, humidity, substrate, and other physical factors which create variation even at the microclimate level has been discussed by Morton (1939) and by Mason-Williams and Benson-Evans (1958). Seeds of angiosperms are often washed into caves and etiolated seedlings are commonly encountered, having germinated in the threshold or dark recesses and appear long, thin, and pale. They have no chloroplasts and are destined only to death in their fruitless search for light. Undoubtedly these life forms contribute nutrients to the intricate food webs within the cave ecosystem.

Bacteria are represented throughout

caves by both heterotrophs and autotrophs, although not usually together in the same community. Numerous forms are carried into the hypogean environment via air circulation, by animals (including man), and by seepage and stream input.

The autotrophic forms are represented by the iron bacteria which derive their energy from the simple oxidation of iron compounds. These bacteria, like the majority of bacteria currently known from caves, are not confined to grottoes, and are also found in many surface soils. A possible exception is the iron bacterium, *Perabacterium spelei*, which may prove to be a true cave species (Caumartin, 1959). Brock, et al. (1973) noted that obligately psychrophilic bacteria have not evolved in or colonized the constantly cool waters of caves. The sulphur bacteria are both oxidizers and reducers of sulphur and yield detectable quantities of sulphide (Cubbon, 1969). Like the iron bacteria they employ carbon dioxide (or bicarbonate) as a source of carbon. Nitrifying bacteria obtain their energy from the oxidation of ammonia to nitrite or to nitrate, also using carbon dioxide as a carbon source. Gram-negative microbes, such as *Azotobacter* sp. and *Clostridium* sp., when supplied with an energy source (e.g., carbohydrate) convert atmospheric nitrogen to organic nitrogen compounds (Mason-Williams and Benson-Evans, 1958, and Guonot, 1967). Heterotrophic bacteria obviously degrade complex organic materials and liberate simpler substances which have potential food value for other organisms (see Fliermans and Schmidt, 1977). Organic debris may be imported by flowing water or by visiting animals, and waste materials deposited by cavernicoles all serve as nutrient reservoirs (see Lavoie, 1980). Regardless of the energy source, these chemosynthetic microbes play a fundamental role in nutrient cycling within cave ecosystems.

Intermediate in character between bacteria and Fungi are the Actinomycetes microflora (mold-like filamentous bacteria) inhabiting caves (Lovett, 1949). These are ubiquitous soil organisms about which little is known except their potential role related to antibiotics. Caumartin (1963) and Picknett (1967) suggested that the peculiar and distinctive "earthly" odor of caves is produced in part by cave actinomycetes.

The occurrence and dynamics of fungi in caves have been treated by Tomaselli (1953), Hazelton and Glennie (1962), Caumartin (1963), Mason-Williams (1965), and Hunter and Thomas (1975). The majority of fungi found in caves are of epigean origin; however, Tomaselli (1956) described a number of forms that may be highly specialized cavernicoles. Upon entering caves, fungi must find a suitable substrate (organic material, living or dead) in order to survive. The debris and animal and plant life that are brought into caves undoubtedly also have a host of microfungal flora associated with them. These fungi will continue to grow as long as that substrate exists. They may completely utilize that substrate or become established members of the cave ecosystem--the ultimate outcome is dependent on the types and counts of nutrients as well as on their tolerence to the physical and chemical condition within the cave. Regardless, in time fungi make available (direct or indirect) food sources (such as nutrients) for organisms already present in the cave community. Dickson (1975) indicated that bacterial and fungal populations may not only serve as basic food sources in caves but also may influence the distribution of specialized invertebrate cavernicoles (see also Dickson and Kirk, 1976). It should be quite apparent that both autotrophic and heterotrophic (see Kirk, 1973) micro-organisms are virtually "all over"

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caves (e.g., mud, water, dung, living and dead organisms, and even speleothems).

