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Floyd Collins was first to explore Sand Cave. Fallen rock trapped him in narrow passages 150 ft from entrance, Jan. 30, 1925. Rescuers reached him with food and heat for short time. Aid cut off by shifting earth closing passage. Engineers sank 55-foot shaft but unable to reach Collins' body until Feb. 16. Rescue attempt publicized worldwide. Aroused sympathy of nation.

*Historical Marker
Kentucky Highway 255
Mammoth Cave National Park*

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COVER PHOTO—Views of Sand Cave, Kentucky by Mike Voligny (top and center) and by George M. Crothers (bottom), all taken in November, 1980.	

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ARCHAEOLOGICAL INVESTIGATIONS IN SAND CAVE, KENTUCKY

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SAND CAVE is historically important, because Floyd Collins died there in the winter of 1925. The site also has significance as an example of prehistoric cave occupation in the Central Kentucky Karst.

My archaeological investigations consisted of 2 parts: (1) A systematic, intensive surface collection of Middle- to Late-Woodland cultural debris in the rockshelter, and (2) expeditions into Sand Cave to record and collect the archaeological remains pertaining to the unsuccessful attempt to rescue Floyd Collins. The field work did not involve excavation either of the rockshelter or of the cave passage. However, I have included an assessment of possible subsurface remains based on the surface survey.

There had been no systematic archaeological survey of the remains inside Sand Cave or at the rockshelter prior to this study. My survey accomplished 3 primary objectives: (1) Documentation of the 1925 remains, (2) collection of material for preservation and display, and (3) correlation of the archaeological remains with the historic record.

The Sand Cave prehistoric site had been recorded by earlier archaeological surveys, and at least one collection had been made (Carstens, 1980). However, no detailed report on the remains has been completed. My prehistoric survey is the first detailed report on and assessment of the surface evidence. It also provides a body of evidence that may be used to test Carstens' placement of Sand Cave in the prehistoric sequence for the Mammoth Cave National Park area (Carstens, 1980).

HISTORY

The Mammoth Cave National Park area is famous for its large limestone caves. Of the one hundred or more caves in this region, the largest and most famous include Mammoth Cave, Crystal Cave, Salts Cave, Great Onyx Cave, Unknown Cave, Colossal Cave, and Horse Cave. Mammoth, Crystal, Salts, Unknown, and Colossal caves are known to be parts of one system, now called the Flint Mammoth Cave system. It is the longest cave in the world (Brucker and Watson, 1977). Surveyed passages exceed 370 km in

length, and the known extent of the system is being increased steadily by members of the Cave Research Foundation, an organization dedicated to the exploration, conservation, and scientific study of caves (Smith and Watson, 1970).

Mammoth and other caves in the area became important in the early Nineteenth Century as a source of saltpeter (potassium nitrate) for the production of gunpowder. After saltpeter mining ended, the owners of Mammoth Cave and several nearby caves developed a large tourist business.

Competition for tourist business among the privately owned caves culminated in the 'Cave

War' of the 1920's and 30's; underhanded methods to attract visitors and discourage them from visiting rival caves were common. There seems to be no single origin to the Cave War, rather ' . . . it just grew' (Halliday, 1966, p. 30). It ended in 1961, when the National Park Service incorporated Great Onyx and Crystal caves, the last privately owned big caves, into the Park. The Park Service maintains the tourist business today, but with a conservation and interpretive program for the public which was lacking under the private owners.

Floyd Collins, as part owner of Crystal Cave,

SUMMARY

The Sand Cave site (Smithsonian no. 15Bn19) includes Middle- to Late-Woodland aboriginal debris overlain and intruded by the remains of the 1925 cave rescue attempt to save Floyd Collins. It lies within Mammoth Cave National Park, in central Kentucky.

Aboriginal materials are restricted to the sandstone rockshelter at the cave entrance; those collected from the surface in 1980 included a bone fragment, a shell fragment, and 64 stone implements and flakes. Historic 1925 materials were collected from the cave floor and from excavations made to reopen the cave passage; all historic artifacts found were removed, excepting 2 nails, electrical wiring, and shoring posts. Aboriginal materials have been deposited in Mammoth Cave National Park (Washington University no. 80-2353B); historic materials also have been deposited in Mammoth Cave National Park (Washington University no. 80-2353A).

Amerind artifacts collected in 1980 are too few to permit detailed reconstruction of the local culture and economy. Materials known to have been collected previously were not available for study. Historic artifacts found in 1980 corroborate the written record of the rescue attempt. They are tangible witnesses to the 1925 local culture and to the cave rescue techniques of that era.

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was deeply involved in the Cave War, and his death in Sand Cave was indirectly related to the competition for tourist dollars. This and other aspects of Mammoth Cave area history are discussed in Lawrence and Brucker (1955), Halliday (1966), Brucker and Watson (1977), and Murray and Brucker (1979).

The Mammoth Cave area is rich in archaeological resources. Archaeologists were first attracted to the large, dry caverns, because vast quantities of ordinarily perishable prehistoric materials were preserved there, including several desiccated human bodies. Archaeological research has centered on Mammoth and Salts caves and, to a lesser degree, on Bluff and Lee caves.

There have been at least 7 prehistoric 'mummies' found in the Mammoth Cave area. Harold Meloy (1977) presents a good account of their discovery and history. The latest mummy to be discovered, and the best recorded, is 'Lost John,' a prehistoric miner killed in Mammoth Cave by a rock collapse (Pond, 1937).

The most notable early report on Mammoth Cave-area cave archaeology is by Col. Bennett Young (1910). His work is impressive, but lacks scientific detail. Nels C. Nelson (1924), of the American Museum of Natural History, is credited with the first scientific investigations. Douglas W. Schwartz was active in the archaeology of the Park in the 1950's and prepared several manuscripts for the Park Service. He is credited with compiling the first survey of surface archaeological sites in the Park (Schwartz, 1958). The most comprehensive and systematic investigations of cave archaeology in the Mammoth Cave area have been directed by Patty Jo Watson (Watson, *et al.*, 1969; Watson, 1974).

Kenneth C. Carstens (1980) recently completed a more thorough survey and excavation of selected surface sites in the Mammoth Cave area. His work is crucial to the prehistoric aspect of my report.

PHYSIOGRAPHY

Location

Sand Cave is in Barren County, Kentucky, near the southeastern boundary of Mammoth Cave National Park (figs. 1 and 2), at N 39°09'15" and W 86°02'52". The Universal Transverse Mercator coordinates are (zone 16) 41/12/320 Northing and 5/83/730 Easting. The floor of the rockshelter is approximately 244 m (800 ft) ASL. The site is approximately 9 km west of Cave City by way of state highways 70 and 255, due north 200 m from the Sand Cave historical marker on Highway 255. East Boundary Road passes 200 m west of the site and intersects Highway 255.

The site may be reached from a light-duty road off Highway 255 that dead-ends at the Park boundary. There are 3 structures at the end of this road: A small barn, the abandoned Sand Cave ticket office, and an abandoned house converted into a chicken coop. A trail winds north from the dead-end road through brush and trees to the

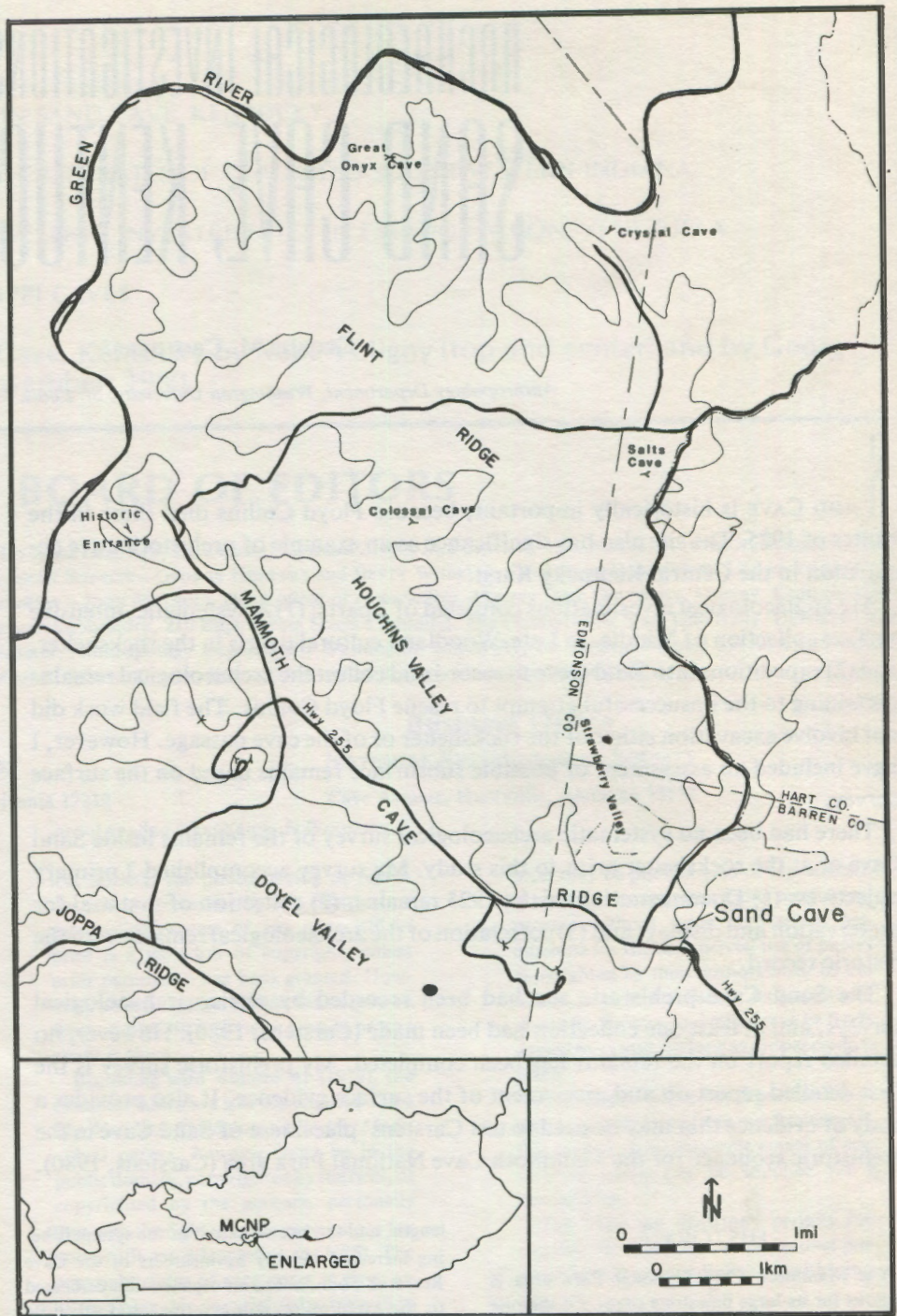


Figure 1. Sand Cave and vicinity, 1983, adapted from the current 1:24,000 U.S. Geological Survey map of Mammoth Cave National Park (compiled from 7.5' sheets).

cave. It approaches the rim of a valley, turns west, dips steeply down the rim along the base of a sandstone outcrop, and enters the shelter from the southeastern corner.

There are 4 sources of water within 900 m of the site. Two ponds are on the ridge above Sand Cave, one 350 m southeast and the other 550 m south-east of the rockshelter. A third pond is 650 m directly north of Sand Cave. Two hundred and

fifty meters north of this pond is an intermittent stream flowing into a valley locally known as Strawberry Valley. The closest major river in the area is the Green River, 6½ km northwest of the site.

Sand Cave rockshelter is a sandstone overhang approximately 20 m wide and 15 m long, with a maximum ceiling height of 6 m. The shelter faces a few degrees north of due east. Large and small

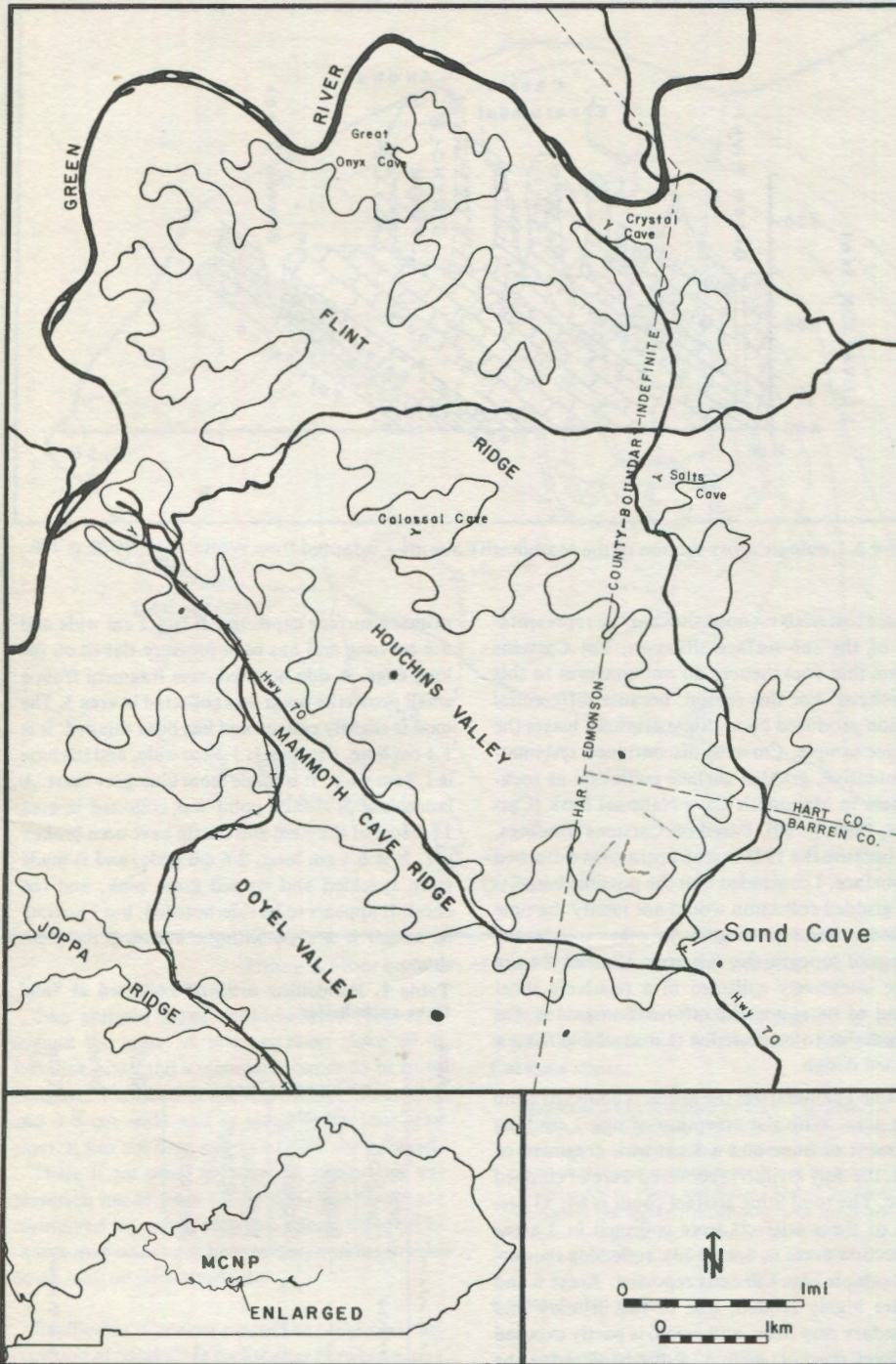


Figure 2. Sand Cave and vicinity, 1925, adapted from the 1:31,680 USGS map of Mammoth Cave National Park published in 1930.

breakdown blocks are scattered around the shelter and are partly buried in its floor (Fig. 3).

A crawlway among breakdown blocks along the left wall of the shelter leads toward the limestone cave below. It is approximately 4.5 m long and ends above a 70 cm square iron grate installed by the Park Service in the 1950's. Peering through the grate, one can see that the passage drops straight down about 1 m, then veers right. A

sandstone-limestone contact can be seen in the ceiling of the crawlway.

The length of the passage to the point where Collins was trapped is approximately 45 m. The passage ends approximately 15 m below the surface of the rockshelter floor, in water-laid gravel and dirt. It is narrow, twisting, and doubles under itself. The actual horizontal distance from the grate to the death site is less than 8 m.

Geology

The classic general source on Kentucky geology is A. C. McFarlan's 'Geology of Kentucky' (1943). Comprehensive analyses of the Central Kentucky Karst are provided by White, Watson, Pohl, and Brucker (1970) and by J. F. Quinlan (1970). Older, but still useful, studies of Mammoth Cave National Park were published by A. K. Lobek (1928) and by Ann Livesay and Preston McGrain (1962). Murray and Brucker (1979) have interpreted the geology of Sand Cave.

Flint Ridge, Mammoth Cave Ridge, and Joppa Ridge are the principal limestone uplands in Mammoth Cave National Park. The cave systems of the area are developed in Upper Mississippian Ste. Geneviève and Girkin limestones underlying these uplands. The ridges are capped by Big Clifty sandstone (Brucker, 1966; White, *et al.*, 1970) (Fig. 3).

Sand Cave is located on the eastern flank of a north-trending upland connecting the southeastern end of Mammoth Cave Ridge to the southeastern end of Flint Ridge, at the edge of the sandstone cap. It faces east toward a large solutional valley.

The edge of the caprock is the area of most concentrated vertical drainage (Pohl, 1955; Brucker, 1966).

In the areas immediately adjacent to the truncated edges of the capping beds, vertical shafts and minor features of vertical solution are abundant. It is in this area of most active vertical drainage that one finds the massive breakdown which divides passages into segments.

The Sand Cave crawlway is formed entirely by spaces between large and small breakdown blocks, as though the known cave were simply a haphazard series of crevices among the blocks of a terminal breakdown which conceals a large solutional cave beyond.

These immense breakdown blocks generally tilted downward away from the cliff face, as if they had once fallen into a void below—a void that could lead to a solid limestone ceiling. (Murray and Brucker, 1979, p. 275)

Ecology and Climate

The best general references to the ecology and climate of Kentucky are those by E. L. Braun (1950) and by Victor Shelford (1963); useful information is also contained in Middleton, *et al.* (1926). More-detailed future analyses of aboriginal artifacts from Sand Cave will have to relate Amerind cultures in the area to local climate and resources. My collections are too limited for such an analysis to be meaningful, here.

PREHISTORIC ARCHAEOLOGY

Archaeological Research

Professor William Funkhouser, head of the zoölogy department at the University of Kentucky (Lexington), was involved in the 1925 Floyd Collins rescue attempt. During the operations, Funkhouser collected or at least recognized prehistoric material at the rockshelter. Funk-

houser and W. S. Webb were the first to report the Sand Cave prehistoric site:

... a number of Indian artifacts were found which indicate that the place had at one time been occupied by the cliff-dwellers. (Funkhouser and Webb, 1928, p. 149)

Douglas Schwartz (1958) included Sand Cave rockshelter in his survey of Mammoth Cave National Park. He reported that a few chert flakes were found during the Collins rescue operation. Presumably, these artifacts were unearthed in the 2 m square, 18 m deep shaft dug during the rescue attempt. There is no indication that Schwartz visited Sand Cave, and he may have relied entirely on Funkhouser and Webb's report. Whatever the source Schwartz relied upon—Funkhouser's notes or collection, or personal trips he may have made to the site—Schwartz designated it site MC-17 in his archaeological survey.

Carstens' archaeological survey (known as the Green River Survey, 'GRS') visited the rockshelter, assigned it number GRS-38, applied for a Smithsonian system number (15Bn19), and collected numerous artifacts. His report on this material is quoted in full below:

Our GRS survey located numerous chert flakes in the shelter's dripline area together with several chert cores and core fragments, limestone tempered, cord-marked Woodland ceramics, and several projectile point fragments. One projectile found by the GRS-survey team resembles the Lowe type (Perino, 1971) and may date from A.D. 1 to A.D. 900. (Carstens, 1980, p. 461)

The Washington University accession number assigned to Carstens' collection is 76-2235.

Surface Material

Data. My field investigations at Sand Cave rockshelter had three primary goals: (1) To construct a topographic map, (2) to photograph the site, and (3) to conduct a systematic, intensive surface collection. The bulk of field work was conducted on 2 days, October 12 and November 29, 1980.

Figure 4 is a topographic map of Sand Cave rockshelter. The contour intervals are based on an assumed elevation of 200 m at Datum A. Carstens states that all USGS benchmarks in Mammoth Cave National Park were removed as part of a Park beautification program (Carstens, 1980, p. 30). Carstens selected a permanent benchmark and assumed an elevation of 200 m for each of his topographic maps. I have followed this procedure on the Sand Cave rockshelter map.

The floor of the rockshelter was subdivided on the basis of topography into 16 sub-areas (Fig. 4). The crawlway as far as the grate was included in the shelter surface collection. The passage beyond the grate is designated area 17, and artifacts within this area were treated separately.

These irregular sub-areas were chosen in preference to a grid system, because differential erosion produced by multiple driplines biases the surface sample. Charles Redman and Patty Jo Watson (1970) have shown that the distribution of

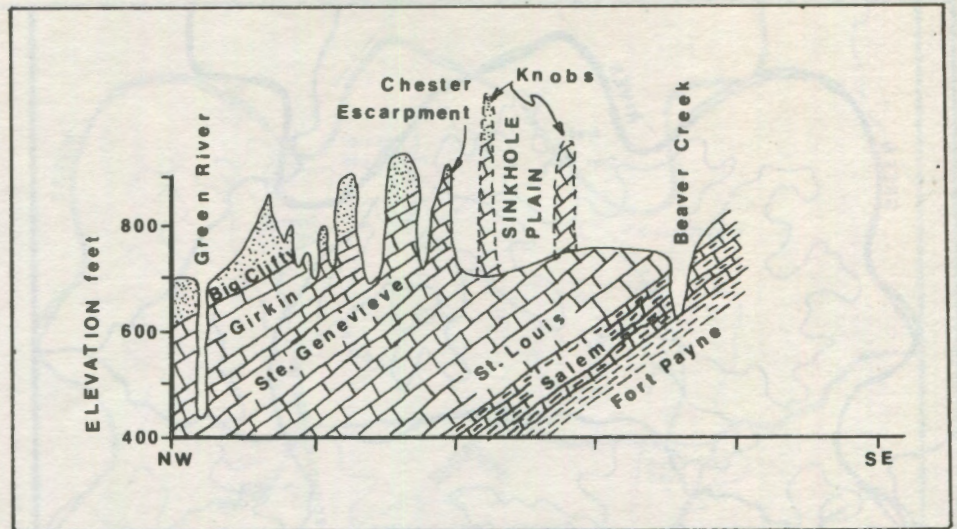


Figure 3. Geologic cross-section of the Mammoth Cave area, adapted from White, et al., 1970, p. 106.

surface materials on open sites may be representative of the sub-surface situation, but Carstens asserts that rockshelters do not conform to this hypothesis. For this reason, because differential erosion produced by multiple driplines biases the surface sample, Carstens discontinued systematic, intensive, gridded surface collection at rockshelters in Mammoth Cave National Park (Carstens, 1980, p. 30). Based on Carstens' findings, and because the 1925 rescue operations disturbed the surface, I concluded that the possible benefits of a gridded collection would not justify the time needed to establish a grid. In other words, the system of topographic sub-areas allowed the site to be intensively collected in a relatively short period of time, and the information gained was comparable to or exceeded that available from a gridded design.

Table 1 summarizes the artifacts collected from each area. With the exception of one 7 cm long fragment of bone and a 3 cm wide fragment of shell, the only artifacts recovered were of chipped stone. The total lithic artifact count is 64; 53 percent of these artifacts were collected in 3 areas (collection areas 6, 8, and 13), reflecting the surface sample bias Carstens reported. Areas 6 and 13 are highly eroded, due to the primary and secondary drip lines, and area 6 is partly exposed to direct rainfall. Area 8, a dirt bank along the south wall, is slightly unusual and may be dirt dug from the entrance crawlway when it was enlarged in 1925.

The chipped stone artifacts include 2 projectile point fragments, a triangular blank, and 2 scrapers. A unifacial end scraper was collected in area 5. It is made from bluish-green chert, is 3.5 cm long and 2.6 cm wide, has primary surface exposure, and the dorsal face has been pressure-flaked on all edges. A bifacial side scraper was found in area 8. It is made from multi-colored blue-gray and reddish-brown chert and has

primary surface exposure. It is 4.2 cm wide and 5.8 cm long and has been pressure-flaked on the long edge. A side-notched stem fragment from a small projectile point was collected in area 3. The base is slightly convex and has been thinned. It is 1.1 cm long, the stem is 1.5 cm wide, and the base is 1.9 cm wide. It is made from blue-gray chert. A lanceolate projectile point was collected in area 13. Most of the stem and the tip have been broken off. It is 6.1 cm long, 2.6 cm wide, and is made from speckled and striped gray, pink, and tan chert. It appears to be side-notched, but I hesitate to assign it a type without knowing the stem shape.

Table 1. Prehistoric artifacts collected at Sand Cave rockshelter.

Area	Chipped Stone					Shell	Bone	Total
	Cores & Core Frags.	Waste Flakes*	Projectile Pts. & Frags.	Scrapers				
	Primary	Secondary						
1			1					1
2				1				1
3		2	2		1			5
4	1	1	2					4
5	1	2			1			4
6	1	6	3					10
7		3						3
8	1	2	4		1	1		9
9		1	2					3
10								0
11		1	1					2
12							1	1
13		6	9	1				16
14								0
15		2	1					3
16		1	1					2
17		1		1				2
Total	6	29	24	3	2	1	1	66

*Primary = partial cortex on flake; Secondary = no cortex on flake.

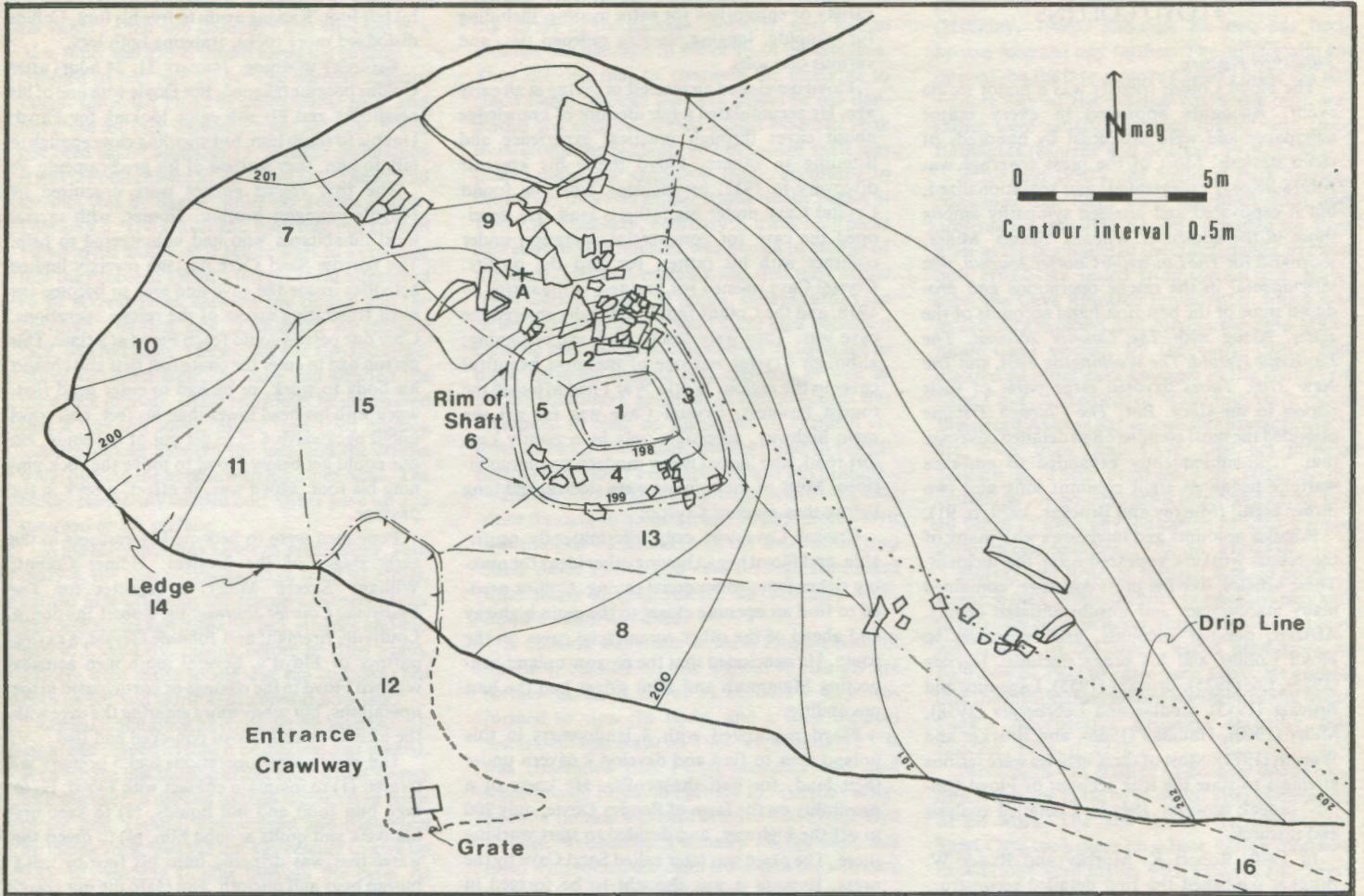


Figure 4. Floor contours of Sand Cave rockshelter, 0.5 m interval. Large numbers identify collection areas.

Two chipped stone artifacts were recovered beyond the grate: A primary chert flake 19 m from the grate and a triangular blank 23 m from the grate. The blank is approximately 5.0 cm long and 3.0 cm wide and is made from blue-gray chert. It has not been notched or pressure-flaked.

There is no other evidence of prehistoric exploration inside Sand Cave; these 2 artifacts are considered intrusive. However, Sand Cave rockshelter may once have been larger, and the breakdown may be post-aboriginal.

Evaluation. Carstens placed the prehistoric occupation of Sand Cave rockshelter between A.D. 1 and A.D. 900, based on the Lowe type projectile point and the limestone-tempered, cordmarked Woodland ceramics collected there (Carstens, 1980, p. 461). This places Sand Cave rockshelter in a Middle-Woodland to Middle-Late-Woodland context.

