

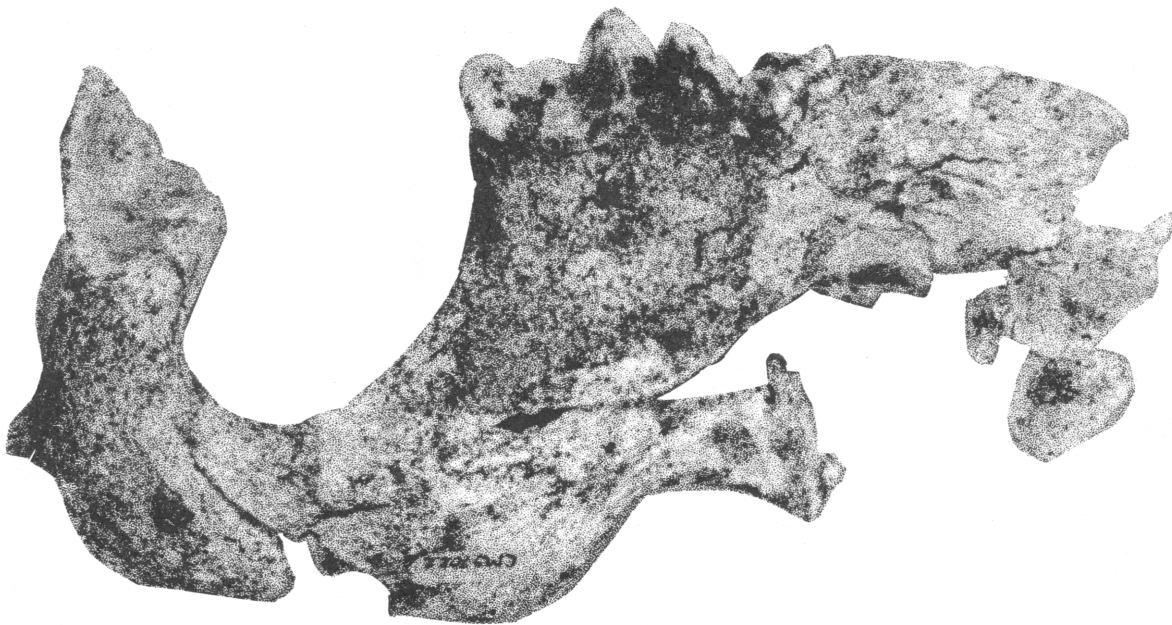
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Cover Photo: Left maxilla from Sabertooth Cat *Smilodon floridanus* (Leidy), Hurricane Cave, Arkansas (Hawksley)

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PREHISTORIC BEAR SIGNS AND BLACK BEAR (*Ursus americanus*) UTILIZATION OF HURRICANE RIVER CAVE, ARKANSAS

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ABSTRACT

INTRODUCTION

DURING OUR EXPLORATION of Hurricane River Cave (Fig. 1) from 1976 through mid-1978, we came to realize that many of the long grooves in the numerous clay fills were bear claw marks. We were fascinated to find them nearly everywhere, including places deep within the cave where we found no evidence that other people had ever been.

Two reactions are commonly elicited when the subject of bear claw marks deep in the cave is introduced. Those are first, the animal must have been lost, and second, there must have been another entrance less distant from the marks than the present one.

Our first realization that neither of these possibilities seemed very likely at Hurricane came when we recognized an error in our assumptions about past use of the cave by people. We had supposed that well worn trails over clay fills in certain parts of the cave were of human origin. However, there were not nearly enough names on the walls in the area of the trails or other evidence of abundant human travel to support this supposition. We realized that the trails must have been made by bears at a time predating human exploration of the cave. We also realized that such well-defined trails could not have been made by only a few lost bears.

We began to examine the trails more closely and learned that they were not separate trails, but parts of a single trail that followed one of the shorter possible routes to the back of the cave from the present entrance. Judging from the depth of the cave below the surface (30 or more meters) it seemed unlikely that any other entrance would have been possible. The trip to the back of the cave requires about ½ hour, even though the first half is over the commercial walkway. It was this extensive penetration of the cave from the present entrance by denning bears that convinced us bears must have been able to find their way in this cave much better than most people would initially assume.