It should be noted that several pathogenic micro-organisms are known to inhabit caves. Holsinger (1966), Wells (1973), Wagner et al. (1976), and Brucker (1979) reported sewage pollution in various cave systems and the occurrence of coliform bacteria is undoubtedly becoming more common in cave ecosystems. This is certainly apparent when one compares the results of Gardiner (1971) and Hoey (1976)--groundwaters in the environs of Bloomington, Indiana, are contaminated with fecal coliforms and fecal streptocci, and their densities have shown marked increases in the five-year time span which separated their studies. This is certainly not uncommon in Ohio as well (e.g., Thompson Cave, Miami County, receives seepage from a residential septic tank). The reader is referred to Prager (1972) for an overview of ground water pollution in U.S. karst regions and Minear and Patterson (1973) for a discussion of ground water contamination resulting from septic tank system failure. In addition to treating pollution, Wilson (1977) briefly demonstrated the effects of cultural eutrophication and certain caver activities on cave ecosystems.

Histoplasmosis is a disease caused by the fungus *Histoplasm capsulatum* Darling. The symptoms and effects are commonly similar to those of tuberculosis, being characterized by loss of weight, fever, anemia, coughs, and severe chest pain, although quite often the infection is mild. This is a cosmopolitan disease and is present in 31 of the 48 contiguous United States (Ajello, 1971), and the Ohio River Valley is a particularly high incidence area (Sarosi et al., 1971). This is an "occupational hazard" for Midwest cavers (particularly for Ohio cavers!). Shacklette and Hasenclever (1968) studied the effect of flooding in a cave system on the distribution of *H. capsulatum* with the air, soil, and animal life of the cave. Beck et al. (1976) discussed the occurrence of histoplasmosis in caves in the central mountains of Puerto Rico. They, DiSalvo (1971), and Ajello et al. (1977) discussed the role of bats in the ecology of *H. capsulatum*, and Smith (1964) presented an eradication method that has proven successful in the fight against histoplasmosis (application of a 3% formalin solution)--undoubtedly this also greatly affects other cave organisms as well!

Cave Fauna A classification system for cave-inhabiting animals has been proposed numerous times (see Schiner 1854, Schiodte 1849, Racovitza 1907, Hazelton and Glennie 1962, and Hamilton-Smith 1971); however, the most commonly used system places animals into one of four ecological-evolutionary categories (Barr 1963, 1968):

Troglobites--obligatory cave species which are morphologically specialized for, and restricted to, the cave habitat; they are unable to exist in epigean habitats.

Troglophiles--facultative cave species which frequently inhabit caves and are capable of completing their entire life histories there (many do!), but may occupy ecologically similar habitats outside of the cave environment.

Trogloxenes--species often occurring in caves but are incapable of completing their entire life history in the cave environment, generally having to exit for feeding and/or mating purposes.

Accidentals--species which accidently wander, wash, or fall into caves and can exist there only temporarily; they may serve as food sources for regular cavernicoles, yet they are of no importance in distributional or evolutionary analyses of cave fauna.

Two other terms are also employed for certain cave (and surface) animals:

Edaphobites--species that are obligatory deep-soil dwelling forms which may occasionally occur in caves.

Phreatobites--species which are obligatory to ground water habitats; they are often found in slowly moving interstitial ground waters; they are not necessarily found in caves and are frequently sampled in seeps, springs, and wells.

The distribution and ecology of numerous cavernicoles are inadequately known, and their assignment to one of the above ecological-evolutionary categories is often, at best, tenuous. Some general groups are characteristically placed in specific categories: *phreatobites*--some copepods, isopods, amphipods; *edaphobites*--earthworms; *trogloxenes*--bats, bears, raccoons, moths, mosquitoes, man!; *troglophiles*--some salamanders, beetles, crustaceans; *troglobites*--blind cave fishes, some flatworms, isopods, amphipods, decapods, pseudoscorpions, spiders, millipedes, and a large number of insects. For a more detailed treatment of cavernicoles, see Vandel (1965) and Jefferson (1976).