Carstens established a cultural-historical framework for the Mammoth Cave National Park area based on excavations at several surface sites. His framework provides a context in which to place the aboriginal remains from the cave and surface sites of the Central Kentucky Karst.

The Middle-Late-Woodland period is represented by Horizon II of the Patch Rockshelter. Carstens states:

The Middle to Late Woodland Period . . . occupancy of the Patch site represents a distinct focal economy as marked by the sole prominence in deer exploitation. The appearance of several ceramic types (Rough River Series, Mulberry Creek Plain, and White Checked Stamped) documents the sporadic presence of both males and females throughout the Middle to Late Woodland sequence at this site. (Carstens, 1980, pp. 192-193)

Carstens also notes

. . . a general increase in the number of bifacial (broken projectile point tip fragments) tool fragments from this site. The increase in this tool form is possibly a reflection of increased hunting activities now occurring during Middle to Late Woodland Period. (Carstens, 1980, p. 193)

My controlled surface collection of Sand Cave rockshelter did not recover any diagnostic artifacts with which to modify Carstens' temporal placement of the site in his prehistoric sequence. Carstens reports collecting limestone-tempered, cordmarked pottery. My intensive survey did not recover any prehistoric ceramics. The amount of

pottery at the site may be so small that Carstens collected all the pottery existing on the surface and, hence, none occurred in my intensive surface collection.

Future investigations of Sand Cave prehistory may take 2 directions. There now exist 2 surface collections from Sand Cave rockshelter: Carstens collection, now in storage at Washington University and at Murray State University, and my own surface collection, housed at Mammoth Cave National Park. A detailed analysis of these collections, especially the diagnostic material which has not been fully studied, may provide better insight into the nature and temporal dimensions of the site.

The second direction is actual excavation of the site. Sand Cave was severely damaged during the 1925 rescue operations, but undisturbed portions may contain important data. Collection area 15, a low, dry, ash-mixed soil west of the shaft depression may be especially informative. A well-placed excavation unit or trench that extends into the shaft slope would define the extent of the shaft wall and possibly uncover some undisturbed deposits in the area of the ash-mixed soil.

FLOYD COLLINS

Published History

The Floyd Collins tragedy was a major media event. Accounts appeared in every major newspaper and were broadcast by hundreds of radio stations. Most of the press coverage was contradictory, exaggerated, and sensationalized, but it captivated and aroused sympathy among those in the audience. William 'Skeets' Miller, journalist for *The Louisville Courier Journal*, was instrumental in the rescue operations and produced some of the best first-hand accounts of the event. Along with *The Courier Journal*, *The Louisville Herald*, *The Washington Post*, and *The New York Times* devoted large parts of their papers to the story. But, *The Chicago Tribune* provided the most complete and detailed coverage that '... subsequently expanded to embrace wartime headlines eight columns long and two inches high.' (Murray and Brucker, 1979, p. 91).

Popular accounts and interviews with many of the rescue workers appeared after the incident. These articles, like the press coverage, contained many inaccuracies and unsubstantiated claims. Articles, popular accounts, and references to Floyd Collins and his ordeal include: Hartley (1925), Lee (1925), Brucker (1955), Lawrence and Brucker (1955), Collins and Lehrberger (1958), Miller (1960), Halliday (1966), and Brucker and Watson (1977). Most of these articles were serious attempts to state the true account of Floyd Collins' ordeal; however, they lack detailed analysis and research.

In 1979, Robert K. Murray and Roger W. Brucker published the first detailed reconstruction and analysis of the event. Their work is a well researched and referenced account that includes documentation of the media coverage, oral interviews with surviving participants, and 6 expeditions into Sand Cave. They are to be credited with ending 54 years of inaccurate, exaggerated, and sometimes quite fictitious renderings of the Collins affair.

Biography

The brief characterization and account of Floyd Collins and his death which follows is taken largely from Murray and Brucker (1979), but emphasizes the type and quantity of material taken into the cave by the rescuers. The purpose of repeating this account is to provide a context into which the archaeological remains can be fitted.

William Floyd Collins was born 20 April 1887 on Flint Ridge, Kentucky. He was the third of 8 children born to Leonidas 'Lee' Collins and Martha Burnett. His mother died in 1915 of tuberculosis, and Lee Collins took a second wife, Sarilda Jane 'Miss Jane' Buckingham. Floyd's older sister died in childhood, and his older brother died in 1922 of typhoid. Floyd thus became eldest of the Collins children.

The Collins family subsisted on a 200-acre farm on Flint Ridge, raising small grains, corn, garden vegetables, and fruits. The family cooperated in a

variety of enterprises for extra income, including fur trapping, logging, cutting railroad ties, and various odd jobs.

Floyd developed an interest in caving at an early age. He accumulated a fair amount of knowledge about caves through practical experience and listening to others. Floyd made his greatest discovery in 1917, by accident, when he found Crystal Cave under his father's land. He developed the cave for commercial operation under contract with his father, for half the profits. Crystal Cave opened for business in the spring of 1918, and the Collins family officially entered the cave war. They were losers from the beginning; although Crystal was one of the most beautiful caves in the region, World War I had affected the tourist business. Crystal Cave was far off the main highway, accessible only by a poorly kept dirt road, and lacked many modern accommodations. Most of the tourists were sidetracked long before they reached Crystal.

Crystal Cave was only intermittently profitable, and Floyd began having other ideas for making riches from commercial caving. Collins needed to find an opening closer to the main highway and ahead of the other commercial caves on the route. He concluded that the narrow upland connecting Mammoth and Flint ridges had the best possibilities.

Floyd negotiated with 3 landowners in this upland area to find and develop a cavern under their land, for half the profits. He knew of a possibility on the farm of Beesley Doyle, only 200 m off the highway, and decided to start working there. The place was later called Sand Cave by the press, because it was thought to be formed in sandstone (Murray and Brucker, 1979, pp. 49-50).

In early January, 1925, Collins began digging and working in Sand Cave to enlarge the passage. On Monday, January 26, he dynamited the breakdown to loosen the rocks blocking his path. On January 28 and 29, he built fires at the entrance, hoping to dry out the cave.

Friday morning, January 30, Floyd Collins entered Sand Cave—alone, as was his usual caving practice. He took with him a kerosene lantern and 24 m of rope. In a small room 25 m inside the cave, he had left a crowbar, a shovel, and burlap bags from his earlier work.

Collins crawled through the breakdown to a narrow ledge. From there, with the help of his rope, he descended a pit some 20 m deep. Exactly what Collins discovered at the bottom of this pit is uncertain; various possibilities are discussed in Murray and Brucker (1979, p. 287).

Collins left his rope where he had tied it when he began to crawl out of the cave, knowing he would be back. He pushed himself into the small crevice he had blasted and dug out earlier, moving his lantern ahead of him. In a narrow part of the crack, his lantern fell over and went out. Collins continued wedging himself through the breakdown in the dark. Kicking out to push himself forward, he broke loose a hanging rock. It fell across

his left foot. Kicking again to free his foot, Collins dislodged more rocks, trapping both legs.

Saturday morning, January 31, 24 hours after Collins became trapped, Bee Doyle with one of his neighbors and his son came looking for Floyd. Unable to reach him, but crawling close enough to talk to him, they learned of his predicament.

The first rescue parties were organized by Floyd's youngest brother, Homer, with several local inhabitants who had volunteered to help. The narrow Sand Cave passage severely limited activities inside the cave and was to become the most frustrating aspect of the rescue operations. Only one person could reach Floyd at a time. This person had to enter the chute feet first and contort his body to work, or he had to enter head first, work with his head lower than his feet, and crawl uphill backwards 6 m to get out of the chute. No one could get below Floyd to move the rock pinning his foot. Floyd was, in effect, a cork in the passage.

Four men were to become key rescuers in the early stages of the incident: Homer Collins; William 'Skeets' Miller, a reporter for *The Louisville Courier Journal*; Lt. Robert Burdon, a Louisville fireman; and Johnnie Gerald, a caving partner of Floyd's. Several more men actually reached Floyd in the passage or participated in the operations, but many more entering the cave with the idea of freeing Floyd panicked and fled.

The early rescue operations had 5 primary interests: (1) to maintain contact with Floyd, (2) to take him food and hot liquids, (3) to keep dry blankets and quilts around him, (4) to divert the water that was dripping onto his face by using burlap bags and oilcloth, and (5) to dig out gravel from around his body with a crowbar and pass it up the passage to be dumped. As the operations became organized, work crews were assembled to enlarge the passage using sledge hammers, ball-peen hammers, cold chisels, and a gasoline blow torch. Other attempts were made to shore the passage.

The men who reached Floyd brought him coffee, milk, water, and hot soup in bottles and mason jars, prescription whiskey in drugstore bottles, and solid food in containers. Volunteers were recruited continuously to take Floyd food, but when Homer Collins entered the cave for the third time Sunday afternoon, he was disturbed by '... the abandoned food and blankets he saw stuck in cracks along the way' (Murray and Brucker, 1979, p. 62). Skeets Miller reported a worse situation Tuesday afternoon, February 3, when he strung an electric drop cord with several light bulbs along it through the cave. Miller could now see the details of the passage clearly:

... there was an amazing amount of debris everywhere—loose boards, broken glass, cigarette butts, spent chewing tobacco, clothes, blankets, and food.' (Murray and Brucker, 1979, p. 99)

Two serious attempts were made to free Collins' body from the crack into which it was wedged. The first, devised by Lt. Burdon, oc-

curred Monday afternoon, February 2. A harness on Floyd's chest and shoulders was attached to a 32 m rope, and 8 men spread along the passage attempted to pull him loose. The harness attempt failed, subjected Floyd to excruciating pain, and unnerved the men who attempted the pull. It was not tried again, although Lt. Burdon maintained it was the best chance to get Floyd out. The second attempt was by Skeets Miller on Tuesday night, February 3. The gravel had been dug out around Floyd to his ankles, and Miller worked a crowbar into the rubble at Floyd's feet. He next attempted to fit several jacks between the ceiling and the crowbar. The first jack, a Chandler automobile jack, was too large. The second was also too large. Miller retreated from the cave and selected the third jack himself. Upon returning, he discovered that it was too small. Miller then tried holding wooden blocks between the jack and the ceiling while turning the handle with his other hand. The blocks repeatedly slipped out; Miller gave up and returned to the surface.

In the early morning hours of Wednesday, February 4, the passage collapsed in front of Floyd, cutting him off from the rescuers. Skeets Miller had only hours ago made his jack attempt and was now in Cave City, resting before he tried again. Efforts were made to dig out the collapse, but both Miller and Burdon declared it hopeless.

Gerald maintained he could get through the collapse and requested that it be dug out and shored. Between the last shoring effort and Gerald's entry into the cave, a second cave-in occurred in front of the first. Gerald, discouraged and frightened by falling rock, was the last key rescuer to give up hope of reaching Collins through the cave. At 10:30 P.M. Wednesday, February 4, Collins lay helplessly entombed. The electric cord still carried electricity through the cave; a single light bulb wrapped in burlap and placed on Floyd's chest was his only source of warmth. He had not eaten since the first collapse, early Wednesday morning.

As the situation worsened in Sand Cave, major events were occurring on the surface. Tuesday morning, at 10:30 A.M., Henry Carmichael, a civil engineer and general superintendent of the Kentucky Rock Asphalt Company, arrived and began organizing the operations. By request of the Governor of Kentucky, a small contingent of National Guardsmen arrived at the site at 10:00 P.M. Tuesday night, February 3, to maintain order. They were reinforced by 25 more National Guardsmen, who arrived late Wednesday night and Thursday morning. Lt. Governor Henry Denhardt, a brigadier general in the National Guard, was appointed commanding officer. The Governor also sent two personal representatives: Highway Commissioner M. E. S. Posey and Professor William D. Funkhouser, head of the zoölogy department of the University of Kentucky.

These 4 men: Carmichael, Denhardt, Posey, and Funkhouser, were to dominate the rest of the rescue operations as the state took full control of

the site. Their first move was to make an engineering survey of the passage; however, they had to estimate the distance to Floyd from the collapse. They decided that to continue the attempts to reach Floyd through the cave would be too dangerous and announced that a shaft would be sunk to intercept the passage. A 2 m square shaft was placed under the sandstone ledge, according to the survey they had made. It was finally begun at 1:30 P.M. Thursday, February 5, using only picks and shovels. Carmichael was placed in charge of the shaft. His first estimate was that they would reach Collins within 35 hours. Delays turned the hours into days as the Sand Cave area became a carnival site. The press stepped up its coverage as more curiosity seekers and drifters, as well as sincere volunteers, gathered. A military court was appointed to clear up suspicions of criminal efforts to block the rescue attempts and to dispell rumors that Floyd's entrapment was not genuine.

Eleven days after the shaft was begun—12 days since the cave-in occurred and 18 days since Floyd was trapped—a lateral from the shaft broke into Sand Cave. The second man through confirmed what many already feared: on February 16th, Floyd Collins was dead.

A decision was made to leave Floyd's body in the cave, because no one wanted to risk his life further in Sand Cave. A coroner's jury was formed to view the body, and a final medical assessment was made on Tuesday, February 17. It was concluded that Floyd probably had died sometime on Friday, February 13. Tuesday afternoon, a funeral was held at Sand Cave for Floyd Collins. Wednesday, February 18, the shaft was filled with rocks, dirt, and trees, and the entrance to Sand Cave filled with debris.

Homer Collins, unsatisfied that Floyd's body still remained in Sand Cave, hired several miners to reopen the shaft and remove the body. This was completed on April 23, 1925, and Floyd received a second burial at Flint Ridge on April 26. The Collins family subsequently sold Crystal Cave. Floyd's body was dug up and placed inside Crystal Cave as a tourist attraction in June of 1927. Even in death Floyd could not rest; on March 18 or 19, 1929, his body was stolen from its casket, but was found a day later and returned. Floyd Collins lies in a casket covered with dust and seldom visited in the great Crystal Cave that he discovered.

Tours of Crystal Cave ceased when the Park Service took control of the entrance and have never been reinstated. Now at peace in the dark, Floyd Collins lies in a casket covered with dust and seldom visited in the Great Crystal Cave that he discovered.

Historical Survey

The last rescue workers departed from Sand Cave Wednesday afternoon, February 18. Carmichael originally planned to seal Sand Cave with concrete, but, when it had not arrived by Wednesday morning, he ordered the passage sealed with debris and the shaft filled. Carmichael's barrier was ineffective, and claims have been made that

persons have crawled into the entrance rooms (Halliday, 1966), although no one has been known to crawl any farther. The miners who reopened the shaft to remove Collins's body did not explore any of the passage below the trap, but rather were satisfied to scan the pit with their flashlights (Murray and Brucker, 1979, p. 232).

In the mid 1950's, the National Park Service, conscious that Sand Cave remained open and presented a possible hazard, installed an iron grate at the beginning of the crawl. Sand Cave was now effectively sealed from the surface. However, the Cave Research Foundation, which systematically explores and surveys the Flint Mammoth Cave system, by the early 1970's had discovered other cave passages in the vicinity of Sand Cave. A segment of Mammoth Cave called Bransford Avenue has several side passages which are lower than Sand Cave. One lies directly beneath it. These passages were intensely investigated for possible leads into Sand Cave, but all failed to have any indication of such a route (Murray and Brucker, 1979, pp. 272-273).

Murray and Brucker realized that, in order to research the Collins incident thoroughly, they had to enter the cave. Brucker, responsible for the caving aspects of the story, asked permission in February of 1977 to enter Sand Cave. He argued that the information gained would be useful to the Park's interpretive program (Murray and Brucker, 1979, p. 273).

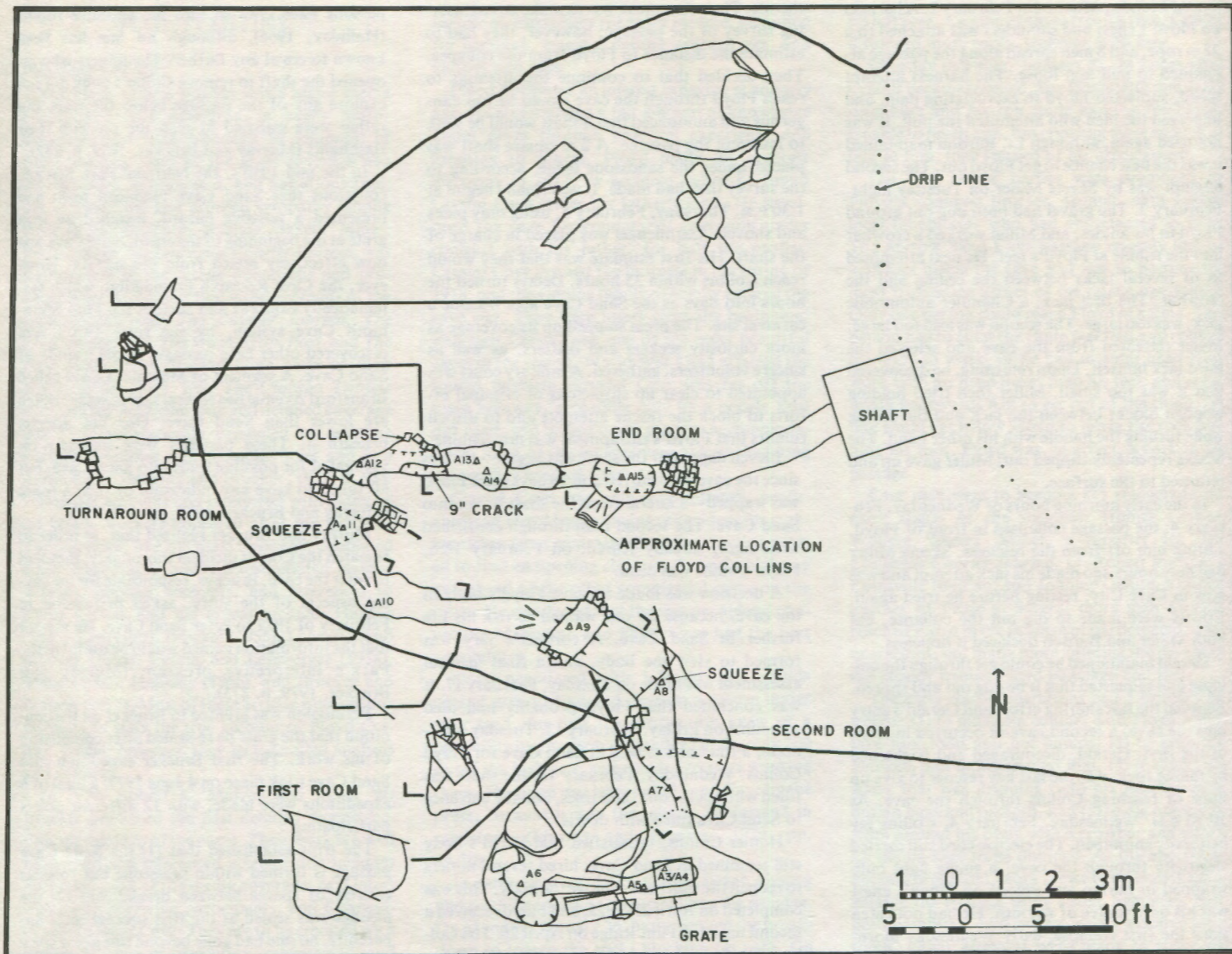
Permission was granted to Brucker on the condition that the grate be re-sealed after completion of his work. The first Brucker expedition into Sand Cave took place on 4 June 1977; a total of 6 expeditions were made, with 12 different cavers participating.

The trips established that (1) the Sand Cave passage is formed within limestone but consists entirely of spaces between breakdown; (2) the passage was sealed at the first squeeze and, apparently, no one had gone beyond this point since 1925; (3) remains from the rescue operation were still present in the cave; and (4) the most startling discovery of all, a 23 cm crack bypassed the Wednesday morning cave-in. The cavers had unknowingly surveyed through this crack and came to within a few cm of where Floyd had been trapped. The 23 cm crack was never used by the 1925 rescuers. The original route lay up and over the crack; when breakdown covered that route, they tried unsuccessfully to dig through it.

Archaeological Survey

My archaeological survey inside Sand Cave involved 2 expeditions. The first occurred on 30 August 1980, when I began recording the remains. The second took place on 11 October 1980. Documentation of the remains was completed at that time, and appropriate materials were collected. Both expeditions were conducted by 3 cavers.

My intention was to record the positions of artifacts in relation to named or designated rooms or features within the cave. This system, although not very precise in designating provenience, was



chosen because movement of the breakdown, attempts to enter by curiosity seekers, and the historical survey invariably disturbed the Sand Cave remains. Movement within Sand Cave is severely limited, and several of the artifacts are fragile. The Brucker expedition was careful to note the locations of artifacts and to move them from the main route of traffic, but some damage inevitably occurred, and any information which could have been gained from their locations was destroyed.

All of the artifacts recorded in the cave were removed, except those whose removal would have required physically altering the cave. The 1925 remains which were not removed included shoring, electrical wires, and imbedded nails. Several modern artifacts were recorded, but were not collected in the survey. These items are intrusive to the cave—dropped through the grate by Park visitors or carried in by pack rats.

A detailed description of Sand Cave is provided by Murray and Brucker (1979, p. 275 ff.) Four

areas within the cave have been designated as rooms (figs. 5 and 6). They are large enough only to sit up and turn around in. Most of the passage consists of body-sized crawls and chutes connecting the rooms. The iron grate is situated above the first and largest of the rooms, which is ample enough for 3 people to rest in. At the end of this room is a drop into the Second Room. Two people, at most, can sit here. At the end of the Second Room is the first squeeze.

This squeeze was sealed by fist-sized rocks and mud when Brucker's party first entered the cave in 1977. In 1980, we discovered the passage to be sealed again. The mud-and-rock seal appears to have kept anyone from entering the passage between the time Carmichael's barrier was removed and the time the National Park Service installed the grate.

The passage continues for 7 m past the first squeeze as a body-sized crawl. The first obvious evidence of 1925 activity was found here—a shoring post and several loose pieces of wood. The

crawl then narrows into a second squeeze and enters the Turnaround Room. This room is an uncomfortable, wet hole large enough to seat 2 or 3 people. The walls are 2 sloping piles of shoeboxed breakdown, and water stands in puddles on the floor. A breeze through the passage increases the discomfort. A concentration of 1925 artifacts was found in this room.

The Wednesday morning cave-in is just ahead of the turnaround room. The bypass is a 23 cm corkscrew, which enters a steeply pitched passage just below the collapse. A pair of electric wires runs along this passage. The passage ends in a small cubby hole, the End Room. One person at a time can crouch here. This is approximately where Floyd Collins was trapped. The largest concentration of artifacts was found in this room.

The passage ends in water-laid gravel and dirt, but the electric wires coming from the steep slope continue into the sediment-filled 45° chute where Collins was trapped. The wires are known to have terminated at a single light bulb placed on Floyd's

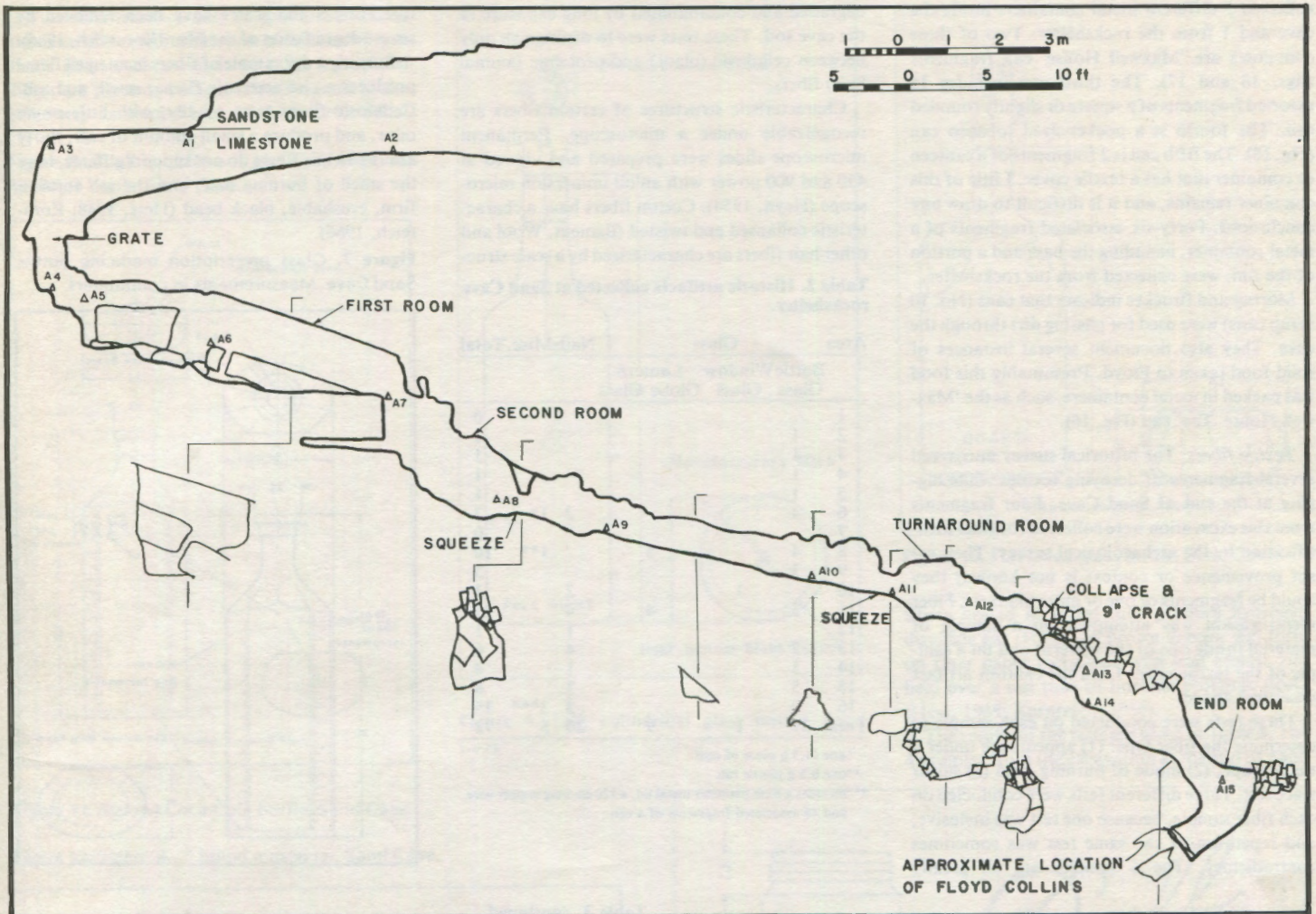


Figure 5. (left) Sand Cave, adapted from Murray and Brucker, 1979, p. 227. Crawlway underlies rockshelter. NSS Standard Map Symbols, 1979.

Figure 6. (above) Extended profile of the Sand Cave crawlway, adapted from Murray and Brucker, 1979, p. 226. NSS Standard Map Symbols, 1979.

chest (Murray and Brucker, 1979). Brucker's survey excavated the chute, following these wires. In doing so, they also uncovered more artifacts, including fragments of one or more decaying blankets. The historical survey halted where the chute fit the description of the position in which Collins was trapped (Murray and Brucker, 1979, p. 282). However, it never reached the end of the wires.

Artifacts

In my systematic, intensive, surface collection of the rockshelter floor, I recovered 72 historic artifacts (Table 2). Detailed descriptions of selected artifacts are given in the Catalog of Artifacts.* The predominant materials recovered were broken glass (65%) and nails (28%).

The locations of artifacts and features along the cave passage are presented in Table 3, recon-

structed from Brucker's historical survey and from my archaeological survey. 'Provenience' refers to a designated room or to distance from a named feature in the cave.

A total of 37 artifacts were collected and 8 features were recorded inside the cave passage (Table 4). Seven categories of material and features are discussed below, including (1) glass bottle and jar artifacts, (2) lantern artifacts, (3) metal container artifacts, (4) textile fiber samples, (5) other artifacts, (6) wood and shoring features, and (7) other features.

Glass bottle and jar artifacts. This is the largest category of artifacts from the Sand Cave historic site. It includes 6 bottles, 2 mason jars, and a glass fragment collected inside the cave and the bases of 2 bottles and 45 other glass fragments collected at the rockshelter. Three of the six bottles are prescription whiskey or medicine bottles (figs. 7 and 8), two are plain (figs. 9 and 10), and the sixth

is a Coca-Cola bottle (Fig. 11). The base of another Coca-Cola bottle and a clear, circular bottle base were recovered at the rockshelter. The 2 jars include an unbroken 'Ball, Perfect Mason' jar with its screw cap (Fig. 12) and the mouth of a broken mason jar.

Glass fragments from the rockshelter include a variety of clear bottle glass, colored bottle glass, and modern beer bottle glass (Table 5).

Lanterns. Three different kerosene lantern bodies (figs. 13, 14, and 15) and 7 other lantern fragments were recovered inside the cave. Presumably, the 7 other fragments are parts of one or more of the 3 lanterns represented by the 3 lantern bodies. The lantern parts are poorly preserved, but a cotton wick can be distinguished in each of the bodies.

Four reconstructed lantern globe fragments (about 33% of the globe) and 9 globe rim fragments were collected from the rockshelter. The archaeological survey did not recover any lantern globes or fragments inside the cave, but the historic survey did record one (Murray and Brucker, 1979, p. 281).

Metal containers. The archaeological survey

*Any reader may obtain a copy of this Catalog at no charge by writing to The NSS Library, Cave Avenue, Huntsville, Alabama 35810.

collected 5 different metal containers inside the cave and 1 from the rockshelter. Two of these containers are 'Maxwell House' can fragments (figs. 16 and 17). The third can includes 15 assorted fragments of a square or slightly rounded can. The fourth is a pocket-sized tobacco can (Fig. 18). The fifth can is 2 fragments of a canteen or container that has a textile cover. Little of this container remains, and it is difficult to draw any conclusions. Forty-six associated fragments of a metal container, including the base and a portion of the rim, were collected from the rockshelter.

Murray and Brucker indicate that cans (No. 10 syrup cans) were used for passing dirt through the cave. They also document several instances of solid food taken to Floyd. Presumably this food was packed in metal containers, such as the 'Maxwell House Tea' can (Fig. 16).