*Interpretation of claw marks, tracks, trails, beds, and bones in Hurricane River Cave led to the realization that the cave was once a regular denning area for black bears, *Ursus americanus*. The existence of a long, continuous trail through a large part of the cave shows that these bears regularly traveled to a denning area 517 m from the entrance. Bones found in a narrow canyon below beds in this area seem to represent animals that died during their winter sleep, not animals lost deep in the cave. A trail leading up a steep clay floor, through a tight fissure, and down a low crawlway indicates that, in addition to great penetration, these bears were able to negotiate relatively difficult caving situations. Claw marks in inaccessible, remnant clay fills near the cave ceiling and others in passages essentially blocked by clay and water indicate that clay fills fluctuated several meters in depth during the time bears used the cave.*

THE LOCALITY

Hurricane River Cave is a commercially operated tour cave in Searcy County, north-central Arkansas, 25 km southeast of Harrison. It is developed beneath the Springfield Plateau in the Ozark province. Local relief varies from 200 m at the Buffalo River six km to the south, to 675 m at Boat Mountain 11 km to the northwest.

The Ozarks of northern Arkansas and southern Missouri today comprise the nation's largest area of pine-free oak-hickory forest. More specifically, the Springfield Plateau is characterized by oak-hickory forest interspersed with cedar glades, upland prairie, and restricted areas containing shortleaf pine (*Pinus echinata*). However, about 5,000 years ago the area was probably cool and arid with desert vegetation. Ten thousand years ago it was probably cool and moist (Foti, 1974).

Most of Hurricane River Cave lies within the St. Joe Formation (Mississippian), but chert characteristic of the overlying Boone Formation is encountered in parts of the upper level.

The cave entrance is at the base of a 38 m bluff. According to communications between Ken Cole (Arkansas Archaeological Survey, 1970-'71) and Jim Schermerhorn, late owner of the cave, archaeological remains at the entrance suggest a periodic occupation by man since the Early Archaic period, 6,000 to 10,000 years ago.

The cave has about 1.8 km of known passage. The north and east branches join shortly beyond the entrance. Access to the east branch is through

a low-passage that is now flooded by a small man made reservoir. In the past, the passage was apparently flooded by water impounded behind a now undermined rimstone dam. The main part of the east branch appears to be a nearly clay-filled remnant of a trunk passage. The stream that flows from the east branch today crosses the trunk in two places where it has removed much of the clay and revealed the trunk's configuration. Generally, however, this stream follows a separate, parallel and smaller passage, mostly crawlway.

The upper level of the north branch appears to have had a phreatic origin. It is today nearly clay filled and is mapped as a broad, low "upper level." Stream downcutting, probably after an episode of fill deposition, formed a narrow canyon, then a low horizontal section, and finally a second canyon. A stream flows slowly through this canyon over a clay bottom. Canopies and redissolved flowstone along the canyon walls suggest that the depth of this clay has varied several meters in the past. The stream depth is generally about 0.6 m, but is shallower or several times deeper in places, depending on bottom configuration and rimstone dams. The stream canyon forms a tightly meandering passage to the back of the cave. The upper canyon is more direct. The two canyons criss-cross in a maze of overhangs and steep ledges. Canyon depths decrease toward the back of the cave and travel there becomes increasingly difficult.

There is no evidence that Indians explored the cave. Charcoal pieces found throughout the north branch might be attributed to the torches used by