Of specific interest is the troglobitic group of cavernicoles. These organisms are highly specialized and show varying degrees of adaptation for existing in the cave environment. For example, there are nearly 60 species of troglobitic decapods known from the Americas (Hobbs et al., 1977), and many of the adaptations common to all troglobites are recognized in this group. The most obvious character that is common to virtually all troglobites is a strong *reduction in pigmentation*, frequently a total loss. Also conspicuous are the *reduced eyes* and, in the case of many troglobitic decapods, they may completely lack faceted corneae. *Attenuated appendages* are characteristic of many forms, and numerous troglobites tend to be *smaller*, or at least superficially more delicately constructed, than their epigean relatives. Although few data are available, a *lower basic metabolic rate* ("metabolic economy" by Poulson, 1963, 1964) is suggested for most troglobites. See Schlagel and Breder (1947), Burbank et al. (1948), Troiani (1954), and Culver and Poulson (1971) for comparative results of oxygen consumption in cave and surface biota. Cooper and Cooper (1976, 1978) presented data that indicate certain troglobitic crayfishes have considerably *longer life spans* than have been proposed for any other cave species. Ginet (1960, 1969) and Turquin (1981) discussed longevity in the amphipod *Niphargus* and a number of troglobitic terrestrial species (e.g., *Anthrobia*--see Poulson, 1978a) have prolonged life histories; all of these examples suggest a correlation with lowered metabolism. Production of *fewer eggs* in troglobitic decapods when compared with related epigean species (see Bechler, 1981) is usually associated with lesser available energy in the cave environment. Also, Hobbs (1973) suggests that individual females within a given population do not necessarily reproduce annually but resorb oocytes and reproduce

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only on a staggered basis. Thus, in addition to obvious morphological adaptations, many troglobites demonstrate low reproductive rates, extended life expectancies, and extreme resource efficiency.

Animal species richness in caves and dispersal potential, among other factors, are greatly influenced by the specific geological formations of the area in which caves are developed (e.g., continuity and separation of limestone units). "In the Appalachian Valley, where limestone is exposed in many narrow, anticlinal strike belts, species density per unit area is high, and dispersal of troglobites through subterranean channels is severely restricted by geologic structure. In the Mississippi Plateau, where thick cavernIferous limestone is widely and continuously exposed, there are fewer species per unit area; and subterranean dispersal has taken place over considerable distances." (Barr, 1967a:488).

## Cave Community Energetics

Generally, cave communities are regarded as relatively simple systems having few species and low productivity (Barr 1968, Poulson and White 1969, Culver 1976). Notable exceptions to this are the approximately 300 species of animal and plant life in the Mammoth-Flint Ridge Cave system in Kentucky (Barr, 1967b), the rich aquatic fauna of the cave communities of the Edwards Aquifer (22 troglobites in the artesian well in San Marcos, Texas--Holsinger and Longley, 1980), and the diverse aquatic community of Shelta Cave in Madision County, Alabama (Cooper, 1975).

As previously mentioned, lacking the autotrophic component, all cave communities ("complex" or "simple") must depend on exogenous organic material to be transferred from the surface. Every cave or cave system will demonstrate variances in energy input over time and space. Hawes (1939) indicated the importance of the flood factor in the ecology of caves, particularly with reference to food input. In addition, he, and others, pointed out that floods may operate as agents of distribution and colonization as well as may function to stimulate reproductive activity and to trigger molting cycles in certain organisms (see Jegla 1966, 1969, and Jegla and Poulson, 1970).

Poulson (1978b:94) has proposed that "Energy availability depends on rigor, variability, and predictability of energy concentration, renewal, and quality." Quite obviously, all organic materials do not have equal caloric values; therefore, energy availability of certain foods is greater than others (e.g., raccoon feces are high payoff foods and leaf litter is a low payoff food--Poulson 1977, 1978b). Undoubtedly energy availability can affect greatly the numbers and biomass that can be supported, can affect foraging behaviors, overall energetics, life histories, and ultimately community organization. Additional information concerning effect of energy availability can be obtained in Poulson (1979).

Most caves receive food in the form of dissolved organic matter, organic litter and detritus, bacteria, protozoans, and other organisms that are washed, blown, or carried in. Temporal variations in quality and quantity are evident, with greatest inputs occurring in late winter and spring. The microflora, as previously stated, are responsible for decomposition and transformation of this allochthonous material, yet they themselves are sources of energy when detritus is consumed (the "peanut butter" on the "detrital cracker"!). These food sources are supportive of both the terrestrial and aquatic cave communities.