Textile fibers. The historical survey uncovered several fragments of decaying textiles while digging at the end of Sand Cave. Four fragments from this excavation were collected for fiber identification by the archaeological survey. Their exact provenience or context is not known; they could be fragments of one or more blankets. Fiber identification was attempted on a sample of material inside one of the lanterns and on a sample of the textile cover from the canteen artifact described above.

Three tests were conducted on each sample to determine the fiber type: (1) appearance under a microscope, (2) mode of burning, and (3) sulfur trace test. Three different tests were conducted on each fiber sample, because one test was inclusive, and repetition of the same test was sometimes contradictory. The 6 samples are all greatly

degraded and contaminated by long exposure to the cave soil. These tests were to distinguish only between cellulosic (plant) and proteinic (animal hair) fibers.

Characteristic structures of certain fibers are recognizable under a microscope. Permanent microscope slides were prepared and viewed at 450 and 900 power with an oil immersion microscope (Heyn, 1954). Cotton fibers have a characteristic collapsed and twisted filament. Wool and other hair fibers are characterized by a scale struc-

Table 2. Historic artifacts collected at Sand Cave rockshelter.

Area	Glass			Nails	Misc.	Total
	Bottle Glass	Window Glass	Lantern Globe Glass			
1						0
2	1					1
3	1					1
4	1					1
5	1					1
6	4			2	1*	7
7						0
8	4		5		1**	10
9	3					3
10		1		2		3
11	3		4	4		11
12				1		1
13	2			4		6
14	3			1		4
15	5			3		8
16	9			3	3***	15
Total	37	1	9	20	5	72

*one 11.3 g piece of coal
 **one 0.5 g plastic tab
 ***includes a 6 cm diameter metal lid, a 120 cm long copper wire, and 46 associated fragments of a can

ture, unless the scales have been removed by severe degradation of the fiber (Kornreich, 1966).

Burning a dry sample of fibers in an open flame produces a characteristic flame, smell, and ash. Cellulosic fibers burn readily, with little or no odor, and produce a small amount of soft, fluffy ash. Proteinic fibers do not support a flame, have the smell of burning hair, and the ash forms a firm, crushable, black bead (Hess, 1948; Kornreich, 1966).

Figure 7. Glass prescription medicine bottle, Sand Cave. Measurements in centimeters.

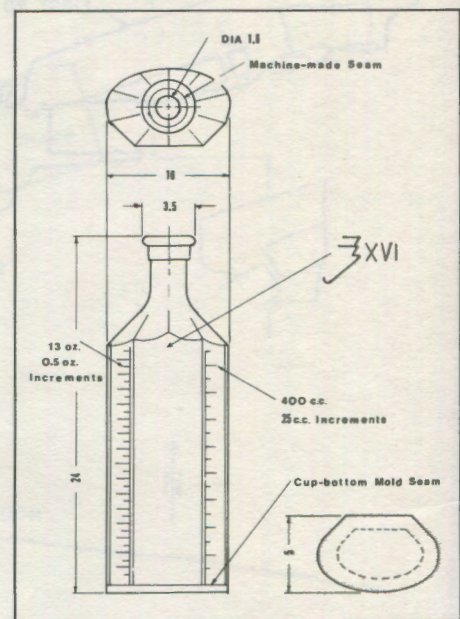


Table 3. Location of artifacts and features inside Sand Cave.

Provenience*	Artifact or Feature	Accession No. or Feature No.
A3	1 nail imbedded in rock	fea. 9
A4	1 butane lighter, modern	17-38
A6	2 rusted cans, modern	
	1 butane lighter, modern	
	1 nail imbedded in ceiling crack	fea. 5
	1 pack rats nest	
A7	1 Coca-Cola can, modern	
A8	many hammer marks on ceiling rock mud and rocks sealing passage	fea. 6
A10 - 1 m	1 shoring post in place several loose pieces of wood	fea. 8
A11	many hammer marks on ceiling rock	fea. 7
Turnaround Room	15 associated metal can fragments	17-35
	1 Coca-Cola bottle	17-4
	1 light bulb	17-6
	1 tobacco can	17-3
	1 chert flake, prehistoric	17 (B)
	several loose pieces of wood	selected sample 17-11
A12 + 2.5 m	rotten wood sample	17-28
A14	2 shoring posts opposite sides of the passage	fea. 2
	2 fragments of circular "Maxwell House" lid	17-34

*Refers to a survey station marked on the map or is a named room within the cave (see figures 5 and 6)

Table 3, continued

Provenience*	Artifact or Feature	Accession No. or Feature No.
	1 prescription bottle	17-20
	1 broken mason jar	17-32
	1 triangular chert blank, prehistoric	17-1 (B)
	beginning of pair of electric wires wrapped around left shoring post	fea. 1
A14 + 1 m	1 wooden wedge driven between two breakdown blocks	fea. 3
End Room	7 miscellaneous lantern fragments	17-21, 29, 31, 33, 36, 42
	4 woven textile samples	17-25, 30, 39, 40
	3 lantern bases with cotton wicks	17-10, 15, 24
	2 prescription bottles	17-7, 8
	2 fragments of metal canteen with textile cover	17-23, 27
	1 "Ball, Perfect Mason" jar with screw lid	17-19, 14
	1 tall cylindrical bottle	17-9
	1 flat-sided bottle	17-5
	1 "Maxwell House Tea" can	17-1
	1 L-shaped iron rod	17-12
	1 6-lb sledge hammer head	17-13
	1 china cup fragment	17-22
	1 glass fragment	17-26
	several loose pieces of wood	
	electric wires disappearing into the sediment	fea. 1

The sulfur trace test may be used to test for the presence of wool, but this test is nullified if synthetic fibers such as casein or other animalized fibers are present, because these respond in the same way as wool (Hess, 1948, p. 170). Wool

Figure 8. Slightly different glass prescription medicine bottle, Sand Cave.

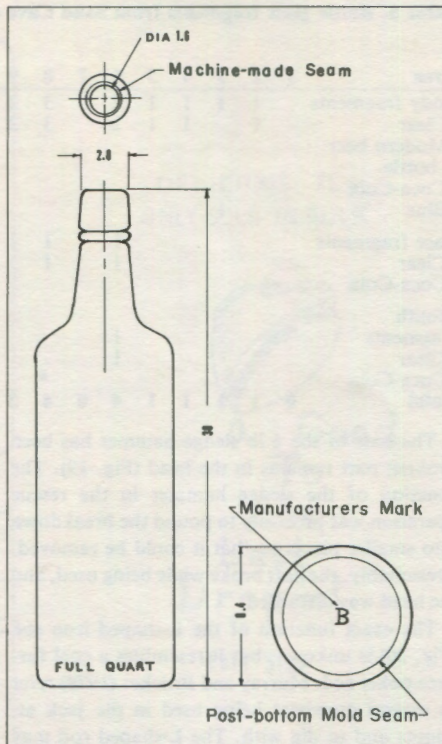
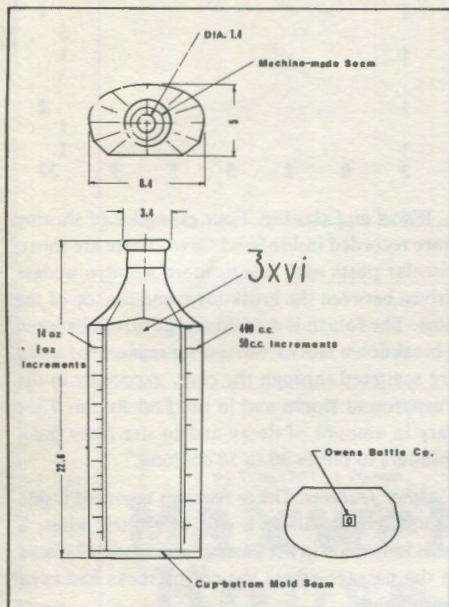


Figure 9. Tall, cylindrical glass bottle, Sand Cave.

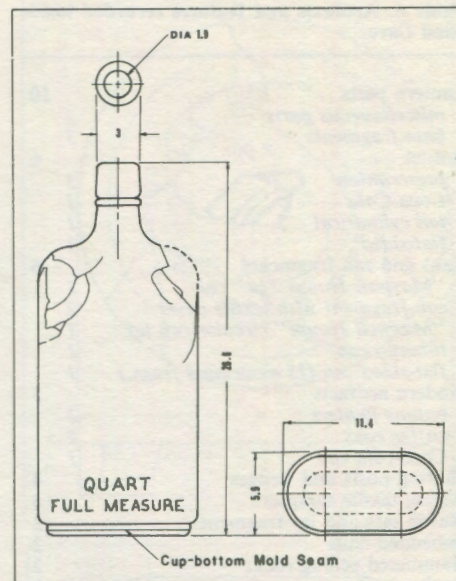


Figure 10. Flat-sided glass bottle, Sand Cave.

fibers heated in a test tube produce hydrogen disulfide gas (H_2S_2). A brown deposit will form on filter paper moistened with lead acetate and held over a test tube of burning proteinic fibers (Hess, 1948; Kornreich, 1966).

The results of the tests are given in Table 6. The 4 samples from the excavation at the end of Sand

Figure 11. (below) Coca-Cola bottle, Sand Cave.

Figure 12. (right) 'Ball' brand mason jar, Sand Cave.

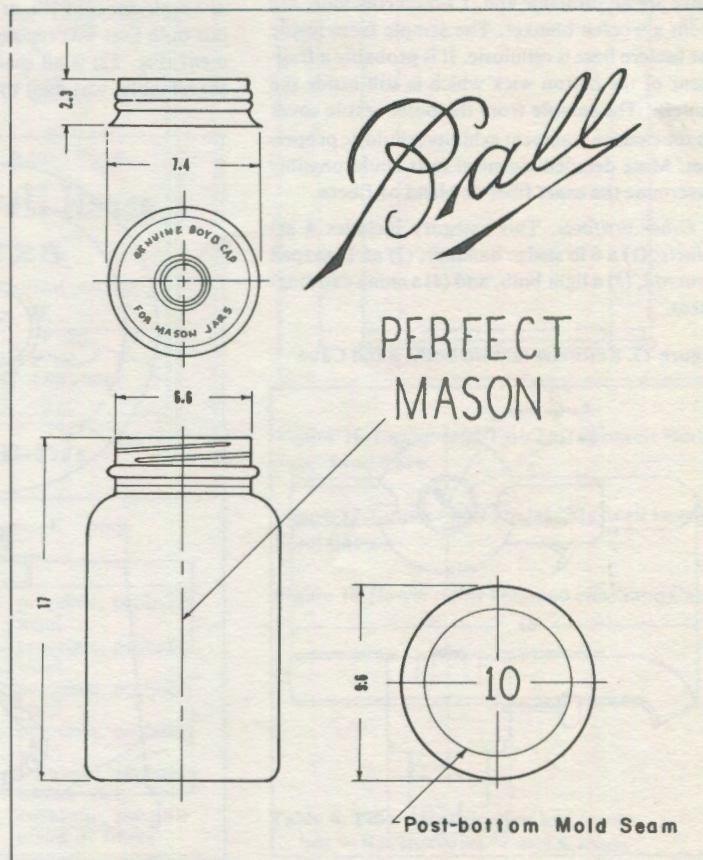
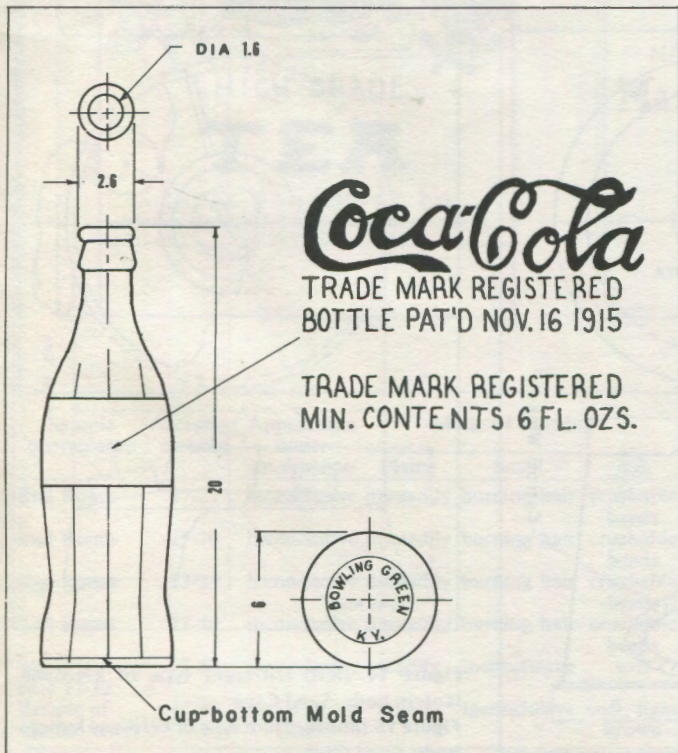


Table 4. Artifacts and features recorded inside Sand Cave.

Lantern parts	10
<i>miscellaneous parts</i>	7
<i>base fragments</i>	3
Bottles	6
<i>prescription</i>	3
<i>Coca-Cola</i>	1
<i>tall cylindrical</i>	1
<i>flat-sided</i>	1
Cans and can fragments	6
<i>"Maxwell House Tea" can</i>	1
<i>can fragment with textile cover</i>	2
<i>"Maxwell House" circular can lid</i>	1
<i>tobacco can</i>	1
<i>flat-sided can (15 associated frags.)</i>	1
Modern artifacts	5
<i>butane lighters</i>	2
<i>coffee cans</i>	2
<i>Coca-Cola can</i>	1
Shoring posts and wedges	4
Woven textile samples	4
Mason jars and jar fragments	2
Imbedded nails	2
Hammered ceiling rocks	2
Tools	2
<i>L-shaped iron rod</i>	1
<i>6-lb sledge hammer head</i>	1
Prehistoric artifacts	2
<i>triangular chert blank</i>	1
<i>chert flake</i>	1
Mason jar screw lid	1
Light bulb	1
China cup fragment	1
Glass fragment	1
Pair of electric wires	1
Total	50

Cave are all proteinic and, I would conclude, are from a woolen blanket. The sample from inside the lantern base is cellulosic. It is probably a fragment of the cotton wick which is still inside the lantern. The sample from the outer textile cover of the canteen fragment exhibits cellulosic properties. More detailed chemical tests could possibly determine the exact fiber or blend of fibers.

Other artifacts. This category includes 4 artifacts: (1) a 6 lb sledge hammer, (2) an L-shaped iron rod, (3) a light bulb, and (4) a china cup fragment.

Figure 13. Kerosene lantern body, Sand Cave.

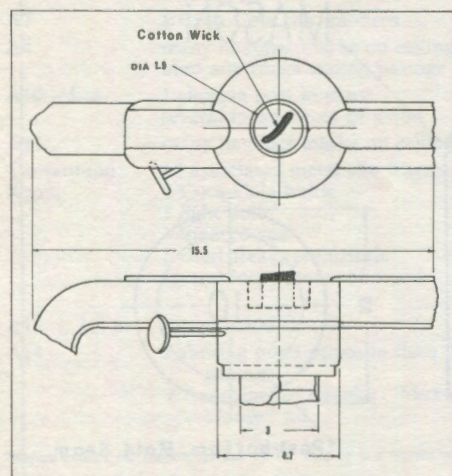


Table 5. Bottle glass fragments from Sand Cave rockshelter.

Area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Body fragments	1	1	1	1	2			3	2		1		2	3	5	9	31
Clear	1		1	1	2			3	2		1		1		5	1	18
Modern beer bottle																7	7
Coca-Cola														3		1	4
Blue			1										1				2
Base fragments					1		1	1			1						4
Clear					1		1	1									3
Coca-Cola											1						1
Mouth fragments							1					1					2
Clear					1												1
Coca-Cola									1		1						1
Total	0	1	1	1	1	4	0	4	3	0	3	0	2	3	5	9	37

The haft of the 6 lb sledge hammer has been broken; part remains in the head (Fig. 19). The function of the sledge hammer in the rescue operation was probably to pound the breakdown into smaller pieces so that it could be removed. Presumably, the haft broke while being used, and the head was discarded.

The exact function of the L-shaped iron rod (Fig. 20) is unknown, but it resembles a coal furnace poker rod. Murray and Brucker (1979) refer to several crowbars being used in the jack attempts and to dig with. The L-shaped rod may have been used as a lever, in an attempt to lift the rock off Collin's foot, or as an extension to reach along his body in the chute and dig out gravel.

The light bulb (Fig. 21) was probably intended as a replacement bulb, or may have been a burned out bulb that was replaced. The china cup fragment (Fig. 22) is all that remains of a cup that, presumably, was used by Floyd.

Wood and shoring. Four examples of shoring were recorded inside Sand Cave. Three are short, circular posts with one or more wooden wedges driven between the breakdown and the top of the post. The fourth is a wood wedge driven between 2 breakdown blocks. Several loose pieces of wood are scattered through the cave, especially in the Turnaround Room and in the End Room. They vary in amount of decay and in size from small splinters to pieces 30 to 50 cm long.

Other features. Other features recorded inside Sand Cave included: a pair of electric wires, 2 nails imbedded in the passage ceiling, and 2 places in the passage where the ceiling rocks had been hammered.

A pair of electric wires stretch inward from the collapse, become buried in the floor of the steeply pitched passage, emerge in the End Room, then disappear into the sediment-filled chute in which

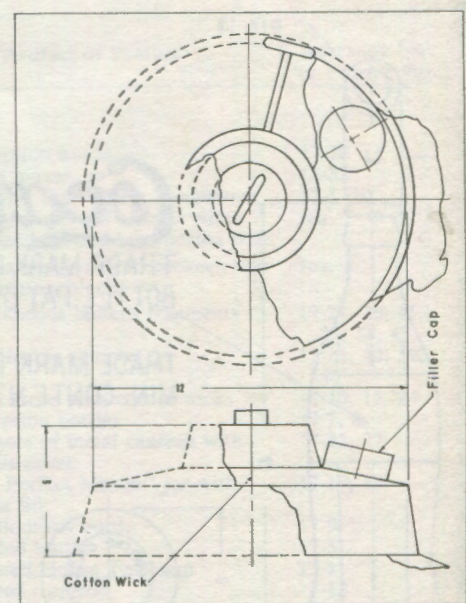
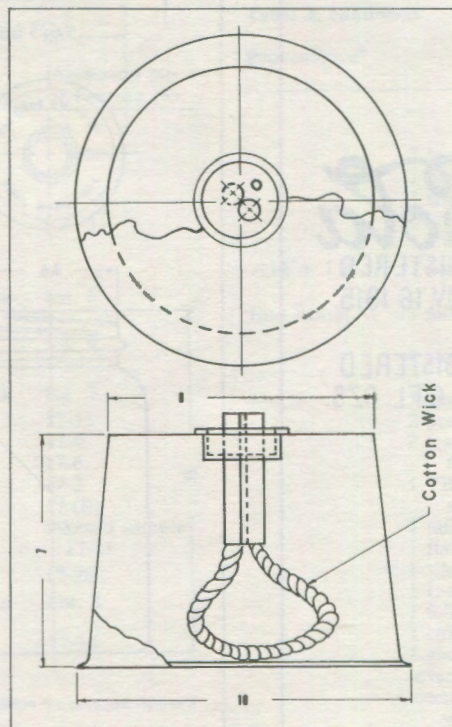


Figure 14. (left) Different type of kerosene lantern body, Sand Cave.

Figure 15. (above) Third type of kerosene lantern body, Sand Cave.

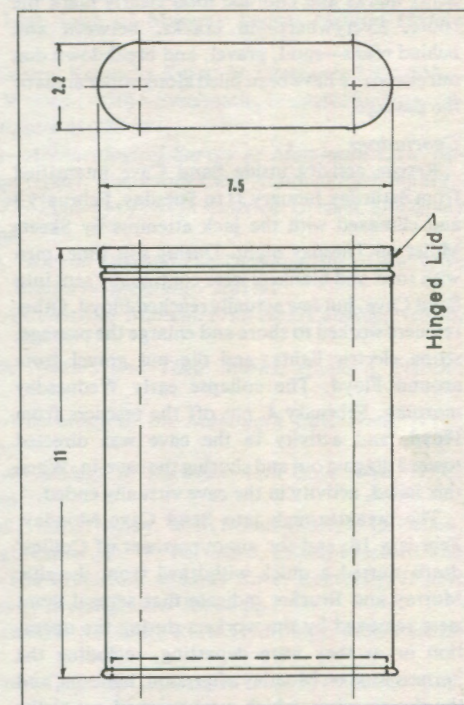
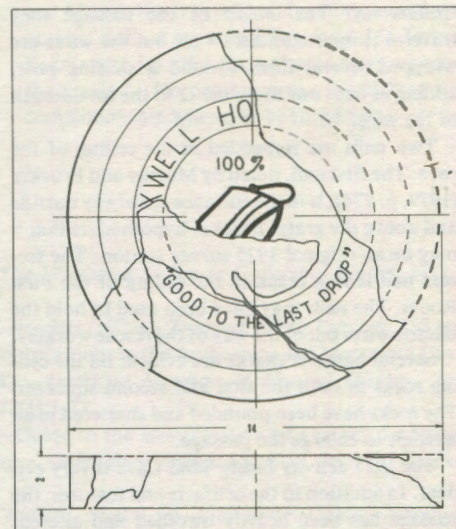


Figure 16. (upper left) Tin can, 'Maxwell House Tea,' Sand Cave.

Figure 17. (upper right) Tin lid, 'Maxwell House,' Sand Cave.

Figure 18. (lower right) Tobacco can, Sand Cave.

Sample provenience	Accession number	Appearance under microscope	Mode of Burning			Sulfur trace*	Fiber
			Flame	Smell	Ash		
End Room	17-25	inconclusive	unreadily	burning hair	crushable beads	pos.	proteinic, probably wool
End Room	17-30	inconclusive	unreadily	burning hair	crushable beads	pos.	proteinic, probably wool
End Room	17-39	inconclusive	unreadily	burning hair	crushable beads	pos.	proteinic, probably wool
End Room	17-40	inconclusive	unreadily	burning hair	crushable beads	pos.	proteinic, probably wool
Inside lantern base 17-15	17-41	inconclusive	readily	inconclusive	soft	neg.	cellulosic, probably cotton wick
Sample of canteen cover	17-23	two distinct fibers	readily	inconclusive	soft, light brown	neg.	cellulosic, possible blend of fibers

Table 6. Fiber identification test results.

*pos. = H₂S, present; neg. = no H₂S, present.

Collins lay. The length of the passage they traverse is approximately 4 m, but the wires are wrapped several times around a shoring post, adding at least one more meter to the total length of the wire.

Two nails are imbedded in the ceiling of the cave. The first nail, noted by Murray and Brucker (1979, p. 274), is in the entrance crawlway outside and above the grate. Brucker hypothesizes that it may be an original 1925 survey station. The second nail is in a crack in the ceiling of the First Room. The nails may have been used to hold the electric wires out of the way of the rescue workers.

Several hammer marks are evident on the ceiling rocks at both the first and second squeezes. The rocks have been pounded and shattered in an attempt to enlarge the passage.

The 1925 activity inside Sand Cave is very evident. In addition to the artifacts and features, the passage has been heavily travelled and altered. Scuff marks and churned mud clearly mark the route. Everywhere—in cracks, between and behind rocks—mud, gravel, and breakdown dug out elsewhere have been piled along wider areas of the passage.

Conclusions

Rescue activity inside Sand Cave intensified from Saturday January 31 to Tuesday, February 3 and climaxed with the jack attempts by Skeets Miller on Tuesday night. During this time, men with food and blankets were continually sent into Sand Cave, but few actually reached Floyd. Other rescuers worked to shore and enlarge the passage, string electric lights, and dig out gravel from around Floyd. The collapse early Wednesday morning, February 4, cut off the rescuers from Floyd, and activity in the cave was directed toward digging out and shoring the cave-in. When this failed, activity in the cave virtually ended.

The breakthrough into Sand Cave Monday, February 16, and the announcement of Collins' death started a quick withdrawal from the site. Murray and Brucker indicate that several items were removed by the workers during the operation or as they were departing, including the harness used on Monday afternoon, lanterns, and the electric wires, which were stripped out to the collapse.

The archaeological evidence supports and enforces the idea that most of the material used in the cave and left by the early rescuers was removed. The artifacts which were recorded archaeologically mainly represent discarded remains of the workers: empty bottles and cans, useless lanterns, and broken tools.

Many of the artifacts were removed, of course, because they were still useable items. Several of the would-be rescuers realized the potential commercial value in the rescue tools.

Kentucky, Tennessee, Indiana, Illinois, and Ohio, elaborating on their rescue activities. (Murray and Brucker, 1979, p. 230)

The artifacts inside Sand Cave became important, not because of their value as serviceable items, but because they could be related to the death of Floyd Collins.

The Sand Cave story does not yet have an end. No one has seen the passage that Collins was on his way out to report that fateful morning in the winter of 1925. Rainwater, seeping through the Sand Cave breakdown, transports sediment, depositing it in the narrow chute which once held Floyd Collins. The pair of electric wires disappear into the fill, enticing the explorer to find their end and indicating that more artifacts may be buried.

Below the trap lies the last passage Floyd Collins explored and which no caver has seen since.

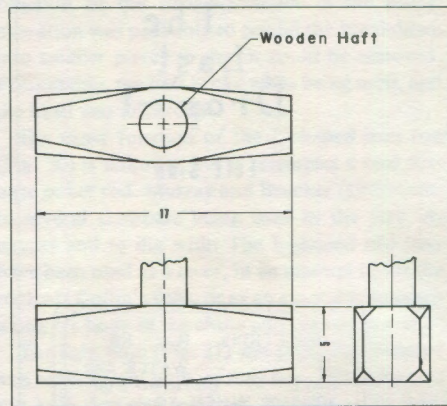


Figure 19. Hafted steel sledge hammer, Sand Cave.

Unlike the men in 1925, who for some reason felt they must risk their lives for a man they had never met, time is on the side of modern cavers, who some day will find their way to the end of Sand Cave. It may be from below, through virgin passage, or it may be as a coordinated effort to excavate the chute, but when it occurs, the final question will be put to rest: 'What did Floyd discover?' William Halliday, one of the many cavers engrossed by the fate of Floyd Collins, wrote in 1966: 'That little rock may have set history back more than anyone but Floyd Collins dreamed' (Halliday, 1966, p. 49).

ACKNOWLEDGEMENTS

The Sand Cave Archaeological Project was initiated while I was an undergraduate student at Washington University in St. Louis. Field work was conducted in cooperation with the National Park Service under Federal Antiquities Permit Number 81-KY-006 and was partially supported by the Cave Research Foundation. I would like to acknowledge Superintendent Robert Deskins and Management Assistant Jim Wiggins of Mammoth Cave National Park, Professors David Browman and Patty Jo Watson of Washington University,

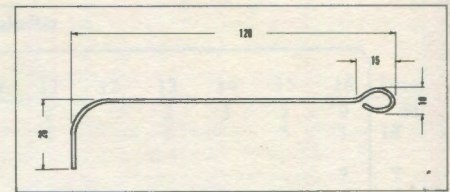


Figure 20. (above) L-shaped iron rod, Sand Cave.

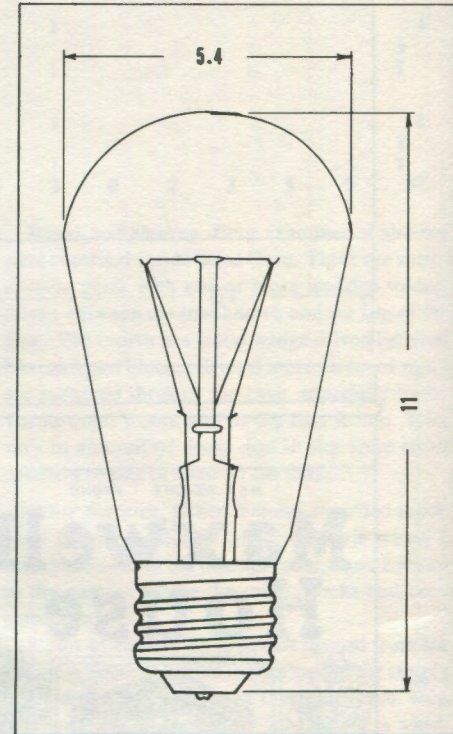
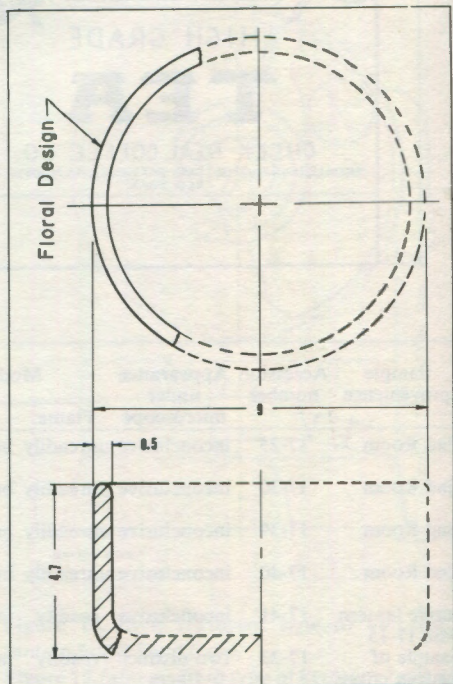


Figure 21. (above) Light bulb, Sand Cave.

Figure 22. Fragment of china cup, Sand Cave.



A number of rescue workers . . . quickly set off on vaudeville tours. Displaying hammers, spades, flashlights, and jacks they claimed had been used in the rescue work, they made rounds of small movie houses in

and Roger Brucker and Charles Hildebolt of the Cave Research Foundation for their support and encouragement. I am indebted to numerous people for their assistance and expertise in both the field and laboratory. Richard Zopf, Gail Wagner,

Jeremy Geller, and Jeff McKee provided field assistance, Laurie Lennox provided lab assistance, and Caroline Smither helped with artifact illustrations. Mike Fuller guided the mapping of Sand Cave rockshelter. Mark Elliott, John Holik,

and Mike Voligny provided their time and photographic skills. I am especially grateful to Tammy Bennington for her help in almost every aspect of the project. Her enthusiasm, friendship, and companionship will never be forgotten.