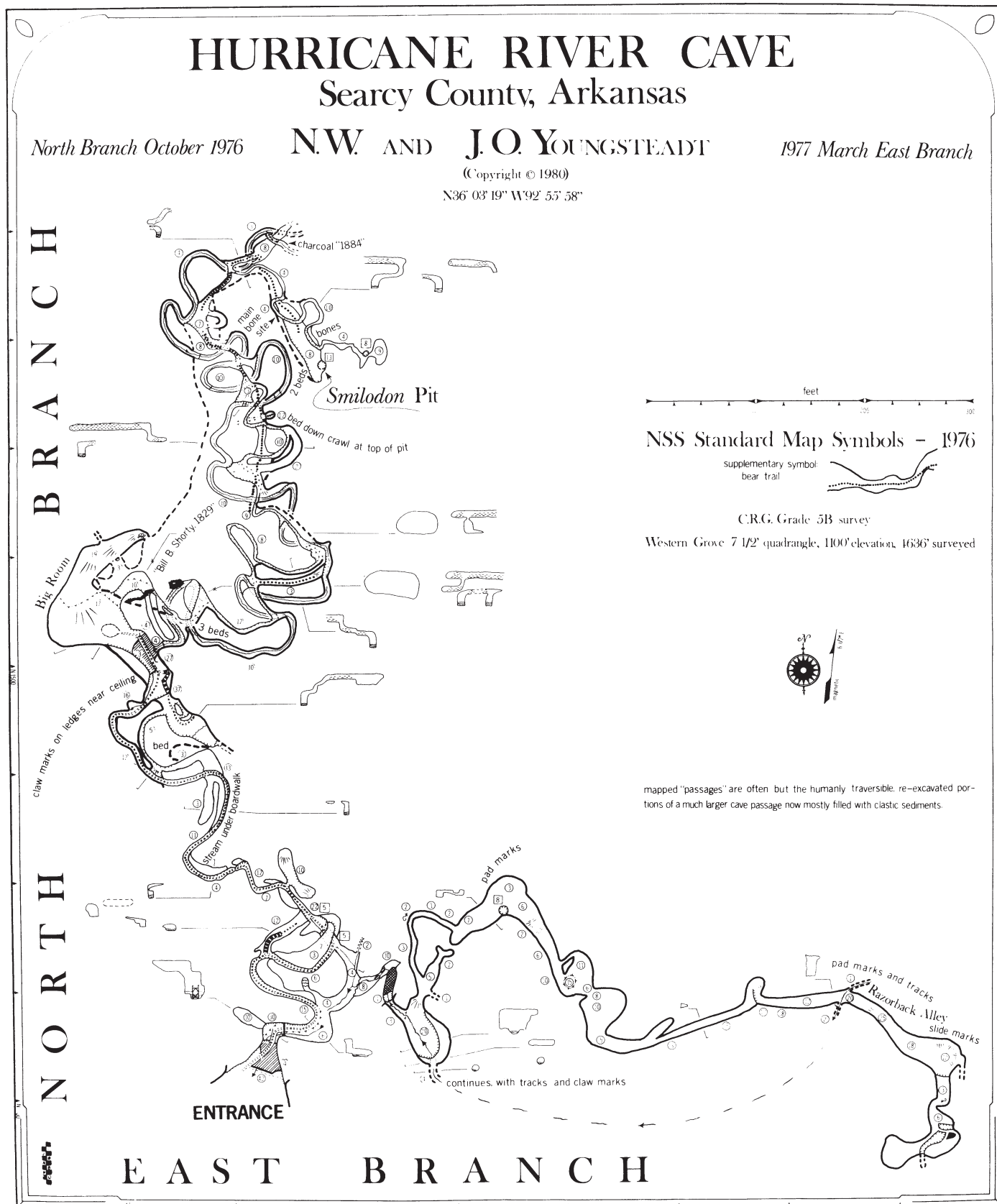


Figure 1. Map of Hurricane River Cave, showing bear trails, bear beds, and bone sites.



Figure 2. Claw marks are the most frequently encountered signs of bears in Hurricane River Cave.

THE BEAR SIGNS

Examples

Claw marks are the most frequently encountered signs of bears in Hurricane River Cave (Fig. 2). The existence of claw marks deep in Ozark caves is fairly common. Tennyson (1976) and Neller (1976) have recently referred to them. Sets of five-claw impressions in Hurricane River Cave span from about 6.3 to 16.5 cm, probably representing cub through adult stages, and occur in clay fills throughout the cave, but are most abundant in areas near bear trails.