Guano is another major food source of may caves. Cricket guano, as well as cricket eggs and dead crickets, can form a major food source (Park and Barr, 1961). Reichle et al. (1965) found that Hadenoecus subterraneus feeds almost entirely on forest floor arthropods outside caves at night, returning to its roosting spot during the day. The crickets move toward entrances in late afternoon and emerge at twilight, often moving up to several hundred meters from the cave entrance prior to their return. The guano accumulates in a thin layer (up to 5-10mm deep) beneath roosts, but its production is largely limited to the warmer months of the year.

Bat guano not only serves as a source of organic matter to a cave, but guano piles also function as distinct and complex ecosystems. Spatial variation in guano piles leads to sharp microzonation; thus there is spatial as well as temporal variability within the ecosystem. The increase in food input (food pulse) that is initiated at each year when bats return to a cave greatly affects the community of guanobites. For further information concerning bat guano ecosystems the reader is referred to the following papers: Mitchell (1970), Richards (1971), Peck (1971), Horst (1972), Poulson (1972), Fletcher (1976), Martin (1977), Franklin (1978), and Hill (1981).

In addition to cricket and bat guano, dung of larger vertebrates (mammals, such as raccoons and rats) is another source of energy to the cave system. The heterotrophic decomposition of this material is successional and somewhat predictable as is discussed by Lavoie (1981a). For further information on dung ecosystems see Lavoie (1980, 1981b).

As fecal material is broken down and as allochthonous materials are transported into the cave, they accumulate as sediments. Silts from aquatic systems as well as various muds, clays, etc., from dry or upper levels contain varying amounts of organic matter that can and are utilized directly and indirectly as energy sources for some cavernicoles. Most organisms, however, are not supported by organic materials from sediments and have evolved strategies for coping with seasonal fluctuations in organic input (see Kane et al., 1978, and Kane and Poulson, 1976).

Although cave trophic webs are comparitively simple and are known for various caves and cave systems, it is difficult to work out complete energy budgets for most systems. The paucity of tropical troglobites may be a reflection of the higher energy input into tropical caves which lessens selection pressures for energy-economising troglobitic adaptations (Mitchell, 1969). This is reflected in less complex food webs in tropical cave communities. For representative cave food webs see Mohr and Poulson (1966), Moore and Sullivan (1978), and Hill (1981).

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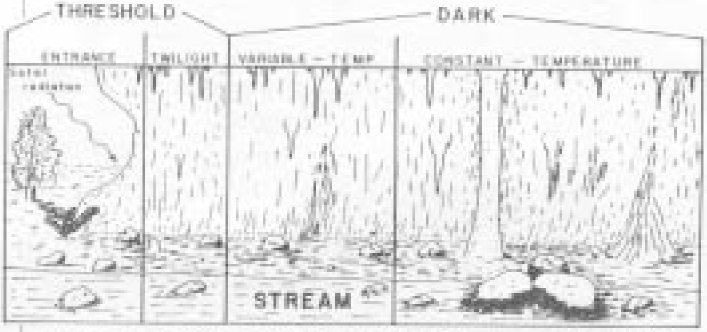

Figure 1: Ecological zonation (modified from Mohr and Poulson, 1966).

**Final Comments** The cave environment supports complex communities although it is generally regarded as "simple" and "predictable" when compared to epigean environments. Even with its comparative simplistic character, the cave collectively is represented by an assemblage of varied habitats. Simpson (1964), MacArthur et al. (1966), and Poulson and Culver (1969) indicate that increased habitat diversity often increases the number of species. Culver (1970) suggests that in a cave the best available measure of spatial heterogeneity is length of the cave (number and complexity of levels are also measures), as greater length increases the probability of varied habitats occurring. Many other factors undoubtedly affect the complexity of cave communities: species diversity (including richness and equitability); food (quality/caloric availability, quantity, predictability); environmental variability and rigor (e.g., flooding --degree and predictability); resource partitioning (competition, niche breadth, niche overlap among species); reproductive and feeding strategies evolved by cavernicoles; and relative age and overall comparative stability of the cave, to mention a few. Finally, it should by stressed that the unique cave environment, although stable, is a sensitive one. With increased ground water pollution and greater utilization of caves by sport cavers, many caves are showing negative (and long-term) effects. Problems of ground water pollution and "overutilization" of caves are not unique to the United States and should be immediate concerns for all speleologists. ■

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Who's the wise guy who said this passage is 3' x 6'1!??!"!.