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ANNOUNCEMENTS

CHANGE OF PUBLICATION FREQUENCY

The NSS Board of Governors has directed *The NSS Bulletin* to change in frequency of publication from quarterly to semi-annual in 1984 (Minutes, 12 March 1983). At that time, the *Bulletin* will begin a policy of producing

annually one symposium or other topical issue and one issue for contributed papers, convention abstracts, news, editorials, advertisements, and miscellanea. Professional-level manuscripts will continue to be accepted for publication: however, we are directed to ensure that '... a significant portion of the theme issue will appeal to the average caver with an interest in speleology' (Report of the Executive Vice-President, 12 March 1983).

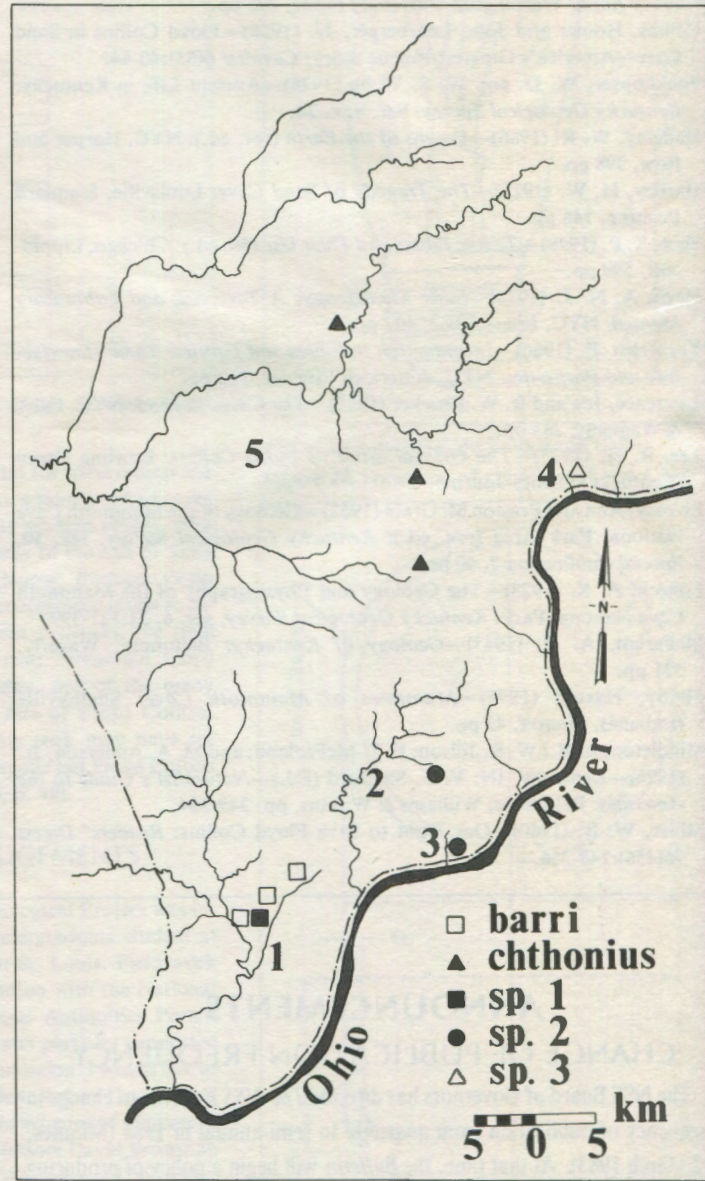
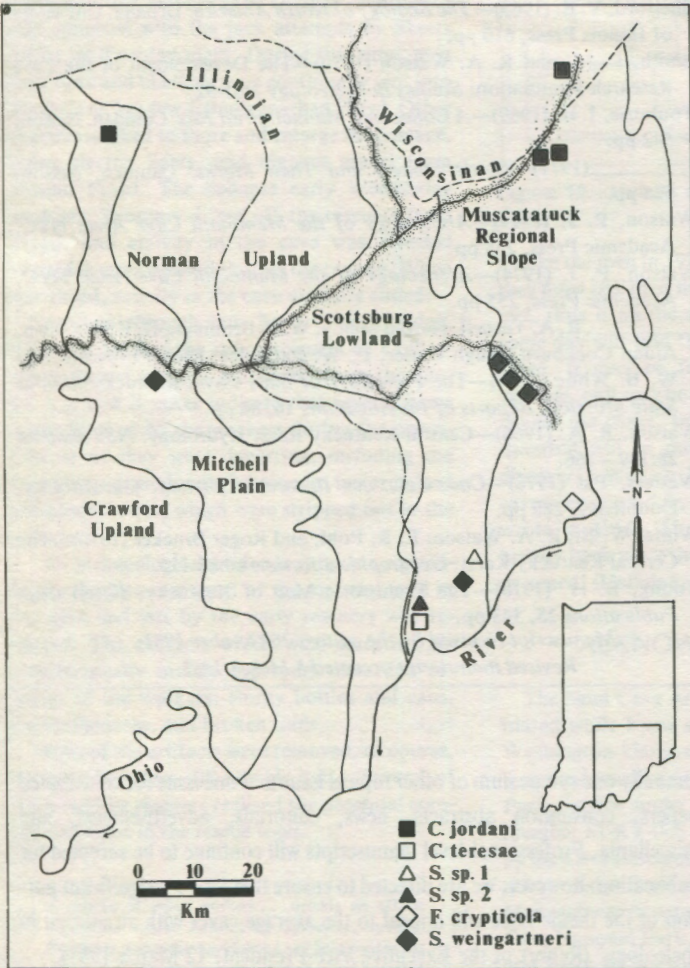
THE OBLIGATORY SUBTERRANEAN INVERTEBRATES OF GLACIATED SOUTHEASTERN INDIANA

JULIAN J. LEWIS

Department of Biology and Water Resources Laboratory
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Figure 1. (below) The distribution of aquatic subterranean invertebrates in the southeastern Indiana karst (Scottsburg Lowland, Muscatatuck Regional Slope) and the adjacent southcentral cave area (Mitchell Plain, Crawford Upland).

Figure 2. (right) Surface drainage areas of the southeastern Indiana karst region and the distribution of troglotic carabid beetles of the genus *Pseudanophthalmus*. The drainage areas are (1) Silver Creek, (2) Fourteen Mile Creek, (3) Bull Run, (4) Clifty Creek, and (5) East Fork of White River. The dotted and dashed line represents the margin of the Illinoian till.



PROCEEDINGS OF THE NATIONAL SPELEOLOGICAL SOCIETY
ANNUAL MEETING, June 27 - July 1, 1983
ELKINS, WEST VIRGINIA
G. Thomas Rea, Editor

ARCHEOLOGY SESSION

PRELIMINARY REPORT ON THE PREHISTORIC ARCHEOLOGICAL
REMAINS IN BIG BONE CAVE, VAN BUREN COUNTY, TENNESSEE

George M. Crothers, Department of Anthropology, University of Tennessee, Knoxville, TN 37916

Big Bone Cave is best known for its extensive and well preserved saltpetre mining works and several finds of Pleistocene ground sloth (*Megalonyx jeffersoni*) remains first discovered by nitrate miners in 1810. Recently, attention has been drawn to the numerous remains left by aboriginal cave explorers in the dry passages which were undisturbed by the saltpetre mining operations. Archeological investigations have begun with the assistance of NSS cavers to record these remains.

A PHOTOGRAPHIC TOUR OF MUD GLYPH CAVE

Bill Deane, 312 Hermitage Road, Knoxville, TN 37920

Charles Faulkner, Department of Anthropology, University of Tennessee, Knoxville, TN 37916

Over the past two years, researchers and cavers, aided by a grant from the National Geographic Society, have investigated a unique display of Indian artwork. Thousands of drawings, called "mud glyphs" because they are carved and scratched in mud, were discovered in an upper level of a cave in the mountains of east Tennessee. Radio carbon dates of torch and hearth charcoal range from the 4th to the 17th centuries A.D. We believe that during the Mississippian period, Indians used this cave as a sanctuary to conduct religious and ritual activities. The discovery of Mud Glyph Cave and of other caves containing glyphs in Tennessee, Virginia, and West Virginia has opened new doors for archeological investigations in the eastern United States.

AN ARCHEOLOGICAL INVESTIGATION OF TCS#FE60:
A CAVE IN NORTH CENTRAL TENNESSEE

Lee G. Ferguson, Department of Anthropology, University of Tennessee, Knoxville, TN 37916

A reconnaissance of a cave in Fentress County, Tennessee, by archeologists and spelunkers has led to the discovery of footprints, torch marks, and charcoal scatters indicating that a number of passages have been visited by prehistoric Indians. Further investigations revealed evidence of intensive aboriginal utilization of one section of the cave. The passages in this section contain evidence of extensive mining of high quality chert nodules from unconsolidated cave sediments and the reduction of these nodules to facilitate transportation from the cave.

The archeological resources of these passages are unique because they are virtually undisturbed. The remoteness of the site has kept

caving traffic low in this area of the cave, so that there are large areas of the passages that have not been significantly disturbed since the prehistoric Indians utilized the site over 3,000 years ago.

THE ARCHEOLOGY OF PREWITTS KNOB, KENTUCKY

Valerie A. Haskins, Department of Anthropology, Washington University, St. Louis, MO 63130

Prewitts Knob is situated on the karst terrain in Barren County, Kentucky, southwest of Cave City and near Mammoth Cave National Park. A commercial cave and four small pits are located on the knob.

Prehistoric skeletal remains have been known to be present in Crystal Onyx Cave since it became commercial in the 1960s. No formal analysis of the remains has been conducted, but one radiocarbon date indicates the bones are more than 2,500 years old. Therefore, at least some of the activity on Prewitts Knob was apparently contemporaneous with exploration and mining in the Mammoth Cave System.

WHAT IS A PETROGLYPH

Robert L. Pyle, Consulting Archeologist, 1964 Negley Avenue, Morgantown, WV 26505

In weathered stone, the trained person can discriminate between natural features and those made by man, and can judge the age of a carving by the degree of erosion and the types of figures represented, along with other factors. It has been commonly believed that early native Americans possessed no alphabet, but in recent years conclusions have been reached as to the origins of certain North American petroglyphs. They have been determined to represent European, African, Semitic, and other languages, and to have been created hundreds of years before Columbus discovered America. There are many theories about those early visitors, but there is no question that they left petroglyphic records that can be accurately deciphered.

PREHISTORIC FOOTPRINTS IN UNITED STATES CAVES

Patty Jo Watson, Department of Anthropology, Washington University, St. Louis, MO 63130

A number of caves in the mid-southern portion of the United States have been found to contain prints of bare or slipped feet left by aboriginal cave explorers. In almost every case, these prints have been discovered by cavers, who have taken great care not to disturb the fragile traces and who have called on professional archeologists to aid in documenting them.

BIOLOGY SESSION

GENETIC ANALYSIS OF REGRESSIVE EVOLUTION

Daniel W. Fong, Department of Ecology and Evolutionary Biology, Northwestern University, Evanston, IL 60201

The two current selection hypothesis for the mechanism of regressive evolution in cave organisms are energy economy and pleiotropic effects. They are in fact mechanistically similar and can be reduced to one pleiotropic hypothesis. This hypothesis is being tested using the amphipod *Gammarus minus* population from Coffman's Cave, West Virginia, and states that reduction in eye size (a presumed neutral trait) results as a correlated response to selection acting on antennae (a trait presumed under selection). The magnitude of the correlated response to selection between the traits can be obtained through quantitative genetics techniques based on full-sib and half-sib analyses of variance for each of the traits and covariance between the traits. The data suggest a significant genetic component in the variation in antennal peduncle length, the selected character. But the same cannot be detected for variation in eye facet number, the unselected trait.

THE FAUNA OF CASTLEGUARD CAVE

C. W. Pugsley, Great Lakes Institute, Department of Biology, University of Windsor, Windsor, Ontario, Canada N9B 3P4

The geographical distribution of troglobites in the holartic region is almost entirely confined to non-glaciated areas of North America and Eurasia. The presence of the few crustacean troglobites that do occur in northern glaciated areas has been explained by post glacial dispersal from non-glaciated areas in the south. The two troglobitic crustaceans already reported from Castleguard Cave -- an isopod *Salmaselius steganothrix* and an amphipod *Stygobromus canadensis* -- are taxonomically so different from their southern relatives that a more likely reason for their presence in the cave is that they survived perhaps several glaciations by living in caves and groundwater beneath the ice sheets. The discovery, this year, of a troglobitic mite from near the terminal ice plug, and the presence of an elusive filter feeding "worm" lends further evidence for the theory that Castleguard Cave is a sub-glacial refugium.

COMPUTER APPLICATIONS SESSION

CAVPT: CARTOGRAPHY BY COMPUTER

Don Conover, 467 West Krepps Road, Xenia Ohio 45385

Adding the third dimension to a cave map gives a more accurate representation of the relative height and depth of cave passages. This is particularly helpful in the study of the hydrology of a particular cave system. The maps also show the multiple levels of the passages relative

to each other in the cave system. The program was originally written for an IBM 1130 and the results were plotted on a Calcomp 718 flatbed plotter. The program has also been implemented on an Amdahl 470 and a CDC 6600. The plots have been produced on Calcomp pen plotters, Versatec electrostatic plotters, and Tektronics CRTs (using PLOT 10 routines).

AN INTEGRATED SYSTEM FOR PROCESSING CAVE SURVEY DATA

Douglas P. Dotson, Department of Computer Science, Frostburg State College, Frostburg, MD 21532

Recent trends in small computer systems technology have brought reasonable computing power at low cost to many cavers. Other than the clerical applications, the most popular use of computers in caving is survey data analysis. Most existing software operates by placing the raw survey data in a file and then using the file as input to a BASIC or FORTRAN program. This paper describes an integrated system which supports all phases of cave survey data analysis. Although not entirely implemented, the described system handles data entry, analysis, loop closing, plotting, and survey file maintenance.

PHOTOTYPESETTING BY MICROCOMPUTER

Lynne and Mike Simms, 505 Roosevelt Street, Oregon City, OR 97045

This paper discusses the techniques, economics, advantages, and pitfalls of using a personal computer to prepare text for phototypesetting. This technique was used in the preparation of the recent American Caving Accidents publication in the NSS News and in preparing the NSS Members Manual.

CONSERVATION AND MANAGEMENT SESSION

CONSTRUCTION OF A CAVE ENTRANCE

Charles S. Bishop, Route 7, Box 635, Frankfort, KY 40601

In May of 1979, a new entrance was opened to James Cave, located in Edmonson County, Kentucky. The decision to open the entrance was not distinct and the amount of work and expense which resulted was not fully anticipated.

The new entrance was created in the top of a dome pit which resulted in an open-air pit 98 feet deep. Because there was no prior existing opening to the surface, it was necessary to gate the entrance and restore the site to minimize the effects of the new entrance on the cave environment. Innovative cave gating techniques were employed which stabilized the top of the pit, sealed the entrance to air flow, and returned the ground surface to its original contour.

PRELIMINARY REPORT ON THE IMPACT OF THE DIXIE BEND LANDFILL ON THE SLOANS VALLEY (KENTUCKY) CAVE SYSTEM

Percy H. Dougherty, Geography Department, University of Kentucky, Lexington, KY 40506

The Sloans Valley Cave System, the third longest cave system in Kentucky, is located in Pulaski County. The system has nearly 24 miles of mapped passage and offers a good laboratory for the study of cave biology, geology, and hydrology. It is located on the edge of the Cumberland Plateau on the eastern side of the Cincinnati Arch where the Cumberland River has entrenched itself into the Mississippian sediments of the St. Louis and Ste. Genevieve formations. Pennsylvanian sediments mantle the cave bearing formations and contain several abandoned coal strip mines. Recently the cave and local wells have experienced a drastic decline in water quality. Local residents are convinced that the trouble is originating from the Dixie Bend Landfill which is located at a higher elevation than the cave in an abandoned coal mine. A system of water collection points has been set up in the cave and from local wells in order to determine the present quality of the water and monitor any change. Standard chemical tests and atomic adsorption analysis have been used to identify heavy metals and other pollutants which are endangering this fragile ecosystem, the only known habitat of the white, blind cavefish, *Typhlichthys subteranens*, on the eastern side of the Cincinnati Arch.

POLLUTION MONITORING IN CAVES OF SULLIVAN COUNTY, NEW YORK STATE

Peter Febroriello, 469 Main Street, Torrington, CT 06790

Upon learning of the direct discharge of supposedly treated sewage into a stream which feeds a popular New York state cave, a task force was formed and monitoring of the effluent was begun on an emergency basis. MacKonkey broth cultures were positive for coliform bacteria and the presence of *E. coli* and two other unidentified coliform bacteria was confirmed by the clinical laboratory at the University of Connecticut in Farmington. Water from a well belonging to the cave's owner yielded cultures of *Pseudomonas*. We are continuing to monitor the stream which enters the cave, and we are now attempting to assay the damage done to the cave, to the caving public, and to adjoining property owners by the accidental discharge of untreated human wastes into the cave environment.

AN APPLICATION OF INTERACTIVE GRAPHICS TO THE STUDY OF CAVES

Fred L. Wefer, Megatek Corp., 3985 Sorrento Valley Boulevard, San Diego, CA 92121

John W. Igoe

P. Ann Gillen

A 3-D interactive computer graphics program designed to aid in the study of the geomorphology of caves is presented. The program provides three basic types of operations: dynamic, function, and script. Dynamic operations include the ability to scale, rotate, and translate the 3-D map interactively. Digital readouts indicate the scales, viewing angles, and the map coordinates at the center of the view. Function operations include the ability to make visible or invisible various portions of the display (that is, fiducial marks, grids, topographic overlays, north arrows, etc.), to produce hard copies of the display, and to perform complete predefined dynamic oscillations in pitch, yaw, and roll. Script operations provide the ability to interactively define, edit, and run movies composed of sequences of dynamic and function operations using the technique of key-frame animation. Topics covered in the presentation include: the user interface, data input methods, the graphics software and hardware employed, and video recording techniques. Examples of the program output feature the Butler Cave - Sinking Creek System in west-central Virginia.

THE JOHN GUILDAY CAVE PRESERVE (TROUT ROCKS): MANAGEMENT GOALS

E. Ray Garton, P.O. Box 200, Barrackville, WV 26559

The John Guilday Cave Preserve was acquired by the NSS on March 15, 1983. While management plans are not final, the primary emphasis for use of these three caves will be recreational. Other values will not be ignored, but will be subordinate to recreation. The final management program will address long, medium, and short term goals for use of the property, addressing both surface and underground questions. Access plans will be developed individually for each cave.

HOW VOLUNTEERISM CAN BENEFIT CAVE RESOURCES, PUBLIC CAVE MANAGERS, AND CAVE CONSERVATIONISTS

Harry B. Mahoney, Forester, Monongahela National Forest, Elkins, WV 26241

Volunteerism provides an opportunity for individuals and organizations to participate in conservation and management of caves on National Forest lands.

Forest Service volunteers are working on every National Forest in practically every aspect of protection and management of National Forest resources. Although volunteers receive no compensation, volunteer agreements may provide for payment of incidental expenses such as transportation, lodging, and subsistence. In addition, the volunteer is protected under provisions of the Tort Claims Act.

CAVE MANAGEMENT: A HISTORICAL PERSPECTIVE OF PAPOOSE CAVE IN IDAHO COUNTY, IDAHO

Terry Shannon, Gem State Grotto, 4070 Linda Vista Lane, Boise, ID 83704

A dangerous cave presents problems beyond those of study and exploration, it also provides administrative difficulties and legal exposure. Papoose Cave is a public cave on National Forest land that contains difficulties beyond the abilities of most novice cavers and weekend adventurers. The cave was threatened with permanent closure in 1971 due to these hazards. Local organized cavers entered a cooperative agreement with the Nez Perce National Forest to control access. The objectives of the local cavers were to protect the cave from closure, prevent damage due to vandalism, protect unwary visitors from potential harm, provide easy access to qualified cavers, provide training to qualified cavers, and administer this program without cost to the government. Problems with this type of program are legal liabilities, defining qualified cavers, and administering the program without projecting an image of controlling the cave.

CONTROLLED ACCESS MANAGEMENT: A HUMAN RIGHTS PROBLEM

Jer Thornton, P.O. Box 752, Boise, ID 83701

The number of controlled access management programs will continue to increase in the United States. Access restrictions have traditionally met heavy vocal resistance from portions of the caving community who view gates and other controls as violations of personal freedoms.

To prevent these attitudes from causing the failure of management

programs requires the administrators to have an understanding of the basis for resistance, requires that the program be administered fairly with emphasis on informing the caving community of the reasons for the regulations, and requires that the caving community be aware of how to use the access system.

CAVE INCIDENTS UPDATED AND COMPARED WITH EMPHASIS ON THE NORTHWEST

Toni Lewis Williams, National Cave Rescue Commission, 7943 Woodvine Circle, Tampa, FL 33615

Incident reports from North American sources from 1976 to 1980 were analyzed, tabulated, and compared to previously analyzed 1967 to 1975 data. Incident reports from Washington, Oregon, and British Columbia from 1967 to 1980 were similarly analyzed. Falls and entrapments were the most common immediate cause of the 107 non-diving incidents during that period. The most common contributory causes were poor judgement and lack of adequate equipment and preparation. These patterns were essentially the same as in earlier incidents. The most common victim, during both periods, is a young male, inexperienced and unaffiliated, caving on a weekend. More older and experienced cavers were involved in recent incidents than during the 1967 to 1976 period. Cave diving accidents, previously nearly exclusive to Florida, increased elsewhere in the U.S. Data for 13 northwest incidents reflect essentially the same patterns, except that more

incidents were caused by falling rock or ice. There was one fatality during the period. It appears that caving is not an especially risky sport.

THE NSS CAVE VANDAL DETERRENCE REWARD. WHAT IT IS, HOW IT WORKS, ITS PURPOSES, AND HOW IT WILL BE IMPLEMENTED

John M. Wilson, NSS Cave Vandal Reward Commission, 7901 Dalmain Drive, Richmond, VA 23228

The National Speleological Society will pay a reward of up to \$500 to the person who provides information leading to the conviction of any person or persons who are convicted of any form of vandalism to caves, their environs, or their contents, whether geological, biological, archeological, or paleontological.

The NSS Cave Vandalism Reward Review Commission, in the Department of the NSS President, consists of three members. It will make the final determination of whether particular information qualifies for the reward. The Cave Vandalism Reward Review Commission determines the amount of the reward based on the seriousness of the offense and the success of the prosecution.

The NSS Cave Vandal Reward goals are to deter cave vandalism, educate cavers and the public to the importance of conservation and responsible caving, support and encourage cave owners to take greater responsibility in managing their caves, and to reward those people who take the initiative in supplying information that leads to the conviction of cave vandals.

EXPEDITIONS SESSION

THE MT. KAIJENDE EXPEDITION TO PAPUA NEW GUINEA

Dave Bunnell and Carol Vesely, 745 Camino del Sur, Cortez Apartments #5, Goleta, California 93117

Ernie Garza

Ray Hardcastle, 9733 Glasgow Place, #9, Los Angeles, CA 90045

July-August, 1982, marked the occurrence of the first American caving expedition to the central highlands of Papua New Guinea. Site of the expedition was Mt. Kaijende, a limestone mountain covered by spectacular pinnacle karst. Basecamp was established below the pinnacles in a large alpine clearing at about 9,500 feet elevation. Although the area was basically uninhabited, it was crossed by numerous native hunting trails which enabled us to scout more area with less jungle-chopping and also led to occasional visits by small hunting parties carrying bows and arrows. A total of about nine kilometers of cave

passage were found, and, as is typical of tropical caves, they tended to be wet, muddy, and highly decorated. Lewaro Kundu, the largest find (3.5 km), consists of a series of waterfall pitches pushed to a depth of 300 meters and still going.

THE THOR EXPEDITION

Kirk McGregor, 78 King High Avenue, Downsview, Ontario, Canada M3H 3B1

In July, 1982, members of this expedition set a new world record by rappelling and prusiking the 3,230-foot west face of Thor Peak in the Canadian arctic. This talk describes the expedition, complete with slides of the people, the equipment, and the arctic scenery.

EXPLORATION SESSION

ICE BOXWORK

Roger V. Bartholomew, 910 Laurel Street, Rome, NY 13440

Ice boxwork was discovered on March 23, 1983, among the ice formations in an upstate New York tectonic cave with about 18,000 feet of horizontal passage. The lowest rooms are at a depth of about 120 feet below a ridge top. Winter air blowing through the cave and settling to the lowest levels removes heat from the igneous rocks. Water from rain and snow melt flowing down into the cave freezes and forms displays of ice formations.

In the lowest level room, ice and water are present year around. The unique conditions have caused two inch deep boxwork to form about 1.5 inches below a fractured but intact surface layer of ice one-half inch thick. In some places on the upper edges of the boxwork, ice crystals extend upward into the space between the boxwork and surface layer and some of these crystals contact the surface layer of ice.

ROPPEL CAVE: APPROACHING 50 MILES

Jim Borden, 589 Over Ridge Road, Frederick MD 21501

Once a route was found leading from the Roppel entrance into the main body of Roppel Cave, exploration in Roppel proceeded at an explosive pace. Roppel is presently over 45 miles long and shows no sign of ending. The most recent explorations in Roppel have both extended the cave's boundaries and increased our understanding of some extremely complex central sections of the cave.

SEA CAVES OF THE CALIFORNIA COAST

Dave Bunnell and Carol Vesely, 745 Camino del Sur, Cortez Apartments #5, Goleta, California 93117

There are three common myths regarding sea caves: (1) all sea caves are basically small, single-room shelters, (2) sea caves are boring (you've seen one sea cave, you've seen 'em all), (3) sea caves are easy to explore and not physically challenging. Actually, there is a surprising

variety to sea caves, some are quite long (1,200 feet), others are maze or multilevel. The tidepool life is even more varied -- from red batstars to green anemones to purple urchins and multicolored slimemolds. Exploring the caves involves climbing along cliffs, swimming with sea lions, and trying to land your boat in crashing surf. Over the past two years, members of the Southern California Sea Cave Survey (SCSCS) have explored and surveyed sea caves from Big Sur in the north to Baja, Mexico, in the south, including the large caves of the Channel Islands. Highlights of this talk will include the most recent and largest caves found, biology of the caves, and the drastic effects of this winter's severe storms on California's sea caves.

BUTLER CAVE -- 25 YEARS AFTER THE DISCOVERY

Gregg S. Clemmer, 22 Native Dancer Court, Darnestown, MD 20878

Butler Cave-Sinking Creek System, Virginia's longest and deepest known cave, is owned and managed by the Butler Cave Conservation Society (BCCS). A brief history of the discovery and exploration, complemented by slides, will be presented. Current exploration, survey, and study projects both in Butler and other nearby caves continue. The continuing cave management plans of the BCCS as well as the functions of the Society itself will be discussed.

PROFESSIONAL CAVING IN CENTRAL KENTUCKY

Don Coons, RR 3, Cave City, KY 42127

The National Park Service has supported an active hydrologic research program at Mammoth Cave for the past nine years. The exploration and survey of over 75 miles of cave passage, along with the production of detailed maps, has been a major portion of the project. An extensive dye-tracing program has been instituted coupled with the installation of stream level monitoring stations. All in all, the program has offered an unparalleled opportunity for caving in one of the unique karst regions of the world.

RECENT EXPLORATION AND MAPPING IN
PALEORESURGENCE CAVES OF THE SIERRA DE GUATEMALA
AND SIERRA DE EL ABRA, MEXICO

Patricia Mothes and Roy Jameson, Rt 4, Box 477, Renick, WV 24966

Many of the caves in the Sierra de Guatemala and Sierra de El Abra in northeast Mexico are paleoresurgence caves developed in Cretaceous limestones along the eastern margin of the El Abra reef trend, where a prominent escarpment rises above the adjacent shales of the coastal plain. The paleoresurgence caves formed in the phreatic zone and exhibit irregular development of rooms; ungraded profiles; spongework; blind ceiling and wall pockets; irregular bedrock spans; and, in places, tubular passages between rooms. These caves typically lie less than 100 meters above nearby springs. These springs drain the nearby ridges as well as karst developed farther west on the main part of the Middle Cretaceous Valles-San Luis Potosi carbonate platform.

In 1981 we visited the southern part of the escarpment of the Sierra de Guatemala and re-explored and re-mapped Cueva de El Nacimiento del Rio Frio. Nearby, at Ojo de Agua, we re-found two long forgotten caves and several minor springs on the east face of Sierra Chica, an outlier of the Sierra de Guatemala. We surveyed a connection resulting in a single cave now known as Cueva de Ojo de Agua with over one kilometer of passage. We also mapped three small paleoresurgence caves in the northern part of the Sierra de el Abra Escarpment.

RECENT CAVE EXPLORATION IN THE ELK RIVER VALLEY
WEST VIRGINIA

William K. Storage, 3103 N. Turkeyfoot Road, Akron OH 44319
Douglas M. Medville, 11762 Indian Ridge Road, Reston, VA 22092

Since May, 1981, several significant caves have been discovered and surveyed in the valley of the upper Elk River, West Virginia. This river valley drains an area of over 90 mi². The caves parallel the river valley but extend to depths of up to 170 feet below the river bed. Large upper

levels in the caves may represent former flow routes of the underground Elk River. A fragment of the present flow path of the underground Elk River can be seen near the end of one of the recently discovered caves. Over five miles of passage have been surveyed in the Elk River caves.

HUAUTLA 1983: EXPLORATIONS IN NITA XHA AND NITA NANTA

Ron Simmons, 2414-4 Barracks Road, Charlottesville, VA 22901

The 1983 expedition to Huautla resulted in the connection of Nita Xha and Nita Nanta caves and the survey of a second 1,000+ meter deep cave system on the Huautla Plateau.