Entire footprints are rare, but we have found some examples in the east branch. Two front tracks were about 15 cm across, and two hind tracks, including several centimeters of claw mark, were about 0.3 m long. One small hind track was about 18 cm long. Pad marks without noticeable toe impressions are more common. Tracks are not always obvious and can be easily overlooked. Floors in areas of heavy bear traffic have a lumpy, packed texture and due to repeated use, may contain no distinguishable tracks at all.

Bear trails mark main bear routes through the cave. Where bears have repeatedly traveled, the thin, black, sooty looking deposit that covers the red clay has been worn away, leaving the red clay exposed (Fig. 3). Thus, there are well defined red trails across sooty looking floors. In addition, these trails are often edged by a thicker-than-normal black deposit resembling the ring that forms around the wet part of a leaky ceiling. We assume these sooty black deposits to be a manganese oxide (Hill, 1976).

In Hurricane River Cave, one trail is trampled to the extent that an obvious rut has been formed (Fig. 3). Both black and brown bears often follow well-established trails. These may be single ruts, or two ruts corresponding to the limbs on either side of the body, or a zig zag pattern of depressions resulting from repeatedly placing the feet in exactly the same places on consecutive trips (Murie, 1975). Gerstaecker (1881) stated that Ozark black bears conformed to the latter "stepping stone" pattern when they left a cave to drink.

Bear beds are shallow, rounded depressions scooped in the clay floors (Hawksley, 1965). The beds in Hurricane River Cave are about 1.5 m in diameter and about 0.3 m deep. We have found at least six bear beds in the north branch. That some of these are in the most remote and inaccessible parts of the cave indicates that some bears may have had a particular penchant for seclusion.

Although Gerstaecker (1881) mentioned polished surfaces in crawlways frequented by bears, we have not observed polished areas in Hurricane River Cave.

Discussion of signs

Claw marks are found in places that would require either good climbing ability on the part of the bears, or a difference in the depth of clay fills relative to today's conditions. Both factors may have operated in Hurricane River Cave.

Claw marks in the balcony and near the ceiling of the Big Room require relatively difficult climbs to reach. Other claw marks above an overhang on a vertical wall 8 m above present stream level are virtually inaccessible. Since canopies and redissolved flowstone in the lower levels of the cave indicate a period of former clay filling, and since much clay still remains in the cave, it seems that some of the difficult-to-reach claw marks were likely made by bears walking on a massive clay fill about 5 m deeper than it is now. Since a clay fill of that depth in the cave today would completely block access to the Big Room, it is assumed that bears must have followed an upper level route from the entrance, a route that is now blocked by flowstone most of the way. Such a route may once have been continuous with the trail beyond the Big Room (Fig. 1), which is essentially an upper level trail.

Claw marks and tracks are also found in unlikely places in the east branch. Up "Razor-back Alley," a long stretch of ear-in-the-water belly crawl over thick and mushy clay near the end of the east branch, are small rooms where there are claw marks and tracks. At our farthest point of penetration up this passage, perhaps 90 m, a short segment of clay floored walking passage was reached. A bear track was found there, and what may have been a segment of water washed trail. Beyond this point, the passage again becomes an ear-in-the-water crawl. It seems unlikely that bears would have traveled under

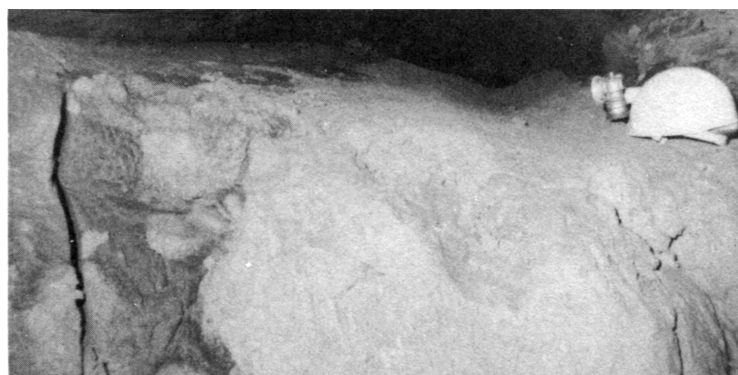


Figure 3. Where bears have repeatedly traveled through Hurricane River Cave, the thin, black, sooty looking deposit that covers the red clay has been worn away, leaving the red clay exposed. This trail is trampled to the extent that an obvious rut has been formed.

such nearly sumped conditions. In this case, we concluded that the passage must now contain more clay than it did when the bears used it.