CAVING HIGHLIGHTS OF THE MT. KAIJENDE
EXPEDITION OF PAPUA NEW GUINEA

Carol Vesely and Dave Bunnell, 745 Camino del Sur, Cortez Apartments #5, Goleta, CA 93117

Peter Bosted, Box 4349, Bin 57, Stanford, CA 94305

Ray Hardcastle, 9733 Glasgow Place, #9, Los Angeles, CA 90045

Initial exploration concentrated on the pinnacles and the many sinkholes found in the clearing surrounding basecamp, but few significant caves were found. Investigations of insurgences shown on aerial photos yielded several significant caves. All had gentle gradients and soon intersected the water table. In the last two weeks of the expedition, a complex multi-level cave (Nambawan Ananda) was surveyed to 1.3 kilometers. Its large, highly decorated passages all ended in collapse or fill, apparently intersected by the many large sinks that surround it. A large cave (Lewaro Kundu) was discovered along a plunging syncline. Cavers pushed down dozens of short waterfall pitches to a depth of over 300 meters in 3.5 kilometers of passage. At the terminus of exploration, the cave stream could be heard continuing beyond a boulder choke. Over 18 infeeding tributaries were left largely unexplored as were several leads in promising caves nearby.

GEOLOGY SESSION

PRELIMINARY MODEL OF THE BIG SPRING CONDUIT SYSTEM
OF CLAYTON COUNTY, IOWA

M. J. Bounk, Iowa Geological Survey, 123 North Capitol Street, Iowa City, IA 52242

Big Spring, located near Elkader on the Turkey River, is a groundwater resurgence discharging from the Galena Formation. Hydrogeologic studies of this karst area by the Iowa Geological Survey and the Iowa Conservation Commission indicate that Big Spring drains a basin of about 232 square kilometers in northern Clayton County.

Dye-tracing, potentiometric surface studies, and analysis of topographic linear features suggest that this area is underlain by a complex conduit system which was developed, in part, by multiple subterranean piracy, one of which is still in progress. Many of the major conduits presumably follow the linear features using those which best facilitate down-gradient movement of groundwater.

THE STATUS OF RESEARCH AT COLD WATER CAVE

M. J. Bounk, Iowa Geological Survey, 123 North Capitol Street, Iowa City, IA 52242

Cold Water Cave was discovered, partly explored, and mapped by cavers in the late 1960s. Later studies of the cavern atmosphere, water quality, fauna, vertebrate remains, speleothems, and geology of the cave by and under the direction of the Iowa Geological Survey were published in "Report on Cold Water Cave" in 1974. A theodolite and subense bar resurvey of about 7,200 feet of the main passage is published in that report, and at a larger scale as an open-file report.

In the eight years since the completion of the Geological Survey's studies, research has continued on the "Cold Water Project." This research consists primarily of completing exploration and mapping of the cave system, which now has a surveyed length of about eight miles. Other recently completed or ongoing studies include air movement, hydrology, development of the upstream part of the cave, variation in stream stage and discharge, and the relationship of the cave to surface features.

PERIGLACIAL TALUS PSEUDOKARST IN NEW ENGLAND

R.W. Carroll, Jr. 23 Pleasant Street, Apt. 4, Potsdam, NY 13676

James Hedges, Big Cove Tannery, Pennsylvania 17212

G. Michael Clark, Geology Department, University of Tennessee, Knoxville, TN 37916

Periglacial talus pseudokarst is widespread in temperate central and eastern North America. In the Adirondacks and in the Green and White Mountains, cliffs of massive igneous and metamorphic rocks yield blocks sometimes larger than 30 meters on a side. Where these taluses have

partly filled small valleys, streams encountering the taluses sink and flow through or beneath them for hundreds of feet before resurging. Forest litter and weathering debris trapped by roots obscure the crevices among the blocks. The remaining underground openings possess karst-like streams, clastic sediments, speleothems, meteorologies, and faunas. They sometimes extend to total darkness.

A periglacial talus pseudokarst cycle begins with glacial advance and intense periglacial weathering. Talus emplacement is followed by ice retreat and the re-invasion of temperate forests. Lichens; mosses; and, finally, vascular plants become established on the talus surface, covering most openings. Stream sedimentation, soil creep, burrowing animals, and disintegration-in-place of the talus blocks eventually fill the subterranean openings. Humanly enterable passages disappear, streams return to the surface, and the pseudokarst is extinguished.

CLASTIC SEDIMENTS AND SEDIMENTATION
IN THE BUTLER CAVE SYSTEM, VIRGINIA

Daniel L. Chess and William B. White, Materials Research Laboratory, The Pennsylvania State University, University Park, PA 16802

The Butler Cave - Sinking Creek System consists of a master trunk passage along the axis of a syncline with a trellis arrangement of dip-oriented side passages. The western set of dip passages contains a sequence of massively and chaotically bedded sand and cobble fills. Massive cobble fills also occur in the trunk passage. The eastern side of the syncline contains more sand and silt.

Microscopic examination of the sediments shows the light fraction to be predominately quartz with some rock fragments. The sediments contain several percent of iron oxides, zircon, rutile, and other heavy minerals.

Diffuse reflectance spectra of the sediments show at least three populations to be present: an iron-rich, clay-poor group; a clay-rich group; and a gypsiferous sediment. Factors controlling the distribution and properties of sediment types include source, age, and depositional mechanism.

COMPARISON OF SCALLOP SIZE DISTRIBUTIONS
GENERATED ON GYPSUM AND ON LIMESTONE

Rane L. Curl, Department of Chemical Engineering, University of Michigan - Dow Building, Ann Arbor, MI 48109

Distributions of the sizes of scallops (measured longitudinally), generated on limestone in Pikhaggorittene [Cave], Norway (collected by S. E. Lauritzen, 1983), and those generated on Plaster of Paris (gypsum) by Blumberg and Curl (1974), have been compared statistically. The mean sizes of scallops from the cave were from 20 to 50 centimeters and

the experiment on gypsum from two to six centimeters.

More than half of the distributions from the cave agreed at better than the 5% level of significance with the distribution generated in the laboratory, when tested with a Kolmogoroff-Smirnov test.

This represents a direct confirmation of the applicability of the theory of scallop scaling between limestone conduits and experiments on gypsum over a wide range of scallop sizes.

AN ANALYSIS OF THE FRACTAL GEOMETRIES OF CAVES

Rane L. Curl, Department of Chemical Engineering, University of Michigan - Dow Building, Ann Arbor, MI 48109

It has been observed that the lengths of all caves in a region (including those without entrances) are hyperbolically (Pareto) distributed (Curl, 1966). This is the same as for other geomorphic phenomena identified by Mandelbrot (1977) and others as exhibiting fractal geometry - figures of non-integer dimension ("Korcak's Law"). Proper cave lengths exhibit a fractal dimension of about 1.4. These concepts have been extended to other geometric properties of caves with the following consequences:

(1) The total length of all caves in a region, of defined modulus (after Curl, 1966) is a fractal of dimension between 2 and 3 (nominally 2.7, like the Sierpinski Sponge).

(2) The length of a cave may be defined as the sum of the diameters of "linked modular cave elements" (touching spheres, for example, that fill the cave passages), of diameters larger than the cave-defining modulus.

(3) The total number of linked modular cave elements in a region is a fractal of the same dimension as total length.

(4) The expected number of modular cave elements in a cave is equal to about the 0.8 power of the length of a cave measured in units of the defining modulus.

GEOMORPHOLOGY OF SHARPS CAVE, POCAHONTAS COUNTY, WEST VIRGINIA

George Dasher, 55 Kalafat Mobile Village, Buckhannon, WV 26201

This paper gives a brief review of the surface geology and hydrology of the Big Springs Fork of the Elk River, and describes the sequence of overall development in Sharps Cave, the on-going piracy of Big Springs Fork into the cave, and the pattern of passage formation and collapse as related to the lowering of the local stream base level and the weathering of the Big Springs Fork valley wall. In addition, a short history of the cave and the recently completed survey will be discussed.

STRUCTURAL CONTROL IN THE PENNYROYAL KARST: LOCAL EXAMPLES

Ronald R. Dilamarter, Department of Geography and Geology, Western Kentucky University, Bowling Green, KY 42101

Two examples of structural control on Pennyroyal karst features are presented. Both examples are located on dip slopes of Mississippian strata near Bowling Green, Kentucky.

The first example is the surface-subsurface network of Indian Creek in the Chester Upland near Richardsville. A small plunging syncline embedded within the generally north-dipping strata appears to control a considerable portion of the surface network, as well as the direction and gradient of a subsurface diverted tributary.

The second example is a tract of very gentle terrain located southeast of Bowling Green in the Drakes Creek - Barren River - Bays Fork interfluvium. Correspondance of surface slope with rock dip, siliceous rock and soil, and chert beds in nearby Bad Gas Cave strongly support the concept that the tract is a stripped structural plain on lower St. Louis strata, marginal to the sinkhole plain.

SEASONAL GEOCHEMISTRY OF TWO TUFA-DEPOSITING SPRINGS IN SOUTHWESTERN WISCONSIN

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Two small springs in southwestern Wisconsin, which emerge from Middle Ordovician dolomites, form waterfalls which flow over massive tufa mounds. Both springs were sampled in summer and winter at the spring outlet and at the base of the falls. Both springs contain very hard water of a calcium-magnesium-bicarbonate type which is supersaturated with carbon dioxide in comparison to the atmosphere. Seasonal comparison of the water quality at the spring outlets shows a summer decrease in pH, saturation with respect to calcite and dolomite, and bicarbonate concentration; and a summer increase in temperature and partial pressure of carbon dioxide. As the spring water emerges and travels over the algae and/or ice covered tufa mound and downward, carbon dioxide is rapidly lost to the atmosphere. This causes dramatic increases in carbonate mineral saturations and pH. Calcite or aragonite is precipitated and results in a subsequent loss of dissolved calcium,

bicarbonate, total hardness, and conductivity. Contrary to other studies, for these springs the strongest loss of calcium carbonate occurs in the winter. The top-to-bottom increase in carbonate mineral saturation in the summer indicates that deposition is inhibited during that season, perhaps because magnesium ions retard calcite precipitation more at higher temperatures. Evaporation does not play a significant role in tufa deposition at this locality.

A SPATHITE OCCURANCE IN VIRGINIA

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Richard S. Mitchell and Janet S. Herman, Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22903

Roberts Cave, a new locality for spathites, is developed in the Shady Dolomite, Smyth County, Virginia. A water sample from a spathite yielded a field pH of 7.6. Subsequent lab alkalinity titrations resulted in a calculated partial pressure of carbon dioxide of 10 (~21.) atmospheres. Saturation indices of 1.12 for calcite and 1.33 for dolomite (an index of zero equals saturation) indicate that this sample was supersaturated with respect to both minerals. Magnesium to calcium ratios of approximately 3 to 1 were obtained from three spathite water samples using atomic adsorption spectroscopy. X-ray diffraction and microscopy show spathite mineralogy to be complex. The outer shell of the spathite form consists of aragonite. Calcite scalenohedrons and some rhombohedrons are found on the inner walls in increasing density away from the terminus of the formation. In the "multi-stage specimens", internal partitions of calcite are found sealing the "plumbing" off from the windows at each "stage" termination. These partitions are hypothesized to form when the flaring termination reaches a critical size and water drops can no longer extend along the termination. The water drops hang from one side and a window into the formation develops as the next "stage" forms. The admission of the cave atmosphere into the window is hypothesized to result in a microenvironmental change and subsequent development of a calcite partition to reseal the "plumbing".

DEVELOPMENT OF LONGHORN CAVERNS, BURNET COUNTY, TEXAS, IN RESPONSE OF BLOCK-FAULTING, SYSTEMATIC FRACTURING, AND TOPOGRAPHIC INVERSION

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Longhorn Caverns, Burnet County, Texas, has developed within an erosional outlier of the upper calcitic facies of the Gorman Formation, Ellenburger Group (Ordovician). Passages consist of shallow-phreatic conduits developed within soluble beds, along fractures and bedding-plane partings, and parallel to the strike of the strata and vadose tributaries of the headwaters of the cave that drain a karsted tableland and are oriented along fractures parallel to the dip. In many respects the cave is one of the best examples of a fully integrated cave system in central Texas. Waters from discrete points of recharge have been concentrated by a dendritic system of feeders at the apex of a plunging syncline and then transmitted through a master shallow-phreatic conduit along the flank of the fold to springs at baselevel. The cave and its drainage lie within Backbone Ridge, an exhumed fault block. Originally a slightly folded graben, this block now stands in relief with respect to adjacent lowlands as a result of differential erosion. Hydraulic gradients in the outlier were steepened as less resistant rocks surrounding the graben were eroded during the Pleistocene. This in turn promoted circulation of water beneath the karsted tableland and enlargement of passages along fractures oriented favorably to the structure and to the potentiometric surface.

PALEOSOL CAVES OF SAN SALVADOR ISLAND, BAHAMAS

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James L. Carew, Department of Geology, College of Charleston, Charleston, SC 29424

San Salvador Island, Bahamas, is located 600 kilometers ESE of Miami, Florida, on an isolated platform associated with the main Bahamas trend. The island consists of various carbonate facies of Pleistocene and Holocene age, with marine facies interfingering at low elevations with eolian calcerenites. The eolian calcerenites extend upward to the maximum elevation of the island, 45 meters above sea level at several locations. Karst processes have dominated in the formation of the landscape, and in conjunction with the Pleistocene climatic and sea level fluctuations, have left a complicated erosional/depositional history.

The erosion of landscapes by solution of the underlying limestone bedrock results in the collection on the bedrock surface of the insoluble components of the bedrock. This material is a residual soil and may be subsequently lithified, becoming a paleosol. The paleosols are more resistant to weathering than the eolian calcerenites. This differential

weathering produces numerous cavities developed in eolian calcerenite but roofed with paleosol. While usually of limited extent and not qualifying as true caves, some examples can be extensive. Crab Cay Cave is a single chamber penetrating through a limestone peninsula, 14 meters by 20 meters by 2 meters high. The chamber roof is paleosol, and is supported by paleosol infillings of former vertical solution tubes, which have weathered out as positive features.

SEASONAL AND DISCHARGE EFFECTS ON THE WATER CHEMISTRY OF HUECO SPRINGS, TEXAS

Albert E. Ogden and Anthony J. Spinelli, Edwards Aquifer Research and Data Center, Southwest Texas State University, San Marcos, TX 78666

Hueco Springs issues from a fault in the Cretaceous Edwards Limestone along the Guadalupe River about three miles north of New Braunfels, Texas. A gauging station was placed on the spring in September, 1981, and samples were taken weekly for 19 months. Three storm events were also sampled. The purpose of this study was to determine the seasonal and discharge effects on spring chemistry and use the data for comparison to other area springs. Discharge ranged from 3.2 to 57 cfs, but a rise of 36 cfs in two days was observed during a storm. Most of the parameters measured are affected by discharge. Total calcium hardness, conductivity, and nitrate show statistically significant decrease with long-term discharge increase, but large changes take place during storm events as well. During one storm, the total hardness changed nearly 200 mg/l. Temperature varies little (20.8 to 23.2°C) with as much as 1.6° change observed during a storm event. Change in dissolved oxygen is related to the amount of organic material which is a function of both season and discharge. Contamination of the spring is primarily related to single storm events as are most of the chemical changes. Fecal strep varied from 20 to 56 colonies/100 ml, and fecal coliform varied from 10 to 400 colonies/100 ml during a single storm event. During storm events, the maximum and minimum values of most parameters occur about 24 hours after maximum discharge occurs.

The results of this study indicate the Hueco Springs is a phreatic conduit with a deeper recharge component supplying base flow and a shallow, rapid-flow, storm runoff recharge component.

TIME SERIES ANALYSIS OF THE WATER CHEMISTRY OF COMAL SPRING, TEXAS

Samual R. Rothermel and Albert E. Ogden, Edwards Aquifer Research and Data Center, Southwest Texas State University, San Marcos, TX 78666

Comal Springs in New Braunfels, Texas, was sampled weekly from September, 1982, to March, 1983. The spring issues from numerous orifices in the Edwards limestone along the base of the escarpment of the Comal Springs fault. Gauges were set up and rating curves made for four separate groups of springs. Two storm events were sampled as well. Range in discharge for the combined flow of all orifices was 29.7 to 84.2 cfs.

Temperature of the largest spring ranged from 22.0 to 23.5°C with a 0.6° change during one storm event. This relatively constant temperature of the water differs slightly from the mean annual air temperature at New Braunfels of 20.6°. Fecal coliform counts never rose above 2 colonies/100 ml of sample even during rain events. Other chemical parameters remained relatively constant even during and after storms. Also, the springs never became cloudy, and attempted dye traces

never reached the springs.

Discharge, nitrate, total hardness, and calcium hardness show good seasonal trends. With the slow rise in discharge, there is a several months delay in the rise of total and calcium hardness. Thus, Comal Springs is interpreted as being a deep-flow conduit system with little or no local recharge.

CRITERIA FOR DEVELOPMENT OF MASTER TRUNK DRAINAGE SYSTEMS IN TROPICAL CLIMATES

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William B. White, Department of Geosciences and Materials Research Laboratory, The Pennsylvania State University, University Park, PA 16802

The formation of master trunk drains requires long critical hydraulic paths. Because of increased rates of reaction in humid tropical climates, groundwater rapidly saturates with calcium carbonate. Long integrated cave systems form where recharge from catchments on non-karstic borderlands provide large supplies of unsaturated water. The insulating effect of the pad of alluvium carried from borderlands helps preserve the undersaturation of the rivers. Large integrated systems in Puerto Rico, Jamaica, Belize, and Malaysia support this hypothesis.

Theoretical calculations of limestone dissolution kinetics show that recharge from catchments entirely underlain by carbonates saturates too quickly for the efficient formation of large integrated systems.

GEOLOGICAL OBSERVATIONS CONCERNING CAVES OF THE NEWSOME SINKS AREA

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Charles A. Lundquist, The University of Alabama in Huntsville, Huntsville, AL 35899

Newsome Sinks is a linear, landlocked valley in the Cumberland Plateau province of north Alabama, just south of the Tennessee River. Many of the caves in Newsome Sinks are aligned along an axis striking about N15°W. If this axis is extended south across a small mountain it intersects Skidmore Cave and both entrances of Cows Home Cave. Skidmore Cave is a large resurgence, as is Hughes Spring Cave just to the south and outside Newsome Sinks. The major caves in Newsome Sinks appear to have been one linear drainage, now interrupted by numerous sinks. The east-west valley to the south of Newsome Sinks is dry east of Hughes Spring, which is the resurgence for most of Newsome Sinks. Water from farther upstream in Hughes Valley reappears at Skidmore Cave. It had been speculated by Varnedoe that a cross piracy of drainage had occurred to form the present pattern of caves and drainage.

Although faults are rare in Brindley Mountain, a fault was noticed in 1982 in a caveless sink near the south end of Newsome Sinks. Further examination disclosed that this fault also appears in Shine Cave Sink and Wildcat Sink. Rock samples and measurements show this fault to be a normal fault striking about N17°W and dipping 70° to the east with a 15-foot displacement. This fault lies along or at the sides of several cave passages, implying that it could control or cause the alignment of the caves. Another fault was found above Hughes Spring Cave striking about N20°W. It is also a normal fault displaced six feet, but dipping about 70° to the west. These fault observations combined with recent dye experiments and more cave mapping have caused us to reexamine the speleological history of this area.

HYDROLOGY SESSION

HYDROLOGY AND GEOMORPHOLOGY OF THE DOUGHERTY PLAIN, GEORGIA

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The Dougherty Plain is an area of covered karst which is developed along the "outcrop belt" of the Tertiary Ocala and Suwannee limestones and is bounded downhill by a cuesta escarpment (the Pelham Escarpment) formed on the overlying clastic Hawthorne Group sediments. It has been proposed that this escarpment is retreating due to the sapping action of karst springs. However, the caves are influent and show no evidence of former spring flow. Some of the steep-sided sinkhole entrances show vertical fluting and appear genetically analogous to vertical shafts. The retreat of the Pelham Escarpment appears to be aided by the dissection of vertical shafts, not the undermining of karst springs. The escarpment retreat leaves exposed a sinkhole plain mantled by up to 100 feet of unconsolidated sediment. Despite the high permeability of these limestones, karst features do mark the Dougherty Plain: caves, dolines, uvalas, sinking streams (ponors), semi-blind valleys, karst fensters, and conduit springs are all present. Big Slough is a surface floodway parallel to the base of the escarpment which is composed of a line of dolines, ponors, and uvalas. It may be localized by a lithologic contact or by a stillstand in the retreat of the escarpment.

SEDIMENTOLOGY AND PALEOHYDROLOGY OF A SEGMENT OF LONGS CAVE, EDMONSON COUNTY, KENTUCKY

James C. Currens, 1320 Dale Drive, Lexington, KY 40502

Some high-level passages in the Mammoth Cave Region have been interpreted as paragenetic in origin. Longs Cave, near the southern boundary of Mammoth Cave National Park, occurs at approximately 680 feet elevation, the highest level of cave development in the park. The morphology and extensive sediment fills of a major side passage were examined for evidence to determine whether or not the passage was developed paragenetically.

The field investigations revealed a passage with a keyhole cross section filled nearly to the ceiling with coarse to very fine sand and silt interbedded in a generally fining upward sequence. Primary sedimentary structures exposed in the passage include large trough-shaped scours, ripple cross-beds, larger dunes, point bars, and lag gravels which include large clasts of unconsolidated silt. Secondary features include micro-faults and degassing structures. Size analysis of the sediments suggests the coarse material was bed and intermediate load while the silt and finer material was suspended load. Paleohydraulic reconstruction from the size analysis suggests mean velocities of 28 cm/sec. Scallops on passage walls suggest more modest velocities in the turbulent, subcritical flow regime. Long Cave was not developed paragenetically.

The development of the passage began with the development of a tubular conduit followed by entrenchment of the stream. Aggradation of the stream resulted in the deposition of the coarser sediments followed by deposition of silts from ponded or sluggish flow.

EVOLUTION OF THE HILLS CREEK BASIN, WEST VIRGINIA

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Recent dye tracing tests conducted in the Hills Creek and Bruffey Creek valley and in the Friars Hole area (West Virginia) have shown the subsurface karst flow routes to be considerably more complex than previously reported. The results of the studies indicate that stream piracy is active in this area and that the Friars Hole Cave System is presently recapturing Hills and Bruffey Creeks from Locust Creek and diverting this water to underdrain its original surface course to Spring Creek.

The geomorphic evolution of Hills Creek, postulated from the dye tracing results and interpretation of the topographic maps, appears to have entailed the following sequence of events: (1) Surficial flow southeast from Yew Mountain and turning southwest to Spring Creek via Friars Hole valley; (2) Initial development of various segments of the Friars Hole Cave System and underdraining of the valley; (3) Subsurface diversion of Bruffey Creek to Millstone Creek; (4) Capture of Millstone Creek by Locust Creek and the diversion of Hills Creek into Hills-Bruffey Cave; (5) Beheading of the North Fork Cherry River by the Friars Hole Cave System; (6) Integration of the major segments of the Friars Hole Cave System; (7) Ongoing rediversion of Hills Creek to Spring Creek via Cutlip, Clyde Cochrane Sinks, and the Friars Hole Cave System.

KARST DRAINAGE SYSTEMS OF THE NORTHERN SPRING CREEK BASIN, WEST VIRGINIA

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The Spring Creek basin, Greenbrier and Pocahontas Counties, West Virginia, has been studied by dye tracing techniques over the last ten years. Spring Creek and its western tributaries flow from clastic mountains, sink at the Greenbrier limestone contact, and flow subsurface to springs perched on relatively impermeable underlying shales. The northernmost part of the area (Hills and Bruffey Creeks) is shared with Locust Creek, although Spring Creek is actively pirating the Hills and Bruffey Creek drainage from Locust Creek.

Bruffey Creek drains mostly to Locust Creek via Hughes and Marthas Caves with some "leakage" into Spring Creek. Hills Creek, during low flow conditions, drains mostly into Spring Creek via Cutlip, Clyde Cochrane, and northern Friars Hole Caves. The high flow water from Hills Creek travels directly to Locust Spring while all the water in Cutlip and Clyde Cochrane Caves flows only to Spring Creek. Rush Run drains only to Spring Creek during low flow, but during high flow it sinks into Herbert Hill Cave No. 1 and drains to both Locust Creek and Spring Creek. Fox Cave and Browns Cave drain to Zotters Folly Cave and into Spring Creek. Under low flow conditions Spring Creek sinks in its own bed south of Oscar and resurges at a complex series of springs about two miles northwest from the mouth of the creek.

The uppermost spring is along the bed of the creek and only discharges during high flow conditions. Two thousand feet downstream is a series of sinkholes in the floodplain which expose the drainage from all the northern Spring Creek basin. The water moves through these sinkholes and resurges briefly from the opposite bank of the creek channel. Under low flow conditions it immediately sinks again into Spur Cave, flows for a thousand feet through a subterranean meander cutoff, and resurges at McFerrin Water Cave.

Dye travel times from the Friars Hole Cave area ranged from two to eight weeks depending on flow conditions. The dye recovery patterns suggest that considerable ponding or a very low gradient route exists between the Friars Hole Cave System and the resurgences.

PSEUDOKARST IN THE MAY 18, 1980, DEBRIS/PYROCLASTIC FLOW OF MOUNT ST. HELENS, WASHINGTON: INITIAL RECONNAISSANCES

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At a mention in the popular press, in late 1980, of piping as a reason for the U.S. Army Corps of Engineers drainage pipeline and pumping plant at Spirit Lake, the Western Speleological Survey made reconnaissances of parts of the May 18, 1980, pyroclastic/debris flow complex. Subsequently the Corps of Engineers provided copies of topographic maps of an area near Spirit Lake where surprisingly extensive pseudokarst is present. Although close to the new shore of Spirit Lake, the bottom of some of the largest sinks is below lake level. The floors of all were dry in October, 1982, and evidence of natural piping and other pseudokarstic processes was abundant. The sinks cannot be explained on the basis of phreatic explosions because they are west of the lobe of the May 18 flows which invaded Spirit Lake. They are well south of the pre-eruption course of the outlet river of the lake. Their relationship to post-eruption drainage of the lake has not yet been determined, but their alignment is along the potential overflow route for the lake and may reflect preferential routes of subsurface flow. The alignment of the largest sinks also suggests ablation of large bodies of glacial ice carried northward in the pre-eruptive avalanche.

HYDROLOGY OF THE NEWSOME SINKS AND SKIDMORE CAVE SYSTEMS

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William W. Varnedoe, Jr., Huntsville Grotto, NSS, 5000 Ketova Way, Huntsville, AL 35803

Hughes Spring Cave and Skidmore Cave are major resurgences for drainage into and through a number of caves in Brindley Mountain, Morgan County, Alabama. A single test with fluorescein dye in 1958 established that the water flowing through Wolf Cave in the north part of Newsome Sinks emerged at Hughes Spring Cave in Hughes Valley south of the Newsome Sinks. This result suggested that many of the caves in Newsome Sinks drain to Hughes Spring Cave. A large insurgence where Boston Hollow and Cagle Hollow join to form the head of Hughes Valley was presumed to be a significant source of the Skidmore Cave flow. A fluorescein dye test in July, 1982, established that water entering the Boston - Cagle Hollow insurgence does indeed resurge at Skidmore Cave. Hughes Cave, the site of the next two experiments, has a main entrance on the north side of Hughes Valley and another, Fox's Lost Entrance, within the Newsome Sinks. Dye was introduced first in a small drain below the large room just inside the main entrance. The time for this dye to reach Skidmore Cave (7 days) relative to the time from the insurgence (11 days) is instructive. Both experiments were done under quite similar dry season flow conditions. The longer time from the insurgence indicates a longer route, greater pooling, or a combination of both. The next experiment introduced dye into the Fox's Lost Entrance. To reach Skidmore Cave, this water passed under the saddle defining the south end of Newsome Sinks, under Hughes Valley, and under Ralph Mack Mountain. Two final experiments from Shine Cave and Bathtub Cave reconfirmed that major parts of Newsome Sinks drain to Hughes Spring. Thus Newsome Sinks is found to have a divided drainage.

SPELEAN HISTORY SESSION

CAVE USAGE DURING THE AMERICAN CIVIL WAR

Marion O. Smith, P.O. Box 8276, U.T. Station, Knoxville, TN 37916

Caves were utilized for a variety of purposes during the American Civil War of 1861-1865. Besides the mining of saltpeter, caves were used as places of hiding, places of recreation, focal points in military operations, burial sites, and prisons. All of these uses can be documented from contemporary sources.

THE SINKS OF GANDY AND JACK PREBLE

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West Virginia is rich in cave history and played an important role during the Civil War in supplying saltpeter. However, the legendary and scenic Sinks of Gandy Creek is perhaps its most noted historic cave, thanks to such authors as Porte Crayon and Jack Preble. Jack also played an important role in the early days of the NSS.

CIVIL WAR WRITINGS FROM THE WALLS OF LOOKOUT MOUNTAIN CAVERNS

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For years it had been rumored that many old Civil War era signatures were to be found on the walls of the Lookout Mountain Caverns, Tennessee. This is a lower level of Ruby Falls, a nationally known show cave.

Although many guides and tourists may have seen some of these writings, little, if any, research was ever conducted. This paper deals with the results of uncompleted research on many of these signatures and other bits of writings that exist in this closed lower level.

Two points of special interest were to be proven if possible: First, to try to prove the story that a military field hospital or aid station was established in the cavern, and second, to establish whether signalmen did, in fact, visit the cave to authenticate the drawings of signal flags in the "Signal Flag Room."

WILLIAM HENRY HARRISON
CAVE OWNER, EXPLORER, AND PRESIDENT

John M. Benton, 2006 Leland Drive, Huntingburg, IN 47542
William Henry Harrison was sworn in as our ninth president in 1841. Harrison moved to Indiana via Ohio and Virginia in 1801. This paper presents some observations on William Henry Harrison and caves he encountered and possibly explored while in Indiana. Evidence is piecemeal and theoretical but Harrison seemed attracted to caves and springs. History records his visit to Wyandotte Cave in 1806. Was Harrison just a casual observer of Wyandotte and other caves, or was he one of America's first spelean explorers?

BRANSFORDS SHOW MAMMOTH CAVE

Harold Meloy, P.O. Box 454, Shelbyville, IN 46176
Four generations of the Bransford family led visitors through Mammoth Cave for over 100 years. In 1838, the brothers Mat and Nick were brought to the cave as slaves. After their emancipation a quarter of a century later, they continued as paid employees and Mat's son, Henry, joined them. Henry's sons, Matt and Louis, followed in the family footsteps. Elzie and Clifford, sons of Louis, and Arthur, Eddie, and George, his nephews, carried on the family tradition until they took other employment. In 1939, Louis was the last remaining Bransford guide at Mammoth Cave.

PALEONTOLOGY SESSION

WEST VIRGINIA VAMPIRES, SABER-TOOTHES, ELEPHANTS,
AND THINGS THAT GO BUMP IN THE NIGHT

E. Ray Garton, Geologic Evaluations, Barrackville, WV 26559
Long, long ago, in a time long forgotten, the area we now call West Virginia was inhabited by a wide variety of strange beasts. We know this to be true because we have found their bones in many of West Virginia's caves. The first bones of these ancient animals found within a West Virginia cave came in 1797. Workers for Thomas Jefferson found several very well preserved bones of a giant ground sloth, Megalonyx jeffersoni, in an as yet unknown saltpetre cave in Greenbrier County. The next discovery did not come for 116 years when part of the jaw of a peccary, Platygonus cf. vetus, was found in Renick Quarry Cave, Greenbrier County, in 1913. An occasional specimen was found over the next few decades mostly in Greenbrier County caves. Beginning in the early 1960s, Carnegie Museum of Natural History in Pittsburgh, Pennsylvania, under the direction of John E. Guilday, Allen D. McCrady, and Harold Hamilton, began an intense effort to locate, preserve, and study Pleistocene age bone deposits in West Virginia and Appalachian caves. This team was joined by Fred Grady and the author in the late 1970s. With the help of dozens of other cavers who not only found some of the sites, but helped to dig and process the material, a large collection of bones has been found, collected, processed, identified, and published. To date, the remains of some 92 different mammals have been found in West Virginia. The remains of dozens of types of fish, reptiles, birds, and amphibians have also been found. Animals ranging from the tiniest shrew, Sorex arcticus, to the medium sized saber-toothed tiger, Smilodon, to the largest of all, the mastodon, Mammut americanum, have

EPHEMERA: ITS LIMITS AND IMPORTANCE
TO SPELEAN HISTORY

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Ephemera collecting seems, at first sight, to be a contradiction in terms since ephemera is intended for one time use and then is normally discarded. In the last few years, many scholars and historians have attempted to classify such items as they present social history previously ignored. These scraps of history fill important spaces in all fields including speleology. Posters, tickets, stock certificates, trade or business cards, brochures, broadsides, newspaper articles, letters, and postcards can inform us of changes in ownership or guides or of other evolutionary changes in show caves.

OWNERSHIP HISTORY OF THE JOHN GUILDAY
CAVE PRESERVE PROPERTY 1787-1983

Edward Ricketts, P.O. Box 55156, Oxon Hill, MD 20744
The tract which comprises the John Guilday Cave Preserve was first surveyed in 1787. Since that time there have been twelve changes in ownership. This paper traces the tract and the surrounding properties that belonged to its owners and records the changes in boundaries. The paper also comments on aspects of early surveying and problems in using the data from early deed books.

been found. Through various dating techniques bone deposits ranging from recent to 8,000 yr.B.P. to 35,000 yr.B.P. to perhaps 500,000 yr.B.P. have been found.

FIRST RECORD OF FOSSIL VERTEBRATES (QUATERNARY)
FROM THE ISLAND OF TOBAGO, WEST INDIES

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Exploration in four caves from the Crown Point area of Tobago in 1979 and 1982, yielded rich fossil vertebrates, the first reported from the island. Three distinct ages are represented. The oldest, the Robinson Crusoe faunule, contains the only extinct taxa (Glyptodon) indicating a minimum age of 4,000 yr.B.P., but 10,000 to 12,000 yr.B.P. is more likely. The second oldest is the Remnant faunule, probably of pre-Columbian age, containing a large percentage of extirpated species suggesting a dryer climate than exists on the island today. The youngest age represented is the Crown Point faunule of post-Columbian age.

The Crown Point Caves System contains significant fossil vertebrates which span and help document the climatic changes which have taken place on a continental island only recently (8 - 12,000 yr.B.P.) separated from South America by post-glacial sea level rise.

VERTICAL SESSION

A SUMMARY OF VERTICAL CAVING EQUIPMENT

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Climbers and vertical cavers have developed a wide variety of devices for the descent and ascent of a fixed rope. The many forms of rappelling devices available represent many designers' approaches, each with its own advantages, compromises, and disadvantages. The writer finds it convenient to classify descenders using a scheme based on the geometry of the rope path through the device. By doing so, one can establish a continuum of potential designs into which each individual device can be assigned a position logically related to the others.

THE USEFULNESS OF THE SAMSON ROPE CONSTRUCTION

Gary Storrack, 400 Churchill Road, Venetia, PA 15367
Samson 2-in-1 rope has been replaced by other brands as a main line for vertical caving but its unique construction offers advantages in certain applications. This rope consists of a loosely braided sheath surrounding a loosely braided tubular core. By using this construction, the rope is easily spliced. The splices are very flexible yet retain a very large percentage of the rope's original strength.

Two applications are suggested. The first is in forming slings for ascenders. In certain climbing systems, the bulk of a knot can be a nuisance. One example is the knot at the upper Jumar in the Mitchell system. An eye splice in 2-in-1 is a much neater approach. The second application is the formation of continuous loops for climbing practice.

An end splice feeds smoothly through several types of friction brakes, eliminating problems caused by splices in other types of ropes.

A PRELIMINARY NOTE ON SQUEEZE BRAKES

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Most rappel brakes work by bending the rope. Squeeze brakes work by squeezing the rope as it passes through the brake. As a result, squeeze brake operation is largely independent of the tension in the rope.

For a squeeze brake (or any other brake) to have reliable control, it must have a fast-acting control system that can respond to the rapid variations in characteristics that can occur along the length of a rope. The screw mechanisms used in the early squeeze brakes were too slow.

Practical squeeze brakes have provision for exerting two independent forces on the rope. The "base" force usually supports most of the rappeller's weight. It is applied by a mechanism that holds its setting without effort by the rappeller, but can be changed as needed. The "dynamic" force supports the rest of the rappeller's weight and can be adjusted at human reaction speed to compensate for rope variation. This force can be applied with levers.

Squeeze brake design problems include obtaining the required 1 to 8 kilonewton (220 to 1800 pound) squeeze force from practical hand operated inputs; deciding on the size, shape, and metal for the gripping surfaces; and achieving adequate strength.

WITHIN THE STATE of Indiana lie two separate cave regions: a southcentral karst developed in strata of Mississippian age and a southeastern karst developed in Ordovician to Devonian strata (Fig. 1). Many accounts of the cave fauna of the southcentral karst have appeared. These are mostly taxonomic studies (e.g., Barr, 1960; Eberly, 1965; Krekeler, 1958) or faunal checklists (Banta, 1907; Blatchley, 1896; Cope, 1872; Hobbs, 1973; Krekeler and Williams, 1966). In contrast, the cavernicolous fauna of the southeastern karst area is poorly known.

Nine species of troglobites or phreatobites have been reported previously from southeastern Indiana. Of these, five were described from localities in southeastern Indiana: the snail *Fontigens*

Malot, 1922; Powell, 1970, 1973). The southeastern karst lies on the west flank of a broad, north-south trending anticline, the Cincinnati Arch. The western part of the study area, the Scottsburg Lowland, is characterized by Devonian shales which grade eastward into Devonian limestone (Powell, 1959). Caves do not occur in the western part of the Scottsburg Lowland, forming a geological gap between the southcentral (Mitchell Plain, Crawford Upland) and southeastern cave areas. Perforated drain tiles placed in poorly drained soil tap groundwater and act as 'artificial caves,' the mouths of which are sometimes profitable sites for phreatobitic invertebrates.

1961), there is no extensive list of caves in the southeastern karst. For this reason, locating caves in which to make invertebrate collections was a major problem during this study. The closest thing to a comprehensive report is that of Powell (1959), although some of his localities are natural bridges or caves for which precise coordinates are not given. Cox (1971, 1972) reported a total of 97 Jefferson County cave entrances (including multiple entrances to single caves). Unpublished cave locations in Jefferson and Jennings counties were also available from the Indiana Geological Survey in Bloomington.

SUMMARY

Nineteen species of troglobites and phreatobites have been found in subterranean habitats in southeastern Indiana, including 17 species of arthropods, 1 turbellarian, and 1 gastropod. Among the arthropod species found were 4 isopods (Caecidotea), 4 amphipods (Stygobromus, Bactrurus, Crangonyx), and 6 beetles (Pseudanophthalmus, Batrisodes). The fauna probably moved into Indiana before the Kansan entrenchment of the Ohio River and inhabited caves in the unglaciated Mitchell Plain and Crawford Upland of southcentral Indiana until the Illinoian glacier retreated. After the southeastern Indiana karst region became free of its ice cover, the ancestors of today's cave fauna invaded the area. Isolation in caves occurred during the Sangamon interglacial. There is little evidence of subsequent range expansion during the Wisconsin glaciation. Today, almost all of the troglobitic fauna is found near the Illinoian glacier's maximum extent.

crypticola Hubricht (1963), the milliped *Pseudotremia nefanda* Shear (1972), the pselaphid beetle *Batrisodes krekeri* Park (1960), and the carabid beetles *Pseudanophthalmus barri* Krekeler and *P. chthonius* Krekeler (1973). Other obligate subterranean species reported from the region are the isopods *Caecidotea stygia* Packard (Fleming, 1972) and *C. kendeighi* (Steeves and Seidenberg) (Lewis and Bowman, 1981), and the amphipods *Bactrurus mucronatus* Forbes and *Crangonyx packardi* Smith (Holsinger, 1972).

STUDY AREA

The cave region of southeastern Indiana is developed in limestones and dolomites of Ordovician through Devonian ages, in the Scottsburg Lowland and Muscatatuck Regional Slope subunits of the Central Lowlands Province (Fenneman, 1938). Although the karst belt corresponds to the Bluegrass Section of the Interior Low Plateaus Province in adjacent Kentucky, the entire Indiana part of the Bluegrass was covered by Pleistocene glaciers and is therefore included in the Central Lowlands Province (Moore, 1973;

In the eastern part of the Scottsburg Lowland, many small spring caves occur along streams which have dissected the glacial till plain, notably Silver Creek (especially its tributary, Pleasant Run), Fourteen Mile Creek, and Bull Creek. All of these streams drain directly into the Ohio River (Fig. 2).

Most of the caves in southeastern Indiana lie within the Muscatatuck Regional Slope, where tributaries of the East Fork of the White River (namely, Big Creek, Sand Creek, and the Muscatatuck River) have cut through the till and exposed Silurian and Ordovician limestones and dolomites. The White River flows across the southcentral cave region before joining the Wabash River, which in turn joins the Ohio River. Most caves in the Muscatatuck Regional Slope are also short spring caves, often not more than 100 to 200 m in length, which open along one of the streams listed above. Since most of the caves lie close to the surface, many also have one or more sinkhole entrances.

Unlike the southcentral cave region, for which many cave locations have been published (Powell,

FIELD STUDY

During the period from 1975 to 1982, 88 trips to 57 caves were conducted for the purpose of sampling the invertebrate fauna. Of these 57 localities, 16 are in Clark County, 4 in Decatur, 31 in Jefferson, 5 in Jennings, and 1 in Ripley. Many springs were also examined, plus several drain tiles in Floyd County. The most important locations are shown in figures 1 and 2; locality data for other sites is available in the publications cited above.

Most of the sampling was accomplished by hand collecting. In addition to this, three other, indirect, methods were used to obtain specimens: (1) pitfall traps, baited with a variety of materials; (2) Berlese extraction of leaf litter (used mostly for small arthropods); and (3) jars baited with uncooked marine shrimp, which were submerged in streams or pools (used to obtain planarians and crustaceans).

FAUNAL LIST

The following list is a compilation of all obligate subterranean species known from southeastern Indiana, both troglobites and phreatobites. The geographic area includes both the southeastern karst belt and the adjacent till plain. The majority of this information was gathered during the field study, although published records and the unpublished data of several taxonomists are also incorporated.

The higher taxa are listed in phylogenetic order, with species placed in the appropriate taxa. The ecological-evolutionary terms 'troglobite' (TB) and 'phreatobite' (PB) have been defined by Barr (1963, 1968), Holsinger and Peck (1971), and Peck and Lewis (1978). Records are listed alphabetically by county and locality.

PHYLUM PLATYHELMINTHES

CLASS TURBELLARIA

ORDER TRICLADIDA

Family Kenkiidae

Sphallophana weingartneri Kenk (PB?)

Clark County: Peyton Beechwood Cave. Jefferson County: Cricket, Deputy Corner, unnamed spring cave near Deputy Corner.

This species was described from a single specimen taken in Donaldson's Cave, Lawrence County, Indiana (Kenk, 1970) and was previously known only from the type locality. Specimens from the 4 localities listed above were shipped alive for identification, but only the Peyton Beechwood and spring cave specimens arrived intact; thus, the other 2 records should be considered sight records. This species is not common at any of the 5 localities from which it is known. The largest collection consists of 3 specimens.

PHYLUM MOLLUSCA
CLASS GASTROPODA
ORDER CTENOBRANCHIATA

Family Hydrobiidae

Fontigens crypticola (Hubricht) (TB?)

Clark County: small spring 3 miles west of Bethlehem. This translucent, blind species is known only from the type-locality (Hubricht, 1963). It was not seen during this study.

PHYLUM ARTHROPODA
CLASS CRUSTACEA
ORDER ISOPODA

Family Asellidae

Caecidotea jordani (Eberly) (TB/PB)

Decatur County: Faulty and Horsethief caves, well at Greensburg. This isopod was previously known only from the type locality, a seep in the sub-basement of Jordan Hall on the Indiana University, Bloomington campus (Eberly, 1965). *Caecidotea jordani* was synonymized with *C. alabamensis* by Fleming (1973), but was resurrected by Lewis and Bowman (1981).

Caecidotea kendeighi (Steeves and Seidenberg) (PB)

Henry County: outlet of drain 3.8 miles north of Knightstown. This species, reported from this locality north of the southeastern Indiana karst by Lewis and Bowman (1981), is a common phreatobite in Illinois, Missouri, Iowa, and Indiana.

Caecidotea stygia Packard (TB)

Clark County: Bridge, Cave Spring, Indian, Moore Brothers Spring, Peyton Beechwood, Peyton Spring, Pleasant Run, Silver Creek and Sunset Village caves. Jefferson County: Boyd's, Cave Spring (Deputy), Cricket, Deputy Corner, Double, Hardy's, Indian, Mud, Slider, Waterfall, and Wilson's caves. Jennings County: Cave Spring, Garbage Hole, Lowry, and Meek caves.

This species was redescribed by Bowman and Beckett (1978) from southwestern Ohio and is also known from Illinois (Peck and Lewis, 1978), Indiana, Kentucky, Tennessee (Steeves, 1963), and Missouri (Fleming, 1972). The only previous record for *C. stygia* from southeastern Indiana was Fleming's (1972) Wilson Cave locality. Although most of the records for this species are from caves (Steeves, 1963; Fleming, 1972), the non-cave localities in Ohio reported by Bowman and Beckett (1978) suggest that this isopod is capable of interstitial dispersal.

Caecidotea teresae Lewis (PB)

Floyd County: drain tiles at Indiana University Southeast Campus, New Albany.

This eyeless, lightly pigmented species is closely related to *C. tridentata* in Kansas, *C. salemensis* Lewis in Missouri (Lewis, 1981) and *C. lesliei* Lewis and Bowman in Illinois (Lewis and Bowman, 1981).

ORDER AMPHIPODA

Family Crangonychidae

Batrurus mucronatus Forbes (PB)

Henry County: outlets of drains 3.5 and 3.8 miles west of Knightstown. Marion County: well at Irvington. Holsinger (1972) reported that this common phreatobitic species occurs across much of central Indiana and Illinois.

Crangonyx packardi Smith (TB)

Clark County: Indian, Peyton Beechwood, Peyton Spring, Sunset Village, and Watson Spring caves. Jefferson County: Cave Spring (Deputy), Foster, Griffith, Waterfall, and Wilson's caves.

These collections may represent an undescribed species, or may be *C.*

packardi, a common inhabitant of caves in southcentral Indiana (Holsinger, 1972).

Stygobromus sp. 1 (TB/PB)

Clark County: Indian Cave.

This undescribed species may be identical with populations occurring in caves of the Kentucky Bluegrass (Holsinger, *in litt.*). In Indian Cave, *Crangonyx packardi* is much more abundant than *Stygobromus*. The genus *Stygobromus* was previously unknown from Indiana (Holsinger, 1972).

Stygobromus sp. 2 (PB)

Floyd County: drain tile on Indiana University Southeast campus, New Albany.

This undescribed species, known from a single specimen, is a member of the *tenuis* Group (Holsinger, *in litt.*).

CLASS ARACHNIDA
ORDER ARANEAE

Family Linyphiidae

Phanetta subterranea (Emerton) (TB)

Clark County: Indian, Moore Brothers Spring, and Sunset Village caves.

Decatur County: Faulty Cave. Jefferson County: Mud Cave.

This species is found in caves throughout eastern United States.

ORDER PSEUDOSCORPIONIDA

Family Chernetidae

Hesperochernes sp. (TB?)

Jefferson County: Wilson's Cave.

Muchmore (*in litt.*) reported the collection of two specimens of a possibly troglobitic, undescribed species from this locality. Species of this genus occur in many caves of southeastern United States, but the taxonomy of the group is currently too confused to separate the species (Muchmore, 1974).

CLASS DIPLOPODA
ORDER CHORDEUMIDA

Family Cleidogonidae

Pseudotremia nefanda Shear (TB)

Clark County: Indian, Peyton Beechwood, Sunset Village and Watson Spring caves.

This species is distributed in Clark County caves found along the Pleasant Run and Bull Creek drainages. *P. nefanda* was previously known only from the type locality, Indian Cave (Shear, 1972).

CLASS INSECTA
ORDER COLLEMBOLA

Family Entomobryidae

Pseudosinella sp. (TB)

Clark County: Moore Brothers Spring and Peyton Spring caves.

This is an undescribed species (Christiansen, *in litt.*). The genus *Pseudosinella* is known from many caves in the Ozarks, Interior Low Plateaus, and Appalachians (Christiansen, 1960).

Sinella alata Christiansen (TB)

Clark County: Indian Cave.

This species was previously known from 2 localities in the south central Indiana karst area (Christiansen, 1960).

ORDER COLEOPTERA

Family Carabidae

Pseudanopthalmus barri Krekeler (TB)

Clark County: Indian, Peyton Beechwood, and Watson Spring caves. Krekeler (1973) reported this species from Indian (type locality) and Peyton Beechwood caves. *P. barri* is known only from caves that lie along Pleasant Run.

Pseudanophthalmus chthonius Krekeler (TB)

Jefferson County: Morris and Wilson's caves. Jennings County: Lowry Cave.

Krekeler (1973) also reported this species from Indian and Peyton Beechwood caves, in Clark County. However, these populations are probably referable to the following species (Barr, *in litt.*).

Pseudanophthalmus sp. 1 (TB)

Clark County: Watson Spring Cave. This species is closely related to, but morphologically separable from, *P. chthonius*. This scenario restricts *P. chthonius* to caves along the White River drainage and *Pseudanophthalmus* sp. 1 to caves (presumably also In-

dian and Peyton Beechwood) along the Pleasant Run drainage.

Pseudanophthalmus sp. 2 (TB)

Clark County: Sunset Village Cave and Cave Spring Cave. This species is undescribed.

Pseudanophthalmus sp. 3? (TB)

Jefferson County: Tunnel Cave in Clifty Falls State Park. This possibly undescribed species is known from fragmentary remains taken from a pitfall trap.

Family Pselaphidae

Batrisesodes krekeleri Park (TB)

Clark County: Cave Spring Cave. This species, the only troglotic pselaphid known from Indiana, is known only from the type locality (Park, 1960). Known previously from a single female specimen, additional specimens were taken from an animal burrow in this cave.

ZOOGEOGRAPHY OF THE FAUNA

A total of 21 subterranean species have been listed from southeastern Indiana, of which 10 are aquatic and 11 are terrestrial. These species (Table 1) are divisible into 4 groups, according to the sizes of their ranges and the geographic areas in which they are found:

- (1) a third of the fauna is known from single localities; these 7 species are the 2 species of amphipods (*Stygobromus* spp. 1 and 2), the isopod *Caecidotea teresae*, the pseudoscorpion *Hesperochnes* sp., the carabid beetle *Pseudanophthalmus* sp. 3, the pselaphid beetle *Batrisesodes krekeleri*, and the snail *Fontigens crypticola*. With the exception of *Hesperochnes* sp. (a questionable troglote), all of these species occur only along the Illinoian glacial boundary, near the Ohio River in Clark and Floyd counties.
- (2) Six additional species are endemic to localities within the southeastern Indiana karst area; these are the collembolan *Pseudosinella* sp., the milliped *Pseudotremia nefanda*, and the carabid beetles *Pseudanophthalmus barri*, *P. chthonius*, and *P. spp.* 1 and 2. Of these 6 species, only *P. chthonius* is known outside of Clark County. The 13 species of categories (1) and (2) comprise the Muscatatuck Fauna, a subsection of the Bluegrass Fauna described by Barr (1967).
- (3) Three species are known from the southeastern and southcentral Indiana cave areas; these are the planarian *Sphalloplana weingartneri*, the isopod *Caecidotea jordani*, and the collembolan *Sinella alata*. These species are found mostly along the White River drainage. In contrast to the species of categories (1) and (2), *S. weingartneri* and *C. jordani* are known primarily in the northern part of the southeastern cave area, and one locality of *C. jordani* in Decatur County is north of the Wisconsinan glacial boundary. The species of category (3) are components of both the Muscatatuck Fauna and the Bedford Fauna, a subunit of the Pennyroyal Fauna of Barr (1967).
- (4) Five species are very widespread and occur both in Indiana and in adjacent states; these are the amphipods *Batrisesodes mucronatus* and

Crangonyx packardi, the isopods *Caecidotea kendeighi* and *C. stygia*, and the spider *Phanetta subterranea*. Of these species, *C. packardi*, *C. stygia*, and *P. subterranea* are found in many caves both in Indiana and in Kentucky. *Caecidotea kendeighi* and *Batrisesodes mucronatus* are phreatobites inhabiting the glacial plains of Indiana and Illinois, but are occasionally found along the northern fringes of the Interior Low Plateaus.

EVOLUTION AND DISPERSAL OF THE FAUNA

The explanation of the origin of a subterranean fauna in Indiana in general, and southeastern Indiana in particular, must begin with an awareness of changes in the geography and climate of the region from the late Tertiary to the present. The scenario proposed here is an extension of the evolutionary theory of Krekeler (1973) and an outgrowth of the ideas presented by Peck and Lewis (1978).

The Tertiary

During the late Tertiary, drainage patterns were much different from those of the present. The Ohio River at that time was a minor stream draining an area west of the Knobstone Escarpment westward to the Mississippi. The Salt River was a more extensive stream than at present, flowing from south to north along the eastern flank of the Knobstone Escarpment toward the Teays River, which then flowed westward to empty into the Mississippi (Powell, 1970). Forests at this time were continuous between the Ozarks, Interior Low Plateaus, and Appalachians (Butzer, 1976; Axelrod, 1960). These conditions would favor the surface dispersal of the litter-dwelling ancestors of today's terrestrial cave fauna (Barr, 1968). Dispersal into the area would not be difficult, because the Salt River provided a direct corridor into Indiana, but separated the southeastern and southcentral cave areas. Thus, the epigeal ancestors of the milliped *Pseudotremia*, the beetle *Pseudanophthalmus*, and other terrestrial invertebrates could move freely into Indiana from

the south or east without encountering major water barriers.

There is little evidence to support a time of subterranean invasion for the members of the aquatic fauna. Different levels of morphological adaptation exist among the members of the aquatic fauna, similar to that discussed by Culver (1976) for Appalachian species. Most of the species, such as the amphipods *Batrisesodes mucronatus*, *Stygobromus* spp. 1 and 2, the isopods *Caecidotea jordani* and *C. stygia*, the planarian *Sphalloplana weingartneri*, and the snail *Fontigens crypticola* entirely lack pigmentation and eyes. However, the isopod *Caecidotea kendeighi* possesses small eyes and light pigmentation; *Caecidotea teresae* is lightly pigmented, but lacks eyes; and *Crangonyx packardi* has small eyes in some populations. These latter 3 species may be more recent inhabitants of groundwater, as evidenced by their retention of morphological characteristics of epigeal facies. Some of the members of the more specialized group, notably *Stygobromus*, are currently thought to represent a rather ancient groundwater invasion (Holsinger, 1978). The second, less specialized assemblage may represent a more recent groundwater invasion resulting from the climatic vagaries of the Pleistocene.

Whatever the case, the presence of the Salt River running through central Indiana provided a dispersal corridor either to the Mitchell Plain west of the river or to the Muscatatuck Regional Slope on the east. If the ancestral species were epigeal at this time, surface dispersal would have been readily accomplished. If hypogean, the presence of continuous limestones through the area, plus the demonstrated ability of some, if not all, of the aquatic species to move via non-cave interstices (as shown by the presence of species such as *Caecidotea kendeighi*, *Caecidotea teresae*, and *Stygobromus* sp. 2 in areas where caves do not occur) should have facilitated movement into the area.

The Pleistocene

During the time prior to the Kansan glacial ad-

vance, the Salt River dissected the Knobstone Escarpment and the Ohio River enlarged its drainage basin into the area just west of present day Madison, Indiana. The Ohio River was still a small stream at this time and probably provided no major barrier to dispersal. Much of what was to become the Ohio River drainage was still held by the Teays River in northern Indiana. However, during the Kansan, the Teays River was buried and the enlarged, ice-marginal Ohio River became a major outlet for glacial melt-water (Wayne and Zumberge, 1965; Powell, 1970). The ancestors of the *Pseudanophthalmus* carabid beetle *barri* and *horni* groups, the milliped *indiana* group and other terrestrial invertebrates are thought to have moved into the areas where they are now found before the Ohio River became a major stream (Barr, *in litt.*).

Glacial drift of both Kansan and Illinoian ages are found over the southeastern Indiana cave area (Wayne and Zumberge, 1965), and the ancestors of its present day cave fauna must have survived the glaciations in adjacent unglaciated areas. Although there is some evidence of isolated subglacial survival of subterranean amphipods (Holsinger, 1978), in general the conditions were probably too harsh under the glaciers for either aquatic or terrestrial species (Krekeler, 1973; Peck and Lewis, 1978; Lewis and Bowman, 1981). Considering the present affinities of the fauna of the Muscatatuck Regional Slope caves with that of the Crawford Upland and Mitchell Plain, it seems likely that caves of these latter areas were the source of much of the current subterranean fauna of southeastern Indiana.

It is difficult to say to what extent, and when, caves became available for colonization after the Kansan and Illinoian ice retreated from southeastern Indiana. Although many were probably totally filled with outwash, some caves may only have been buried. Caves located in the southern part of the study area, along the Ohio River, would have been cleared of sediments first. The caves of present day Clark County were ice-free and apparently available as habitats prior to those to the north in Jefferson and Jennings counties.

As the caves became available, invasion of them by species utilizing cool, moist habitats probably began to occur not only in the area concerned here, but also in other cave areas along the glacial maxima in Illinois (Peck and Lewis, 1978) and Ohio (Hobbs, 1981). Different modes of dispersal from unglaciated areas into southeastern Indiana were probably used, depending on the degree to which the different species had become adapted to subterranean existence. Much of today's cave fauna in southeastern Indiana is troglonecotic or troglomorphic and could have dispersed freely into the area as the glacier retreated. Some of the current troglonecotic fauna, such as the milliped *Pseudotremia nefanda*, were also probably capable of epigeal dispersal. This species retains relatively large eyes (16 ocelli, each) and some pigmentation (Shear, 1972), suggesting that it is a recent inhabitant of caves. By

comparison, *P. soco*, a pigmented epigeal species from the mountains of North Carolina, possesses only 14 ocelli. *Pseudotremia nefanda*'s closest relative, *P. indiana* (inhabiting caves of the Crawford Upland and Mitchell Plain), has 15 ocelli but is unpigmented (Shear, 1972). This suggests that the ancestor of the *Pseudotremia indiana* group, having moved into Indiana prior to the Kansan (before entrenchment of the Ohio River), occupied caves in southcentral Indiana during the Kansan, then invaded caves in southeastern Indiana during the late Illinoian or early Sangamon.

Another group of species, e.g., *Pseudanophthalmus* spp., *Sinella alata*, *Caecidotea stygia*, *C. jordani* and *Sphalloplana weingartneri* are all eyeless and unpigmented and may have required subterranean dispersal corridors. (Barr, 1979). Of this group of species, all but the *Pseudanophthalmus* spp. are found in both the southcentral and southeastern karst belts. Although *Pseudanophthalmus* is certainly well represented in southcentral Indiana, close relatives of the species occurring in southeastern Indiana have not yet been found, if they exist. Although dispersal of animals from the Mitchell Plain to the Muscatatuck Regional Slope through cave passages would have been precluded by the shales of the Scottsburg Lowland, other means may have been available. Interstices suitable for the dispersal of terrestrial invertebrates could exist in the coarse unconsolidated till, or in the till-bedrock interface, as described by Juberthie and Delay (1981). Three species, *Pseudanophthalmus chthonius*, *Caecidotea jordani*, and *Sphalloplana weingartneri* occur mostly along the White River or its tributaries. Thus, although the greatest cave colonization was along the southern margin of the Illinoian till (Clark County), some dispersal apparently occurred via tributaries of the White River which deeply dissected the till plain in Jefferson and Jennings counties.

Whatever the case may have been for the dispersal and colonization of southeastern Indiana caves by each of these species, the Sangamon warming trend left the cave populations geographically and genetically isolated (Barr, 1967). Repeated glacial advances and accompanying colder intervals during the Wisconsin provided additional opportunities for dispersal. However, it appears that few if any of the terrestrial species established in caves along the Illinoian boundary immigrated at this opportunity. More caves should have been available for colonization during the Wisconsin than during the Illinoian, but if species like *Pseudotremia nefanda* had originally invaded southeastern Indiana, or had dispersed from Clark County caves, at this time, a broader distribution would be expected.