However, not all claw marks in difficult places can be explained by changes in the cave's configuration. We sat one night below a ceiling fissure recording details for the cave map. One end of the fissure opens to a small dome that can be reached by climbing and chimneying about 3 m up the fissure on a steep clay deposit that fills the fissure below the dome. We had hastily checked the dome for leads on an earlier trip but had dismissed it as an unlikely possibility. As a diversion from mapping, we investigated it again. This time, to our amazement, we noticed claw marks in the clay fill around the top of the dome where a relatively well defined trail led down an unhopeful looking belly crawl. Entering the crawlway proved difficult because it is about 1.2 m above suitable footholds. Chert chunks broke from the clay and bounced down the fissure. We were impressed by the climbing ability the bears must have had, and, in this case, it was evident that former clay fills could not have helped. Investigation revealed an obvious trail leading up the steep clay floor of the fissure we had just climbed.

After 6 m of belly crawl, we were in a small room about 3 m long where we could nearly stand. Another 11 m of belly crawl brought us to a larger room about 6 m by 4.6 m by 3.4 m high. Near its entrance was a bear bed about 1.8 m across. The clay excavated to make the bed was neatly deposited in a conical pile beside the bed.

At first we thought it unlikely that bears would enter low crawlways, but this trail indicates they surely did. The conclusion is supported by Gerstaecker's (1881) account of an Ozark bear hunt in a cave where crawls using toes and elbows were required to reach the bear. Perry's (1970) account of a female black bear (*Ursus americanus americanus*) and three cubs denning under tree roots in a space only about 1 m wide and 0.5 m high also supports the view that bears are not averse to tight quarters.

In *Grizzly Country*, Andy Russell (1967) quotes F.H. Riggall regarding a bear's olfactory sense: "He can take one sniff of you half a mile downwind and tell you the color of your grandmother's wedding dress." A keen sense of smell may have been the key to bear navigation in the dark, and well defined trails may have been the scented highways of generations.

How were such trails selected in the first place? The trail that led from the top of the fissure, for instance, did not follow what seemed to us the more obvious route. A relatively long belly crawl went one way, a more open hands and knees route went the other. The bear trail followed the belly crawl, while the other route appeared to be unused. Perhaps the exploratory bear chanced to use the tighter route and others simply did not vary from this assured way. However, the presence of claw marks almost everywhere in the cave indicates that exploration was not particularly unusual. That a relatively direct route to the

back of the cave was ultimately selected hardly seems attributable to chance. Perhaps this route was established at the time the lower level meanders were clay filled and there were relatively few alternatives.

THE BONES

We found bones 517 m from the entrance in a pit about 4 m deep. This was by the denning area at trail's end near the end of the north branch. Bear signs were abundant there. The bones were partially covered with clay, but their relative positions indicated that they had not been disturbed since the animal died. Lacking experience with bone digs, we contacted Dr. Oscar Hawksley at Central Missouri State University who arranged an excavation. To our astonishment, considering our orientation toward bears and their abundant signs in the cave, the bones were those of a sabertooth cat (*Smilodon floridanus*) (Hawksley, Youngsteadt & Youngsteadt, this issue).

However, we did find other bones in this general area, and they were of bears. They were in a diagonally slanted crawlway portion of the upper canyon near the pit. Excavation yielded some teeth, a few phalanges, and an assemblage of bone fragments. Eventually, elements representing several bears were recovered.