A noteworthy possible exception is *Pseudanophthalmus chthonius*. As discussed above, this species may have entered southeastern Indiana via the White River drainage. An alternative explanation is the movement of the

ancestor of *P. chthonius* and *P. sp. 1* into Clark County and its northward dispersal to Jefferson and Jennings counties, either during the end of the Illinoian or during the Wisconsin.

The dispersal of the aquatic fauna during and subsequent to the Wisconsin is a different matter. At least one species, *Caecidotea jordani*, has entered the area covered by the Wisconsin glacier, presumably after its retreat. Other aquatic troglonecotes, such as *Crangonyx packardii* and *Caecidotea stygia*, are ubiquitous and probably disperse freely in groundwaters, entering caves where they are available. This may also be the case of the obviously phreatobitic *Caecidotea teresa* and *Stygobromus* sp. 2, although they appear less common because non-cave habitats in which to collect phreatobites are uncommon in southeastern Indiana. There is some evidence that *Caecidotea stygia* may be able to travel under the Ohio River via subfluvial conduits. The Ohio traverses the Devonian limestone just north of Louisville, Kentucky, at the Falls of the Ohio. During low flow, springs are exposed in the bed of the river, behind a navigation dam. *Caecidotea stygia* has been taken from these springs, and it seems likely that other conduits exist in the continuous limestone beds under the river, allowing phreatobite dispersal under the river.

THE PRESENT

Table 1 is a compilation of the obligate subterranean species of Indiana, excluding *Caecidotea kendeighi* and *Bactrurus mucronatus*, which, as phreatobites, are not typical inhabitants of either of Indiana's cave regions. The southcentral column was derived from the lists of Nicholas (1960) and of Krekeler and Williams (1966), by the deletion of non-troglonecotes and of names that are no longer used. Undescribed species were added where the information was available. The list for the southcentral cave area will probably increase as the fauna becomes better known.

Only 19 species are listed from the southeastern Indiana area, in contrast to 31 species known in the southcentral region. The faunal paucity of the southeastern area is directly attributable to repeated glaciation, which both destroyed cave habitats and caused the extinction or migration of the fauna. Most of the terrestrial troglonecotes are found only along the Illinoian glacial boundary, relicts of the Sangamon isolation. As a result, the overall size of troglonecotic communities decreases markedly from caves near the Illinoian boundary toward the Wisconsin boundary. For example, the largest troglonecotic communities found exist in Indian Cave (7 species), the Peyton caves (6), Watson Spring Cave (5), and Sunset Village Cave (5). All of these caves lie adjacent to the Illinoian glacial boundary in Clark County. In contrast, the largest cave in Jefferson County, Wilson's Cave, is inhabited by only 4 species of troglonecotes. Most other caves in Jefferson and Jennings counties contain only 2 troglonecotes, typically an isopod (*Caecidotea stygia*) and one of the other arthropod species.

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Table 1. Obligate subterranean animals of southern Indiana.

Southcentral Area (Crawford Upland, Mitchell Plain)	Southeastern Area (Muscatatuck Regional Slope, Scottsburg Lowland)
<i>Sphallopilana weingartneri</i> <i>S. chandleri</i>	<i>Sphallopilana weingartneri</i>
<i>Caecidotea jordani</i> <i>C. stygia</i>	<i>Caecidotea jordani</i> <i>C. stygia</i> <i>C. teresae</i>
<i>Crangonyx packardii</i> <i>Bactrurus</i> sp.*	<i>Crangonyx packardii</i> <i>Stygobromus</i> sp. 1 <i>S.</i> sp. 2
<i>Orconectes inermis</i>	
<i>Phanetta subterranea</i> <i>Willbaldia cavernicola?</i>	<i>Phanetta subterranea</i>
<i>Rhagidia cavicola?</i>	
<i>Apochthonius indianensis</i> <i>Kleptochthonius packardii</i>	<i>Hesperocharnes</i>
<i>Pseudotremia indianae</i>	<i>Pseudotremia nefanda</i>
<i>Sinella alata</i>	<i>Sinella alata</i> <i>Pseudosinella</i> sp.*
<i>Arrhopalites bimus</i> <i>Hypogastrura lucifuga</i>	
<i>Pseudanophthalmus emersoni</i> <i>P. eremita</i> <i>P. leonae</i> <i>P. shilohensis</i> <i>P. stricticollis</i> <i>P. tenuis</i> <i>P. youngi</i>	<i>Pseudanophthalmus barri</i> <i>P. chthonius</i> <i>P.</i> sp. 1* <i>P.</i> sp. 2* <i>P.</i> sp. 3*
<i>P.</i> sp. 4-9*	<i>Batrissodes krekeleri</i>
<i>Antroselates spiralis</i>	<i>Fontigens crypticola</i>
<i>Amblyopsis spelaea</i>	

*Refers to undescribed species

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Chapman, Philip (1983)—Quantitative Analysis of Cave-Dwelling Invertebrates in Estado Falcón, Venezuela: *NSS Bulletin* 45: 40-44

SUMMARY

Beds of bat guano and of seeds dropped by oilbirds in 2 Venezuelan caves have very different invertebrate faunas. The bat guano fauna in Camburales Cave is dominated by tineid moth and leiodid beetle larvae. The seed bed fauna in Coy-Coy Cave is dominated by pseudoscorpions and histrid beetles. None of the recorded predators, and only a few non-predators, are common to both sites. This reflects their very different food supplies: On one hand, feces with a high proportion of insect cuticle fragments and, on the other, the regurgitated seeds and oil-rich pericarp of palm fruits. In both of the Venezuelan caves, quadrat sampling shows the density of macroscopic arthropods to be far below that reported for a guano-based community in Fern Cave, Texas. This is probably due to the lower rates of food-energy input into the Venezuelan cave ecosystems. The preponderance of predatory species recorded from Coy-Coy Cave (81 percent of sampled individuals) is due to the omission of *Collembola* and *Acari* from the recorded figures. In a brief study of fauna associated with fruit bat guano in a third cave (Trapichito), *Collembola* and mites were found to comprise 76 percent of the macroscopic fauna.

QUANTITATIVE ANALYSIS OF CAVE-DWELLING INVERTEBRATES IN ESTADO FALCÓN, VENEZUELA

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THE 1973 British-Venezuelan Karst Research Expedition spent 6 months in and around the Serranía de San Luís, Estado Falcón, Venezuela. Data on the caves are given in Chapman and Checkley (1981). Prior to our visit, members of the Sociedad Venezolana de Ciencias Naturales and of the Sociedad Venezolana de Espeleología had made some faunal collections in two caves in the Serranía Coy-Coy and in one of the caves at Hueque. Some interesting species were taken (Ravelo, 1975; Ruffo, 1957; Sanfilippo, 1958), but no detailed survey of the cavernicolous fauna ensued. It was therefore decided that our expedition should systematically collect the faunas of all the caves as they were explored and should later attempt a quantitative study in one or two selected caves.

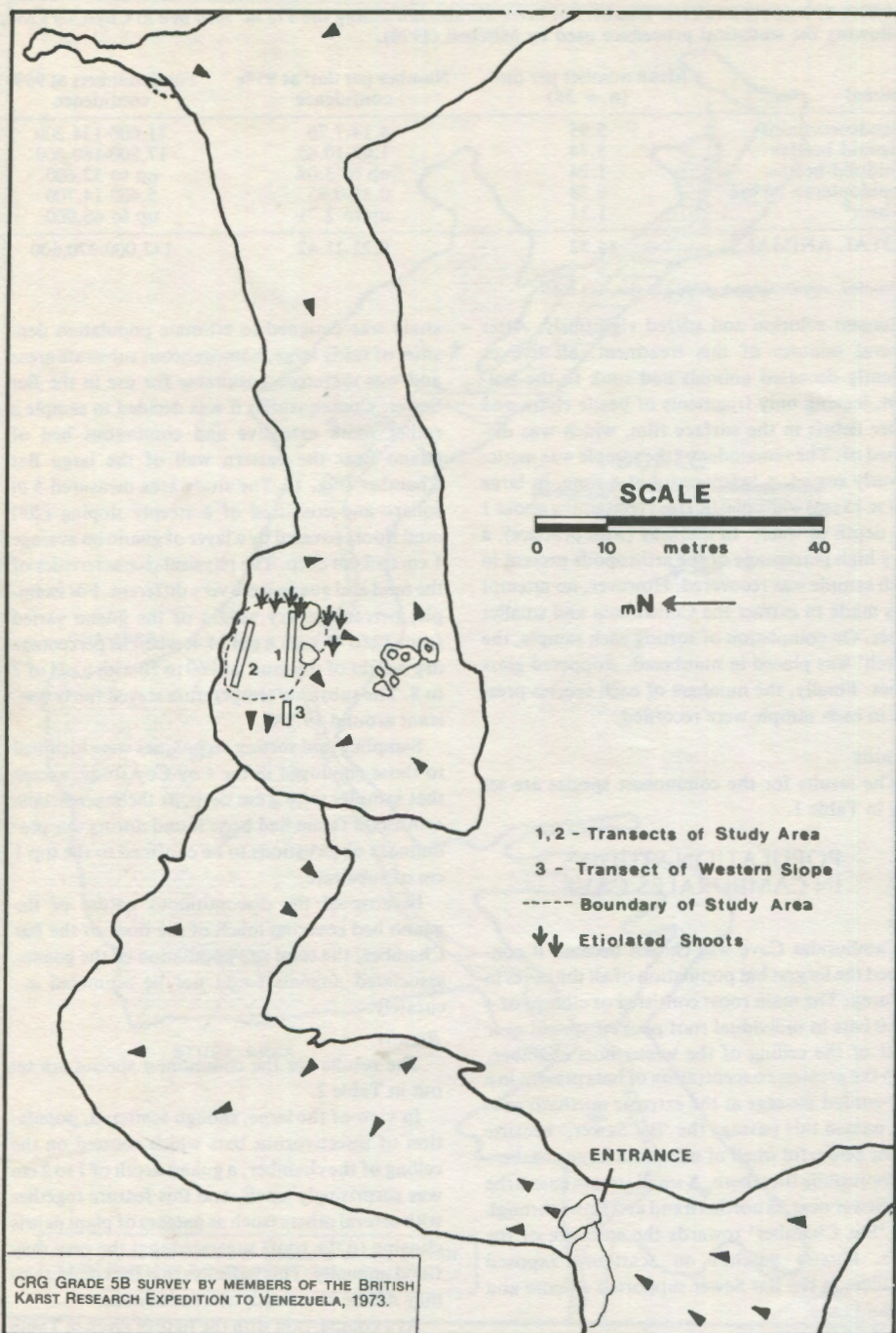


Figure 1. Part of Coy-Coy Cave, showing the location of the study area.

A detailed account of the cave fauna, including systematic lists, has already been published (Chapman, 1980). This paper reports on the quantitative population study.

Our first encounters with the local cave fauna came with visits to Coy-Coy and Trapichito Sink caves. Both are diversely populated. Coy-Coy inhabitants depend for food on seeds dropped by roosting guácharos (oilbirds), while those of Trapichito feed on guano of a mixed colony of insect- and fruit-eating bats. Coy-Coy features a rich predatory fauna consisting almost entirely of

troglophiles and dominated by arachnids. As more caves were visited, this pattern was seen to be a general one. In fact, the only predators which looked like troglobites were an opilionid (*Vima chapmani* Rambla) and an amblypygid (*Speleophrynus tronchonii* Ravelo).

Subterranean streams typically contained gammarids and cycloids, large crabs and fish of several families including synbranchids and bagrids. Conspicuous and widespread terrestrial predators were mygalomorph, ctenid and pholcid spiders, amblypygids, scutigermorph centipedes

and opilionids. The most frequently encountered detritivores (or perhaps polyphages) were gryllid crickets, polydesmid millipedes, campodeid diplurans, oligochaete worms, and terrestrial isopods. In addition, a large number of animals were found associated with bat guano and with seeds dropped by oilbirds. These were: Pselaphid, tenebrionid, leiodid, curculionid, nitidulid and scolytid beetles; moths; springtails; flies; ants; mites; and snails. These animals, in turn, provide food for: Schizomids; histerid, carabid, and staphylinid beetles; pseudoscorpions (particularly chernetids); some Hemiptera; and a number of spiders of various families, in addition to the predators already mentioned.

In the 2 caves which were most closely studied during the course of the expedition, Camburales and Coy-Coy, the final tally of species collected in each cave included more than 20 species of arthropod predators and considerably more than twice this number of macroscopic non-predatory species.

POPULATION STUDIES IN COY-COY CAVE

Site

Coy-Coy was chosen because it contained a breeding population of oilbirds, *Steatornis caripensis* Humboldt, whose habit of regurgitating the seeds of palm fruits (after digesting the oily pericarp) has led, over several hundred years, to an accumulation of rotting seeds and seed remains which in places reaches a thickness of 10 m or more. These seed beds support a large and varied invertebrate fauna and a population of mice (*Heteromys anomalus*). The latter were seen on several occasions and are reputed to occur frequently in Venezuelan caves (C. Naranjo, pers. comm.). Evidence that the cave at one time supported a much larger population of oilbirds comes from the series of ancient seed beds which occur throughout the cave. These beds consist of largely decomposed seeds which support very little life. We estimated the oilbird population of Coy-Coy at around 100 adults. As a comparison, de Bellard Pietri, writing in 1957, estimated a population of 30 birds, while on a more recent visit, members of the Sociedad Venezolana de Espeleología saw only 2 birds. This marked fluctuation in numbers suggests that the population may be migratory.

Oilbirds are nocturnal in their habits, spending the daytime in the caves, emerging at around 1930 to search for food, and finally returning to roost at around 0600. They find their way around in the darkness of the cave by echolocation, using clicks with a frequency between 6 and 10 KHz (compared with frequencies between 30 and 100 KHz used by most insectivorous bats). In Coy-Coy, the nests are built on inaccessible ledges high above the cave floor. This made collection of animals living on and around the nests hazardous, as well as making photography difficult.

After 2 preliminary visits, it was decided that the study area should be a large seed bed below the

innermost oilbird roosting site, occupied by about 20 adult birds, and situated some 120 m from the cave entrance (Fig. 1). Owing to the topography of the cave floor and distance from the entrance, it seemed probable that the community of this seed bed would be considerably less affected by sporadic introduction of 'stray animals' and, consequently, more stable than the community of the main entrance chamber seed bed. The bed consisted of partly decomposed and freshly dropped seeds and measured approximately 15 m long by 10 m wide. Seeds at the damper eastern and south-eastern edges had sprouted, forming sparse clumps of etiolated, leafless shoots up to 60 cm tall. To the west, the bed sloped steeply down at about 40°. This area consisted of wet, fragmented seed debris and no fresh seeds.

The 173 m² study area was bounded by the zone of sprouting seeds to the east, two large boulders to the south, the cave wall to the north and the top of the steep slope to the west. Within this area, the bed was fairly homogeneous with dry matter of the decomposed seeds between 40 percent and 55 percent, a pH of 4, and interstitial temperature remarkably constant at 18.4 to 18.6°C. In contrast, dry weight of the decomposed material forming the western slope rapidly decreased down-slope to around 20 percent with a corresponding drop in interstitial temperature to 18.1°C and a rise in pH to 6.

Method

The method of population density estimation used in the Coy-Coy study was based on that used by Mitchell (1970) in his study of the guano-inhabiting fauna of Fern Cave, Texas.

Firstly, 2 strips each 1 m wide were marked out using 2 tape measures. Then using random number tables to give decimetre coordinates, two samples were taken from each square metre along the two strips. A Plexiglass sampler (see Mitchell, 1970) was used to take substrate samples 10 cm by 10 cm by 4 cm deep. Our preliminary examination had showed that most of the macroscopic arthropod fauna was restricted to the uppermost 2 or 3 cm of the seed bed. To take a sample, the sampler was pushed vertically downwards until the surface of the seed bed was level with a line drawn on one wall. A sliding aluminum bottom was inserted to cut off the sample, which then was removed from the substrate and transferred to a labelled polyethylene bag. The sample depth was necessarily approximate, owing to the large size (up to 4 cm long) of the seeds. A piece of cotton wool saturated with ether was quickly dropped into the bag and a knot tied in the top, sealing the sample. By this method, two separate transects of 9 m and 10 m (see Fig. 1) were sampled on 2 visits to the cave, giving a total of 38 samples. A transect of the western slope was sampled in a similar manner.

Samples were returned to base camp, where they were transferred individually to a fine-mesh nylon bag and washed under running water until all the fine organic sludge had been removed. Each sample was then placed in a jar containing

TABLE 1. Density and total numbers of invertebrates inhabiting the 173 m² seed bed in Coy-Coy Cave, following the statistical procedure used by Mitchell (1970).

Animal	Mean number per dm ² (n = 38)	Number per dm ² at 95% confidence	Total numbers at 95% confidence
Pseudoscorpions	5.95	4.14-7.76	71,600-134,200
Histerid beetles	5.74	1.03-10.45	17,800-180,800
Nitidulid beetles	1.24	up to 3.04	up to 52,600
Lepidopteran larvae	0.58	0.31-0.85	5,400-14,700
Others*	1.31	up to 2.71	up to 46,900
TOTAL ANIMALS	14.82	8.22-21.42	142,000-370,600

*Woodlice, curculionid and scolytid beetles, and ticks.

detergent solution and stirred vigorously. After several minutes of this treatment, all live or recently deceased animals had sunk to the bottom, leaving only fragments of beetle elytra and other debris in the surface film, which was disposed of. The remainder of the sample was meticulously sorted, a teaspoonful at a time, in large (40 × 15 cm) white plastic trays containing about 1 cm depth of water. In this way (with practice), a very high percentage of the arthropods present in each sample was recovered. However, no attempt was made to extract the Collembola and smaller mites. On completion of sorting each sample, the 'catch' was placed in numbered, stoppered glass tubes. Finally, the numbers of each species present in each sample were recorded.

Results

The results for the commonest species are set out in Table 1.

POPULATION STUDIES IN CAMBURALES CAVE

Site

Camburales Cave was chosen because it contained the largest bat population of all the caves in the area. The main roost consisted of clumps of 4 to 10 bats in individual roof pockets spread over most of the ceiling of the westernmost chamber, with the greatest concentration of bats present in a low-roofed passage at the extreme northern end. We named this passage the 'Bat Sewer,' because of the powerful smell of urine and large numbers of coprophile flies there. A small stream enters the Bat Sewer near its northern end and flows through the 'Bat Chamber' towards the entrance of the cave. Guano patches on scattered exposed boulders in the Bat Sewer supported a dense and varied fauna.

Methods

The sampling method used in the Coy-Coy

study was designed to estimate population densities of fairly large, homogeneous substrate areas and was therefore unsuitable for use in the Bat Sewer. Consequently, it was decided to sample a rather more extensive and continuous bed of guano near the eastern wall of the large Bat Chamber (Fig. 1). The study area measured 5 m square and consisted of a steeply sloping (20°) mud floor, covered by a layer of guano on average 1 cm to 2 cm deep. The physical characteristics of the mud and guano were very different. For example, percentage dry weight of the guano varied from 32 to 45 with a pH of 4, whereas percentage dry weight of the mud was 60 to 70 with a pH of 7 to 8. The substrate temperature stayed fairly constant around 19.5°C.

Sampling and sorting techniques were identical to those employed in the Coy-Coy study, except that samples were 2 cm deep, as the macroscopic arthropod fauna had been found during our preliminary observations to be confined to the top 1 cm of substrate.

Because of the discontinuous nature of the guano bed covering much of the floor of the Bat Chamber, the total site population of the guano-associated animals could not be estimated accurately.

Results

The results for the commonest species are set out in Table 2.

In view of the large, though scattered, population of insectivorous bats which roosted on the ceiling of the chamber, a guano depth of 1 to 2 cm was surprisingly small, and this feature together with several others (such as patches of plant debris clinging to the roof) suggested that the cave may flood annually. This indicates that the community may not be in a steady-state condition.

As a comparison with the figures given in Table 2, two quadrat samples taken from small mounds of guano in the Bat Sewer together yielded 380 lepidopteran larvae!

TABLE 2. Density of guano-associated invertebrates inhabiting bat guano in Camburales Cave, following the statistical procedure used by Mitchell (1970).

Animal	Mean number per dm ² (n = 25)	Number per dm ² at 95% confidence
Lepidopteran larvae	1.56	up to 3.20
Leioidid beetles and larvae	0.32	0.13-0.51
Others*	0.44	0.15-0.73
TOTAL ANIMALS	2.32	0.72-3.92

*Crickets, wasps, pseudoscorpions, ants, and a spider.

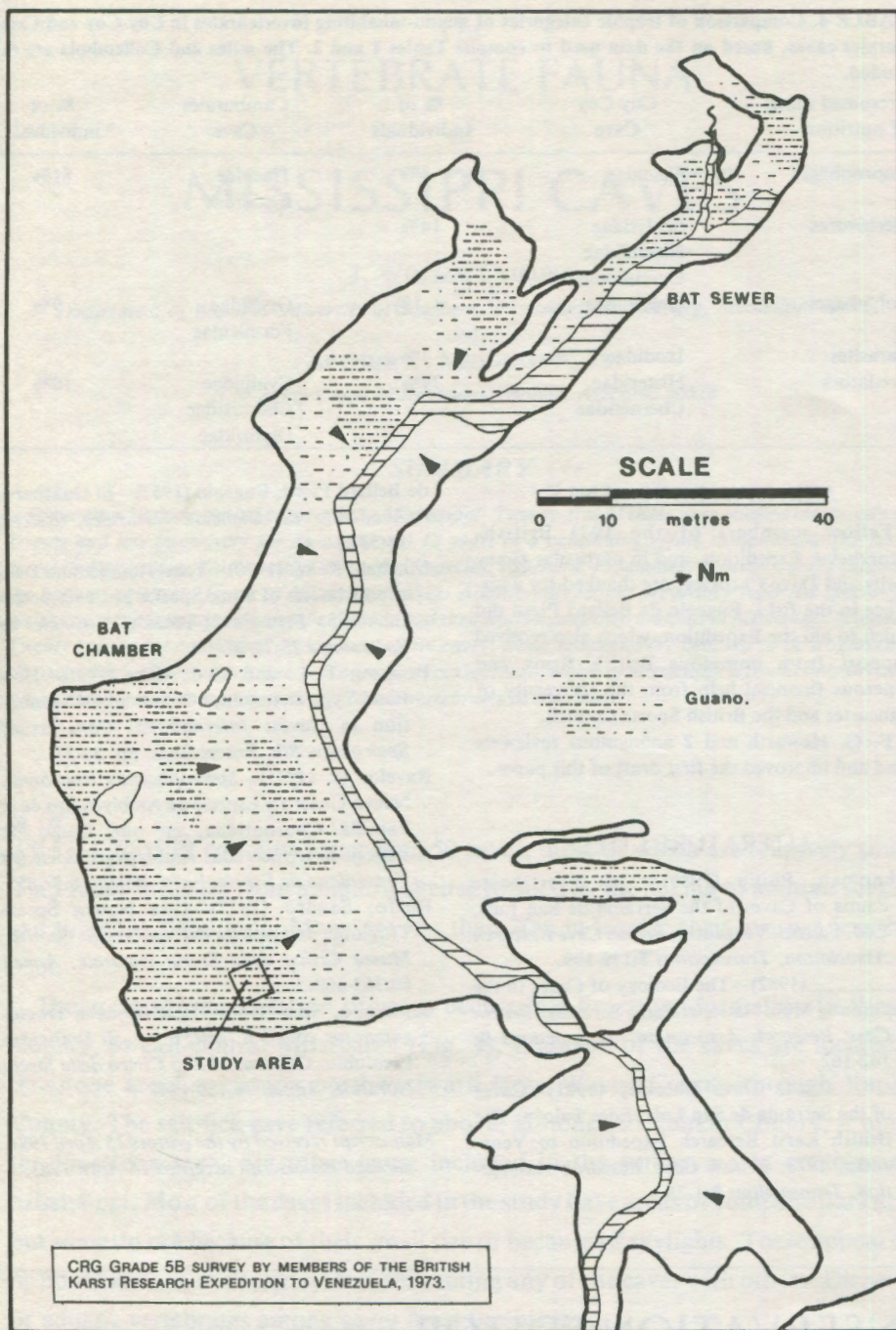


Figure 2. Part of Camburales Cave, showing the location of the study area.

POPULATION STUDIES IN TRAPICHITO SINK CAVE

The final population study dealt with a heavily populated guano bed in Trapichito Sink cave, in order to show the relative abundances of all the arthropod species there.

This cave contains a population of 40 to 50 fruit-eating bats which roost in one closely-packed group in the dark zone, 20 m from the entrance. Below the roost is a wet, evil-smelling mound of guano about 60 cm across, which probably represents less than one year's accumulation

of feces, as the cave is reputed to flood annually. This single small mound supports a large population of arthropods, the most conspicuous of which are Diptera and tiny white mites. The guano-based community in Trapichito, like that studied in Camburales Cave, may not be in a steady-state condition.

Methods

A single quadrat sample 10 cm by 10 cm by 4 cm deep was removed from the apex of the guano patch, transferred to a fine-mesh nylon bag of

known weight, treated with 20 ml ether, and then stored overnight in 30 percent isopropyl alcohol containing several ml of detergent. The sample was then washed carefully until all the fine sediment and excreta had been removed, drained of excess water, and weighed. After thorough mixing, a sub-sample of one tenth by weight was transferred to another container and carefully sorted, a small amount at a time, in large white plastic trays. By this method, a very high percentage of all the macroscopic arthropods present in the subsample were recovered.

Results

Results are shown in Table 3.

TABLE 3. Numbers of invertebrates recovered from a 0.1 dm² subsample of bat guano from Trapichito Sink Cave.

Animal group	Number
Trombidiform mites	42
Small white mites	220
Other mites	21
Ticks	13
Apterygota*	59
Beetle larvae	18
Dipteran larvae	38
Dipteran pupae	33
Oligochaetes	11
Other†	5
Total	460

*Mostly Collembola.

†2 beetle larvae, 1 staphylinid beetle, 1 juvenile spider, and 1 very small dipteran.

DISCUSSION

When the study area faunas of Camburales and Coy-Coy caves are compared (Table 4), several striking differences emerge. Coprophages make up 81 percent of the total of animals sampled on the guano bed in Camburales, but only 4 percent of the sampled seedbed fauna in Coy-Coy. This difference is undoubtedly due to the very different nature of the substrates. Whereas energy input into Camburales is primarily in the form of bat feces, fecal material makes up only a small part of the input into Coy-Coy Cave. In the latter, most energy input is in the form of protein- and carbohydrate-rich seeds, and a smaller quantity of oily pericarp material. Consequently, coprophages in Coy-Coy are outnumbered by the detritivores and herbivores.

Because Table 4 does not include mites and Collembola in its lists of detritivores and herbivores, a very unbalanced impression is given of the proportion of predators in both caves. The brief study conducted in Trapichito Sink Cave shows that Collembola and mites together comprise 76 percent of the sampled fauna. In view of the peculiar nature of the food base in Coy-Coy, it is probable that Collembola and mites make up an even higher percentage of the total numbers of animals in this cave. There is little doubt that it is Collembola and mites which make up the bulk of the prey of the large predators sampled on the

seed bed, as well as of predators from among their own ranks.

The results of Mitchell's (1970) study of Texas cave guanobia form an interesting comparison with those presented here. Mitchell studied Fern Cave, which contains a densely-packed population of migratory Mexican freetail bats, *Tadarida brasiliensis mexicana*, which shower the ground below their roost with a rain of feces and urine. Of the invertebrates which he sampled, by far the most numerous were pseudoscorpions and fleas (Collembola and mites were not counted). Pseudoscorpions were present in densities up to 335 per dm² sample and fleas up to 426 per dm². The mean numbers per dm² were 135.85 for the former and 111.31 for the latter.

These figures are in marked contrast to those obtained in Coy-Coy and Camburales, where the highest recorded densities per dm² sample were 87 histider beetles (mean of 5.74) in Coy-Coy and 20 lepidopteran larvae (mean of 1.56) in Camburales. The sampled community in Camburales Cave may be disrupted or largely destroyed annually by floods, and it appears to subsist on a relatively meagre supply of guano from the small, well-spaced groups of roosting bats. The rate of seed deposition in Coy-Coy Cave is probably also small, as the oilbird population has a low density. Differences in numbers of individuals sampled by Mitchell in Fern Cave and by myself in Camburales Cave and Coy-Coy Cave may therefore be due mainly to differences in the rates of energy input.

Not only population density, but also the species composition of a guano-associated fauna may be affected by the rate of deposition of guano. Recent work by Poulson and Kane (1981) suggests that energy availability may be the main basis for species specialization to food type. My own work in caves in Sarawak (Chapman, 1982) suggests that large guano accumulations and scattered feces of cave swiftlets each may support a distinctly different community. The very different rates of guano deposition between Mitchell's study site and Camburales Cave may be in part responsible for the very different compositions of their respective faunas.

TABLE 4. Comparison of trophic categories of guano-inhabiting invertebrates in Coy-Coy and Camburales caves, based on the data used to compile Tables 1 and 2. The mites and Collembola are excluded.

Presumed mode of nutrition	Coy-Coy Cave	% of individuals	Camburales Cave	% of individuals
Coprophages	Tineidae	4%	Tineidae Leiodidae	81%
Herbivores	Scolytidae Nitidulidae Curculionidae	14%		
Polyphages	Oniscoidea	< 1%	Gryllidae Formicidae	9%
Parasites	Ixodidae	3%		
Predators	Histeridae Chernetidae	79%	Cynipidae Chernetidae Dipluridae	10%

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CONSERVATION EDITOR

Allen Kurta came aboard January, 1983 as the *NSS Bulletin* Conservation Editor. A Michigan native (born in 1952), Kurta holds a BS in Zoology from Michigan State University. He taught high school science courses at Berrien Springs, Michigan, from 1975 to 1978. In 1980, he received an MS in Zoology from Michigan State University. He has been enrolled in the PhD biology program at Boston University since 1981 and is a graduate teaching assistant there in Human Anatomy and Human Physiology.

Kurta has published extensively on the natural history and behavior of the Chiroptera. His MS thesis concerned the ecology of bats in southern Lower Michigan. Other papers have discussed bat rabies, sex ratios, sum-

mer activity, flight patterns, distribution, parasites, survival rates, and thermoregulation.