The diagonal canyon where the bones were found opens at the top to the broad, low, upper phreatic level through which the main bear trail leads to a bear bed. The bones were probably those of bears that died in that bed during their winter sleep. We assume that subsequent occupants pushed the bones aside and into the protected canyon below. The canyon was not on the main bear route through the cave, so the bones were not trampled by passing bears. In the upper level in the vicinity of the beds, a thin paste of crushed bone covers the floor.

It appears that the bears had died of natural causes rather than of accidents resulting from travel in a hazardous environment. Another case in which an Ozark bone find is associated with a bear bed is described by Hawksley (1965). In that situation, however, an upper level bed apparently collapsed through the ceiling of a lower level passage where bones of modern and extinct subspecies of black bear and of the extinct Pleistocene short-faced bear (*Arctodus simus*) were found.

Exhaustive taxonomic study of the bear bones from Hurricane River Cave has not yet been undertaken. Large teeth indicate that at least some of them represent the large extinct Pleistocene black bear *Ursus americanus amplidens* (Hawksley, pers. comm.). Whether or not modern black bears (*U. a. americanus*) used the cave historically is uncertain. All bones from Hurricane River Cave are deposited in the Pleistocene vertebrate collection at Central Missouri State University, Warrensburg.

OZARK BEARS

Bear signs in Ozark caves might represent any of the following four species, two of which are now extinct.

Ursus americanus: two subspecies of black bears, the present *U. a. americanus* and the extinct Pleistocene *U. a. amplidens*, seem to have been the most common residents of Ozark caves (Hawksley, et al., 1973; Gerstaecker, 1881; Kurtén, 1976); thus, their signs are those most likely to be encountered. The latter was a larger bear than the present form with much larger teeth, as indicated by the name. The present form was exterminated in the Ozarks during the 1800's, but the species has been reintroduced.

Arctodus simus: short-faced bears were huge bears that became extinct at the end of the Pleistocene. They were much larger than black bears, and their bones have been reported from three Missouri caves (Hawksley, 1965; Hawksley, et al., 1973). Thus, their signs might be encountered in Ozark caves.

Ursus arctos: the brown bears include the European brown bears, the Alaskan brown bears, and the grizzly bears as variants of this single species (Kurtén, 1976). They are not yet known from the Ozarks, but they may have been here. Historically, they are known only from west of the 100th meridian; however, some fossil remains are known from the eastern U.S., one from a cave in Kentucky (Guilday, 1968), so it is possible their signs might be encountered in the Ozarks.

Tremarctos floridanus: the Florida spectacled bear is another extinct Pleistocene species that has not yet been reported from the Ozarks, but since remains of the species have been found in a cave as near as central Tennessee (Guilday and Irving, 1967), the species may once have been here.

Bears are highly variable in size, so track size is of limited value in species identification. We have found reference to the width of front pads or tracks of adult black bears ranging from 8.9 cm to 19 cm (Murie, 1975; Ormond, 1961; Russell, 1967), and comparable measurements for brown bears (*Ursus arctos*) ranging from 10.2 cm to 22.9 cm (Kurtén, 1976; Murie, 1975; Ormond, 1961). Although brown bears have longer front claws than black bears (Murie, 1975), claw marks do not always register in a track, and overlap in track size is great. Furthermore, when contemplating bear signs in a cave, one is confronted with size variation through time and the possibility that one is dealing with an extinct species.

CONSERVATION

Ancient marks in clay fills may provide clues to an interesting story, but they are easily overlooked and destroyed if one is not concerned with them. It seems reasonable that cavers should be on the lookout for such marks and provide them the

protection befitting their nonrenewable nature. Unfortunately, such marks are often found most abundantly in the same places humans find convenient to travel. Some of the bear trails in Hurricane River Cave are found where alternate routes can be taken. We have placed markers at these trails in an attempt to encourage future travelers to use the alternate routes.

ACKNOWLEDGMENTS

Dr. Oscar Hawksley suggested we write this paper and assisted in its synthesis by providing bone identification, map reductions, and insights about bear behavior. His students, Marlin Rice and Len Gilmore, prepared and catalogued some of the bear material, and Marlin Rice assisted in the initial excavation.

Wilbur T. Damron, Instructional Resources Production Area, Central Missouri State University, contributed some of the photo processing.