The National Speleological Society awarded Kurta research grants in 1979 and, again, in 1981. He has received other funding from the Society of Sigma Xi, the Theodore Roosevelt Memorial Fund, the American Society of Mammalogists, and Boston University.

Kurta joined the NSS in 1973 and has been actively interested in *The NSS Bulletin* for several years. His broad interest in an environmentally sensitive order of cave fauna makes him especially well qualified to fill the position of Conservation Editor. **JH**

The VERTEBRATE FAUNA of MISSISSIPPI CAVES

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SUMMARY

*Fewer than 50 documented caves exist in Mississippi. Twenty-five of these were studied intensively for 2 years and less intensively for an additional 12 years in a continuing effort to determine the fauna associated with them. This investigation adds 17 species, 16 genera, 15 families, 10 orders, and 2 classes to the known vertebrate fauna of Mississippi caves. Additionally, some previously reported species for which limited information was available have had their known cave distributions in Mississippi extended. Twenty species are considered accidentals within caves, while 12 species are believed to be troglonenes. The only troglophile is the cave salamander, *Eurycea lucifuga*, which in Mississippi is found only in caves. Amphibians were the most commonly found vertebrates in the caves.*

MISSISSIPPI contains fewer than 50 caves, most of which are relatively small. They range in length from a shallow shelter formed by the licking of animals seeking salt to about 390m long. Many are less than 30m in length; their average length is 55m.

The greatest concentration of caves occurs in a limestone formation in Wayne County, in east-central Mississippi (Fig. 1). Eighteen of the caves are located in limestone areas stretching northwestward from Wayne County through Rankin County. The salt-lick cave referred to above, although in Rankin County, is not in the limestone area. Six other caves included in the survey are in northeastern Mississippi. Most of the caves included in the study have areas of complete darkness, but some do not because of their small size or because of skylights. There appears to be no subterranean stream system connecting any of the caves with others. Dispersal of aquatic vertebrates among caves must be epigeal.

The existing list of vertebrate species observed in Mississippi caves is brief. Previous observations have been limited to only 6 caves. Most of these reports were based on a single visit to a cave and usually do not give the date of observation. Consequently, no conclusion can be reached in most cases with respect to casual, seasonal, or permanent occurrence of a particular species in the caves of this state.

Twenty-five of these caves were studied intensively from late March 1973 through July 1975, in an effort to determine the fauna associated with them and to determine ecological and seasonal relationships. Ambient weather conditions, air temperature, and relative humidity were recorded in certain caves during both summer and winter

to determine the seasonal ranges. All species of invertebrates were also recorded. This information was reported by Middleton (1976). Additional investigations have been undertaken since 1975 by Cliburn and by students under his direction.

All caves referred to in this paper have been explored, documented, described, mapped, named, and catalogued by members of The National Speleological Society (Knight, *et al.*, 1974). Their exact locations have been deposited in the Cave Files Committee of the National Speleological Society, but they are located only by county in this paper. Vandals had removed most speleothems from West Quarry Cave No. 1 and West Quarry Cave No. 2 before these caves were destroyed by mining. The habitats of Pitts Cave and Mingo Cave No. 1 have been greatly altered by human presence, vandalism, and pollution. The small population of *Eurycea lucifuga* in the Mingo Caves has been noticeably reduced since 1968 by human activity, including collecting by herpetologists who require dead specimens as proof of a living population.

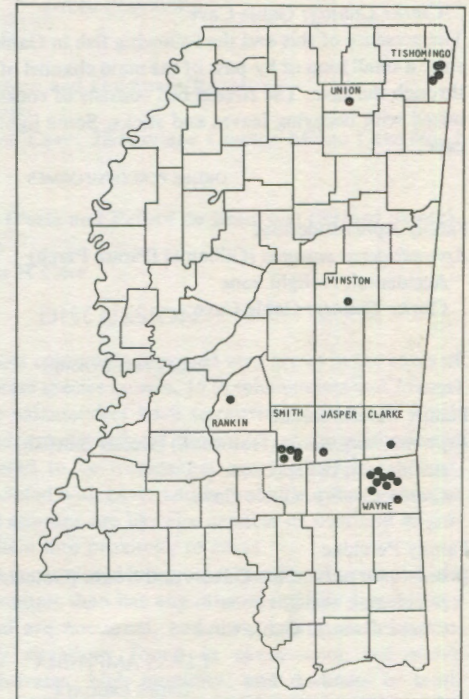


Figure 1. Distribution map of Mississippi caves.

ANNOTATED LIST OF VERTEBRATE CAVE FAUNA OF MISSISSIPPI

This list contains both new and previously published records from Mississippi caves. Pertinent comments on some species are included, and references to prior literature records are made. The listed species are classified as troglonenes, troglonenes, or accidentals, using the definitions of Barr (1968).

PHYLUM CHORDATA
CLASS OSTEICHTHYES
ORDER CYPRINIFORMES

Family Cyprinidae

Notemigonus crysoleucas (Mitchill) (Golden Shiner)

Accidental; twilight zone

Tishomingo County: Mingo Cave No. 1

The presence of this fish in a cave with no epigeal connection (even during floods) with a surface water system suggests that a subterranean connection joins this cave with a stream 0.5 km distant. However, no additional fish have been observed in this cave despite more than 100 examinations over a 15 year period. This negative result indicates strongly that no such connection exists. The aquatic habitat of Mingo Cave No. 1 consists of a single pool with a sloping mud bottom. Water depth increases gradually to several meters. There is no current.

Semotilus atromaculatus (Mitchill) (Creek Chub)

Accidental; twilight zone

Wayne County: Indian Cave

A shallow stream tributary to Buckatunna Creek flows through this cave over a sandy bottom.

Family Ictaluridae

Ictalurus natalis (Lesueur) (Yellow Bullhead)

Accidental; twilight zone

Clarke County: Gable Cave

The presence of this and the following fish in Gable Cave is to be expected, since a small loop or by-pass of the main channel of an epigeal stream flows through the cave. The stream bed consists of rocks, gravel, and sand intermixed with decaying leaves and sticks. Some light reaches all parts of the cave.

ORDER PERCOPSIFORMES

Family Aphredoderidae

Aphredoderus sayanus (Gilliams) (Pirate Perch)

Accidental; twilight zone

Clarke County: Gable Cave

ORDER PERCIFORMES

Family Centrarchidae

Lepomis marginatus (Holbrook) (Dollar Sunfish)

Accidental; twilight zone

Clarke County: Gable Cave

Family Percidae

Etheostoma parvipinne Gilbert and Swain (Goldstripe Darter)

Accidental; twilight zone

Clarke County: Gable Cave

CLASS AMPHIBIA

ORDER CAUDATA

Family Salamandridae

Notophthalmus viridescens louisianensis (Walterstorff) (Central Newt)

Accidental; twilight zone

Tishomingo County: Mingo Cave No. 2

One specimen in the eft stage was found under a rock in a dry part of the twilight zone.

Family Plethodontidae

Desmognathus fuscus conanti Rossman (Spotted Dusky Salamander)

Trogloxene; twilight zone, dark zone

Smith County: Waddell Cave, Waddell Sink Cave; *Tishomingo County*: Charles Poole Cave; *Wayne County*: Eucutta Cave, Pitts Cave, Ramey Pit Cave, Indian Cave

The presence of larvae indicates breeding in Indian Cave. Reported from Pitts Cave by Knight (1972).

Plethodon glutinosus glutinosus (Green) (Slimy Salamander)

Trogloxene; twilight zone, dark zone

Jasper County: Belding's Cave; *Smith County*: Indian Cave, Waddell Cave; *Tishomingo County*: Mingo Cave No. 1, Mingo Cave No. 2, Nunley Cave, Charles Poole Cave; *Wayne County*: Eucutta Cave, Pitts Cave, Ramey Pit Cave; *Winston County*: Nanih Waiya Cave.

Reported from Pitts Cave (Brode 1958, Brode and Gunter 1958, Knight 1972), Eucutta Cave (= Carter's Cave) by Brode (1958), and Mingo Cave No. 1 (Woods and Wake 1968).

Gyrinophilus porphyriticus porphyriticus (Green) (Northern Spring Salamander)

Trogloxene; twilight zone

Tishomingo County: Mingo Cave No. 1, Mingo Cave No. 2

Reported from Mingo Cave No. 1 by Woods and Wake (1968).

Pseudotriton ruber vioscai Bishop (Southern Red Salamander)

Trogloxene; twilight zone

Jasper County: Belding's Cave; *Tishomingo County*: Charles Poole Cave

Reported from Pitts Cave and Eucutta Cave (= Carter's Cave) by Brode (1958).

Eurycea longicauda guttolineata (Holbrook) (Three-Lined Salamander)

Trogloxene; twilight zone, dark zone

Clarke County: Gable Cave; *Jasper County*: Belding's Cave; *Smith County*: Craft's Cave, Indian Cave, Waddell Cave; *Wayne County*: Eucutta Cave, Indian Cave, Lamar Graham Cave, Little H Cave, Pitts Cave, Ramey Pit Cave, Triple H Cave; *Winston County*: Nanih Waiya Cave

The presence of larvae in the dark zone of Waddell Cave indicates breeding. Reported from Pitts Cave by Brode (1958), Brode and Gunter (1958), and Knight (1972); and from Eucutta Cave (= Carter's Cave) by Brode (1958).

Eurycea bislineata cirrigera (Green) (Southern Two-Lined Salamander)

Trogloxene; twilight zone, dark zone

Clarke County: Gable Cave; *Smith County*: Craft's Cave; *Wayne County*: Eucutta Cave, Indian Cave, Pitts Cave, Ramey Pit Cave

Knight (1972) reported this salamander from Pitts Cave.

Eurycea lucifuga Rafinesque (Cave Salamander)

Troglophile; twilight zone, dark zone

Tishomingo County: Mingo Cave No. 1, Mingo Cave No. 2

Reported from Mingo Cave No. 1 by Woods and Wake (1968). The Mingo Caves are the only known Mississippi localities for this species.

ORDER ANURA

Family Microhylidae

Gastrophryne carolinensis carolinensis Holbrook (Eastern Narrow-Mouthed Toad)

Accidental; twilight zone

Tishomingo County: Mingo Cave No. 2

Family Bufonidae

Bufo americanus americanus Holbrook (American Toad)

Accidental; twilight zone

Tishomingo County: Mingo Cave No. 1

Family Hylidae

Hyla cinerea cinerea (Schneider) (Green Treefrog)

Accidental; twilight zone

Wayne County: Ramey Pit Cave*Acris gryllus gryllus* (Le Conte) (Southern Cricket Frog)

Accidental; twilight zone

Smith County: Waddell Sink Cave

Family Ranidae

Rana sphenoccephala Cope (= *R. utricularia*, *R. pipiens sphenoccephala*)
(Southern Leopard Frog)

Accidental; twilight zone

Rankin County: The Rock House

Reported also from entrance to Pitts Cave by Brode (1958).

Rana palustris Le Conte (Pickerel Frog)

Trogloxene; twilight zone, dark zone

Smith County: Craft's Cave, Indian Cave, Waddell Cave; *Tishomingo*

County: Mingo Cave No. 1, Mingo Cave No. 2, Charles Poole Cave;

Wayne County: Eucutta Cave, Indian Cave, Pitts Cave, Ramey Pit Cave

Reported from Pitts Cave by Brode (1958), Brode and Gunter (1958), and Brode (1960); and from Eucutta Cave (= Carter's Cave) by Brode (1958).

Rana clamitans clamitans Latreille (Bronze Frog)

Accidental; twilight zone

Clarke County: Gable Cave; *Wayne County*: Eucutta Cave, Indian Cave, Ramey Pit Cave

CLASS REPTILIA

ORDER TESTUDINES

Family Emydidae

Terrapene carolina carolina (Linnaeus) (Eastern Box Turtle)

Accidental; twilight zone

Tishomingo County: Nunley Cave

ORDER SQUAMATA

Suborder Serpentes

Family Colubridae

Diadophis punctatus stictogenys Cope (Mississippi Ringneck Snake)

Accidental; twilight zone

Tishomingo County: Mingo Cave No. 2

Reported from Pitts Cave by Brode (1958).

Elaphe guttata guttata (Linnaeus) (Corn Snake)

Accidental; twilight zone

Reported by Brode (1958) from Pitts Cave. Not seen by us.

CLASS AVES

ORDER PASSERIFORMES

Family Tyrannidae

Sayornis phoebe (Latham) (Eastern Phoebe)

Trogloxene; twilight zone

Jasper County: Belding's Cave; *Tishomingo County*: Mingo Cave No. 1

Nesting and roosting phoebes have been seen in Mingo Cave No. 1 on several occasions.

CLASS MAMMALIA

ORDER MARSUPIALIA

Family Didelphidae

Didelphis marsupialis Linnaeus (Opossum)

Accidental; twilight zone

Smith County: Indian Cave

ORDER CHIROPTERA

Family Vespertilionidae

Pipistrellus subflavus subflavus (F. Cuvier) (Eastern Pipistrelle)

Trogloxene; dark zone

Smith County: Craft's Cave, Waddell Cave; *Wayne County*: Indian

Cave, Lamar Graham Cave, Little H Cave, Pitts Cave, Triple H Cave

Reported from Pitts Cave by Davis (1959).

Myotis lucifugus (Le Conte) (Little Brown Myotis)

Trogloxene

Reported from Pitts Cave by LaVal (1967). Not seen by us.

Myotis austroriparius (Rhoads) (Southeastern Myotis)

Trogloxene

Reported from Pitts Cave by LaVal (1967). Not seen by us.

ORDER LAGOMORPHA

Family Leporidae

Sylvilagus floridanus mallurus (Thomas) (Eastern Cottontail)

Accidental; twilight zone

Tishomingo County: Mingo Cave No. 2

ORDER RODENTIA

Family Sciuridae

Marmota monax monax (Linnaeus) (Woodchuck)

Accidental; twilight zone

Union County: Land of Caves No. 1

Family Cricetidae

Peromyscus leucopus leucopus (Rafinesque) (White-Footed Mouse)

Trogloxene; twilight zone

Tishomingo County: Mingo Cave No. 1, Mingo Cave No. 2; *Wayne*

County: Triple H Cave

ORDER CARNIVORA

Family Procyonidae

Procyon lotor varius Nelson and Goldman (Raccoon)

Accidental; twilight zone

Smith County: Waddell Cave; *Tishomingo County*: Mingo Cave No. 1

Family Mustelidae

Mephitis mephitis nigra (Peale and Palisot de Beauvois) (Striped Skunk)

Accidental; dark zone

Wayne County: Triple H Cave

DISCUSSION

Amphibians are the most commonly observed vertebrates in the caves of Mississippi. Of 34 vertebrate species known, 15 (8 salamanders and 7 frogs) are amphibians. All the salamanders have terrestrial adaptations which allow them to locate and occupy isolated caves. All of the plethodontid salamanders are considered to be troglloxenes except *Eurycea lucifuga*, which is commonly associated with caves and is probably a troglophile, at least in Mississippi. The anurans are likewise capable of overland migrations which may bring them into proximity to caves.

Amphibians have been encountered in a greater number of caves and in a greater variety of cave habitats than has any other vertebrate group. They generally avoid light and are nocturnal, and their habitat or refuge requirements are met by situations found in caves—cool and stable temperatures, damp substrates, high humidity, and darkness or semi-darkness. Some may find at least a supplementary food supply there.

Certain of the plethodontid salamanders apparently are able to spend their entire life cycles in the cave environment, if the food supply is adequate. *Plethodon glutinosus glutinosus* and, apparently, *Eurycea longicauda guttolineata* may breed in caves (Brode and Gunter 1958); Woods and Wake (1968) implied that *Gyrinophilus porphyriticus porphyriticus* and *Eurycea lucifuga* breed in caves.

In the Mississippi climate, a cave habitat probably is necessary only to *Eurycea lucifuga*, because this is the only species that appears to be restricted to caves. *E. lucifuga* is not known from surface habitats in Mississippi and may be a relict of a more widespread Pleistocene distribution, having taken refuge in caves as the surrounding area became warmer and drier.

Reptiles were rarely seen in Mississippi caves. Only two species of snakes have been previously reported (Brode 1958), and only one of these was seen

by us. One turtle probably entered the cave by accident.

Nests occupied by brooding *Sayornis phoebe* were observed in Mingo Cave No. 1 during late May of four different years. Each year's new nest was in a different place in the more brightly illuminated part of the twilight zone of the cave. A Phoebe occupied one of these nests during September, October, and January following the May of initial observation. The nest was located 3 to 4 m above the floor on a slightly overhanging wall facing the entrance.

In May 1981, a nest was located in a crevice in the semi-darkness of this cave. By February 1982, this nest had been destroyed. A Phoebe was seen clinging to the wall in approximately the same position as the nest mentioned in the preceding paragraph, although there was no longer a nest there, either. At this location, the wall was covered by a dense growth of green mosses and ferns which formed a carpet 75 to 100 mm deep.

It is not known how many individual birds were involved in these sightings. Elsewhere in

Table 1. Monthly occurrence of vertebrates in Mississippi caves.

	N	D	J	F	M	A	M	J	J	A	S	O
<i>Notophthalmus viridescens</i>												X
<i>Desmognathus fuscus</i>			X	X			X		X			X
<i>Plethodon glutinosus</i>	X		X		X	X	X		X	X	X	X
<i>Gyrinophilus porphyriticus</i>						X	X					
<i>Pseudotriton ruber</i>									X	X		
<i>Eurycea longicauda</i>			X	X	X	X			X	X		X
<i>Eurycea bislineata</i>			X	X		X	X		X	X		X
<i>Eurycea lucifuga</i>	X		X			X	X		X	X	X	
<i>Gastrophryne carolinensis</i>											X	
<i>Bufo americanus</i>	X											
<i>Hyla cinerea</i>			X									
<i>Acris gryllus</i>			X									
<i>Rana sphenoccephala</i>								X				X
<i>Rana palustris</i>			X	X	X	X	X		X	X	X	X
<i>Rana clamitans</i>		X	X	X			X			X	X	
<i>Terrapene carolina</i>							X		X			
<i>Diadophis punctatus</i>												X
<i>Sayornis phoebe</i>			X	X			X			X		
<i>Didelphis marsupialis</i>									X			
<i>Pipistrellus subflavus</i>		X	X	X	X						X	
<i>Sylvilagus floridanus</i>						X						
<i>Marmota monax</i>							X					
<i>Peromyscus leucopus</i>					X		X					X
<i>Procyon lotor</i>	X		X									
<i>Mephitis mephitis</i>		X										

Table 2. Caves in which vertebrates were observed during this survey, arranged alphabetically by county. Asterisk indicates cave having a dark zone. Two caves in Wayne County, West Quarry No. 1 and West Quarry No. 2, were destroyed by mining during the early part of the investigation and are not included in the table.

	Gable Cave	*Belding's Cave	The Rock House	*Cat's Den Cave	*Craft's Cave	Indian Cave	*Waddell Cave	Waddell Sink Cave	*Mingo Cave No. 1	Mingo Cave No. 2	*Nunley Cave	Charles Poole Cave	*Land of Caves Cave No. 1	*Eucuttia Cave	*Graham Waterfall Cave	Indian Cave	*Lamar Graham Cave	Little H Cave	*Pitts Cave	Ramey Pit Cave	*Stanley Cave	*Triple H Cave	*Nanah Waiya Cave	
<i>Notemigonus crysoleucas</i>									X															
<i>Semotilus atromaculatus</i>	X															X								
<i>Ictalurus natalis</i>	X																							
<i>Aphredoderus sayanus</i>	X																							
<i>Lepomis marginatus</i>	X																							
<i>Etheostoma parvipinne</i>	X																							
<i>Notophthalmus viridescens</i>									X															
<i>Desmognathus fuscus</i>							X	X			X		X		X			X	X				X	
<i>Plethodon glutinosus</i>		X				X	X		X	X	X		X						X					
<i>Gyrinophilus porphyriticus</i>									X	X										X				
<i>Pseudotriton ruber</i>		X										X												
<i>Eurycea longicauda</i>	X	X			X	X	X							X		X	X	X	X				X	
<i>Eurycea bislineata</i>	X				X									X		X			X	X				
<i>Eurycea lucifuga</i>									X	X				X		X			X	X				
<i>Gastrophryne carolinensis</i>										X														
<i>Bufo americanus</i>									X															
<i>Hyla cinerea</i>																				X				
<i>Acris gryllus</i>							X																	
<i>Rana sphenoccephala</i>			X																					
<i>Rana palustris</i>				X	X	X		X	X		X		X		X	X		X	X					
<i>Rana clamitans</i>	X				X	X								X		X			X					X
<i>Terrapene carolina</i>											X													
<i>Diadophis punctatus</i>										X														
<i>Sayornis phoebe</i>		X							X															
<i>Didelphis marsupialis</i>						X																		
<i>Pipistrellus subflavus</i>				X		X									X	X	X	X					X	
<i>Sylvilagus floridanus</i>									X															
<i>Marmota monax</i>													X											
<i>Peromyscus leucopus</i>								X	X												X	X		
<i>Procyon lotor</i>							X		X													X	X	
<i>Mephitis mephitis</i>								X																X

northeastern Mississippi, Phoebes nest under bridges and beneath overhanging cliffs. *Sayornis phoebe* is a permanent resident of certain cave entrances.

Pipistrellus subflavus, which is widely distributed in Mississippi caves, is nocturnal and makes use of dark, protected places, including caves, for resting, breeding, and hibernation. In these respects, it is typical of the cave-inhabiting bats.

Most of the other mammals seem to enter caves only occasionally, but the rodent, *Peromyscus leucopus*, is apparently common in the cave habitat. *P. leucopus*, as well as its feeding and nesting sign, was seen in three caves. Although the species was seen only in March, May, July, and September, the sign indicated its presence in the caves throughout the year. *Peromyscus* occupied deep crevices in the walls and floor of the Mingo Caves, usually near the cave entrance. Permanent occupation of the Mingo Caves was indicated by repeated sightings

over a period of 14 years.

Table 1 indicates the monthly occurrence of vertebrates in Mississippi caves. Caves in which vertebrates were seen are listed in Table 2.

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EDUCATIONAL OPPORTUNITIES IN SPELEOLOGY

The Department of the (NSS) President includes a 'Committee on Educational Opportunities' charged with maintaining a record of educational institutions and individual educators with special interests in speleology. The following list was received on 1 October 1983—just before press time. Please send corrections to the Chairman: **Randy Parson, 301 Scenic Drive, Tunnel Hill, Georgia 30755.**

INSTITUTIONS

ALASKA METHODIST UNIVERSITY ()

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UNIVERSITY OF KENTUCKY ()

Institute of Speleology, Thomas Hunt Morgan School of Biological Sciences, Lexington, Kentucky 40506.

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UNIVERSITY OF MINNESOTA (Calvin Alexander)

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MERAMEC COMMUNITY COLLEGE ()

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Box 100, Old Fort, North Carolina 28762.

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LATE NEWS FLASH

It is rumored that Percy Dougherty will edit the Fall, 1984 NSS Bulletin, to follow Bill Jones' Spring issue on groundwater tracing. Official confirmation has not been forthcoming, however.

JH

INSTRUCTIONS FOR CONTRIBUTORS

The NSS^{to} Bulletin

Scope. *The NSS Bulletin* is an interdisciplinary journal of world-wide distribution. Papers discussing any subject related to caves or karst-lands are welcome. The material presented must be original and of lasting interest. Authors need not be members of The National Speleological Society.

Articles should not exceed 40 manuscript pages, plus necessary illustrations, without prior consent of the Editor. We are especially interested in receiving articles on important new discoveries and techniques, in addition to critical reviews and other definitive studies. Reports on work in progress and presentations of raw data only, are not acceptable.

Style. Use a narrative style of writing. Standard usage is required of all authors, because written language must communicate through time as well as across space. New terms or expressions should be introduced only if needed to express new concepts or to record new percepts.

For general style, refer to papers in the *Bulletin* and to the following handbooks: 'Suggestions to Authors' (U.S. Geological Survey), 'Style Manual for Biological Journals' (American Institute of Biological Sciences, Washington, DC), and 'A Manual of Style' (The University of Chicago Press).

A significant portion of the material in the annual theme issue must appeal to the average caver with an interest in speleology (*e.g.*, cannot exceed the comprehension level of someone with 2 years of college).

Manuscript Preparation. *The NSS Bulletin* is printed in English for the convenience of our largely English-speaking audience. However, manuscripts in any European language may be submitted; if accepted, they will be translated into idiomatic English by the staff at no charge to the authors.

Prospective authors are invited to submit rough drafts and pencil drawings to the appropriate associate editor for comment before preparing formal manuscripts, if they have any question about style or content.

Submit 2 copies of each manuscript, including all illustrations; the second set of illustrations may be facsimiles. Include a self-addressed, stamped envelope for the return of the edited manuscript.

Type only on one side of ordinary white letter paper. Use double spacing. Leave 3 cm margins on all sides. Put the title and the author's(s') name(s) and current mailing address(es) on the first page. If a former institutional address must be included, insert the current address as a footnote. Titles, sub-titles, names, addresses, and section headings should be centered horizontally on separate lines. Capitalize proper nouns, but do not use all capital letters.

Put a brief summary on the second page; this must recapitulate the author's discoveries and conclusions, not merely tell what was done. Begin the introduction on the third page, and continue with the balance of the presentation in logical order. Place the acknowledgements at the end of the paper. Follow the acknowledgements with a list of all references cited in the text, arranged alphabetically by author surname.

Make all text references to the literature by author and date, with specific page numbers following the date where desirable. Give the full titles of all books and journal articles. Spell out all journal names completely, in their original languages, including diacritical marks. State the inclusive page numbers of articles and the total number of pages in books. All persons to whom 'personal communications' are attributed must be named in the bibliography and a

current address provided for each. Consult recent issues of the *Bulletin* for examples.

Give direct quotations from non-English sources in the original languages, with English translations in footnotes.

Assign mathematical equations consecutive numbers in parentheses at the right-hand side of the page. Define in footnotes all unusual symbols.

State all measurements in units of the *Système International*, except in verbatim quotations where the original used other units. Where it is necessary to relate numbers of SI units to sources using other units, place the original units in parentheses following the SI units.

Prepare captions for all illustrations; arrange these in numerical order on one sheet of paper and attach the sheet to the illustrations. Do not place caption material within drawings. The captions will be set in type and added by the printer.

Assign consecutive numbers to the illustrations as they are mentioned in the text; pencil these numbers lightly on the backs of the illustrations. Pencil the author's name on the back of each illustration, also, and indicate which side is the top. Group all illustrations at the end of the manuscript.

Prepare tables in the same way, but number them in a separate series.

Only well-executed drawings and photographs will be considered for publication. Render all line drawings neatly in 'India' ink. The smallest symbols must be large enough to remain at least 2 mm high after reduction by the printer. Typed lettering is not satisfactory. Black-and-white photographs must be sharp, high in contrast, and printed on glossy paper. Color negatives will be converted to black-and-white prints at the author's expense. Color slides and prints are not acceptable, unless they are to be printed in color at the author's expense.

Refereeing. Articles should be sent directly to the appropriate specialist on the Board of Editors (see masthead); papers not clearly falling into any of those categories may be sent to the Editor. All submissions are evaluated by a member of the Board of Editors and are then sent to 2 other specialists, one a speleologist and the other a person having a different perspective on the subject.

All papers are then returned to the author for consideration of the referees' remarks and possible revision. Revised papers are re-submitted to the responsible associate editor, who then forwards them to the Editor with a recommendation for acceptance or rejection. Accepted manuscripts are copy edited by the Editor and returned to the authors once again, for inspection and clarification. **Proofs.** Each submitting author will receive one set of galley proofs; these should be corrected and returned within 2 weeks. Page proofs may be viewed upon request.

Reprints. Reprints may be ordered when corrected galleys are returned to the Editor; a list of charges is included with the proofs. Fifty reprints will be sent to the submitting author free of charge, if requested in advance of publication.

Page Charges. By Act of the Board of Governors of the NSS (#81-277, dated 12.viii.74), a payment of not less than \$25 per printed page will be requested after a paper has been refereed, edited, and sent to the printer. Payment will not be expected from authors whose research was not sponsored or whose budgets do not include money earmarked to subsidize publication.

Summary

(1) Data and/or interpretations must be original; (2) use a narrative style of writing; (3) follow standard English usage; (4) use only SI units of measurement; (5) pay close attention to the quality of photographs and drawings; (6) submit 2 complete copies of the manuscript; and (7) please enclose a SASE.

JH, Rane L. Curl

NOTICE!

The NSS Bulletin will change in frequency from quarterly to semi-annual in 1984. After 1983, one issue each year will consist of a symposium or group of papers on a single theme. The other issue will include contributed papers, commentary, news, and advertising. Editorial responsibilities for these issues were still being discussed at the time these 'Instructions' were set in type.

Potential symposium convenors should write: NSS Executive Vice-President, 1 Cave Avenue, Huntsville, Alabama USA 35810. Other contributors and advertisers please write 'Bulletin Editor' at the same address.

JH

ADVERTISING WANTED

The NSS Bulletin wishes to obtain display advertisements for professional books and journals, laboratory equipment and supplies, field equipment and supplies, field equipment used in research, and similar products. Any individual or agency interested in acting as our agent please contact the Editor.

Beginning in 1984, The NSS Bulletin will be a semi-annual publication (spring and fall). One issue will be reserved for a symposium or other collection of papers on a single theme. The other issue in each year will contain advertising, news, reviews, and editorials, as well as short to moderately long contributed papers. Advertisements, thus, will have one insertion per year.

The potential 'market' for advertisers in The NSS

Bulletin consists of a few hundred employed scientists and science students who are members of the National Speleological Society or subscribers to The NSS Bulletin, plus readers in national and large institutional libraries worldwide. The minimum rate for camera-ready copy will be \$150 per page, plus commissions (proportionately less for fractional pages). Classified ads and display ads prepared in our own art department will be billed at the camera-ready rate, plus labor and materials.

New publications and products will continue to be reviewed once as a service to our readers. Publishers and manufacturers are invited to submit review copies to the Editor. Unsolicited reviews are also acceptable, provided that the reviewer has no personal interest in the publication or product discussed. JH

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