The late J.H. Schermerhorn, and later the trustees of the J.H. Schermerhorn Trust, permitted our access to the cave for study and exploration.

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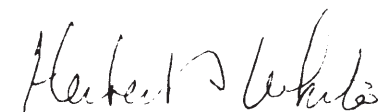
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A SABERTOOTH CAT *Smilodon floridanus* (LEIDY), FROM HURRICANE RIVER CAVE, NORTHWEST ARKANSAS

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and

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ABSTRACT

The skeletal remains of an adult sabertooth cat, Smilodon floridanus (Leidy), were recovered from a pit at the rear of Hurricane River Cave. Searcy County, Arkansas. The only other remains in the pit were those of extinct Black Bear, Ursus americanus cf. amplidens Leidy. Measurements are compared to those of sabertooth specimens from Nashville, Tennessee and Crescent, Oklahoma as well as to the large series from Rancho La Brea. Anomalies involving sacralization and the fusion of tarsal elements are described and figured. Insufficient carbon was present to allow dating of the bones.

INTRODUCTION

ALTHOUGH abundant *Smilodon* remains have been recovered from California and Florida, relatively few have been recorded from the American midlands. The only other records of *Smilodon* sp. from the Ozark Plateaus are from Conard Fissure, Arkansas, 26 km west of the Hurricane River Cave (Brown, 1908) and Crevice Cave, Missouri, 326 km northeast (Oesch, 1969). However, Slaughter (1963) considers the Conard Fissure material to be *S. fatalis* and the single canine from Crevice Cave cannot be determined to species with certainty. Other definite midland sites for *S. floridanus* appear to include only Logan County, Oklahoma (Kitts, 1958), the First American Bank Site in Nashville, Tennessee (Guilday, 1977) and Harrodsburg Crevice, Monroe County, Indiana (Parmalee, *et al.*, 1978).

Location and Environment

Hurricane River Cave is a commercially operated tour cave located on the Springfield Plateau in the Ozarks of northcentral Arkansas in Searcy County, 25 km southeast of Harrison, latitude N 36° 03' 19", longitude W 92° 55' 58". Surface elevation is about 336 m above sea level at the cave entrance, but local relief varies from 200 m at Buffalo River six km to the south, to 675 m at Boat Mountain 11 km to the northwest.

The Ozarks of northern Arkansas and southern Missouri today comprise the nation's largest area of pine-free oak-hickory forest. More specifically, the Springfield Plateau is characterized by oak-hickory forest interspersed with cedar glades, upland prairie, and restricted areas containing shortleaf pine (*Pinus echinata*) (Foti, 1974). However, about 5,000 years ago, the area was

likely cool desert, "characterized by round clumps of bushes which gave rise to prairie mounds" (Beckman, 1969), and 5,000 years before that it was probably cool and moist (Foti, 1974).

Hurricane River Cave has been dissolved out of Mississippian age limestone. Most of the cave lies within the St. Joe Formation, but chert characteristic of the overlying Boone Formation is encountered in parts of the upper level.

The cave entrance is at the base of a 38 m bluff. According to communications between Ken Cole of the Arkansas Archeological Survey (in 1970-71) and Jim Schermerhorn, late owner of the cave, projectile point types recovered from the 2 to 3 m of cultural deposit at the entrance suggest a periodic occupation by man since the Early Archaic, 6,000 to 10,000 years ago.

Description of Site and Fieldwork

The cave (Fig. 1) has about 1.8 km of known passage in north and east branches that join shortly beyond the entrance. The junction is near a low sump passage that is now flooded by a small man-made reservoir. In the past, the sump passage was apparently flooded by water impounded behind a now undermined rimstone dam. The main part of the east branch appears to be a nearly clay filled remnant of a trunk passage. The stream that flows from the east branch today crosses the trunk in two places where it has removed the clay to reveal the trunk's configuration, but generally this stream follows a separate but parallel and smaller passage, mostly crawlway. Tracks and claw marks indicate that bears had visited the east branch.

The *Smilodon* bones were found in the north

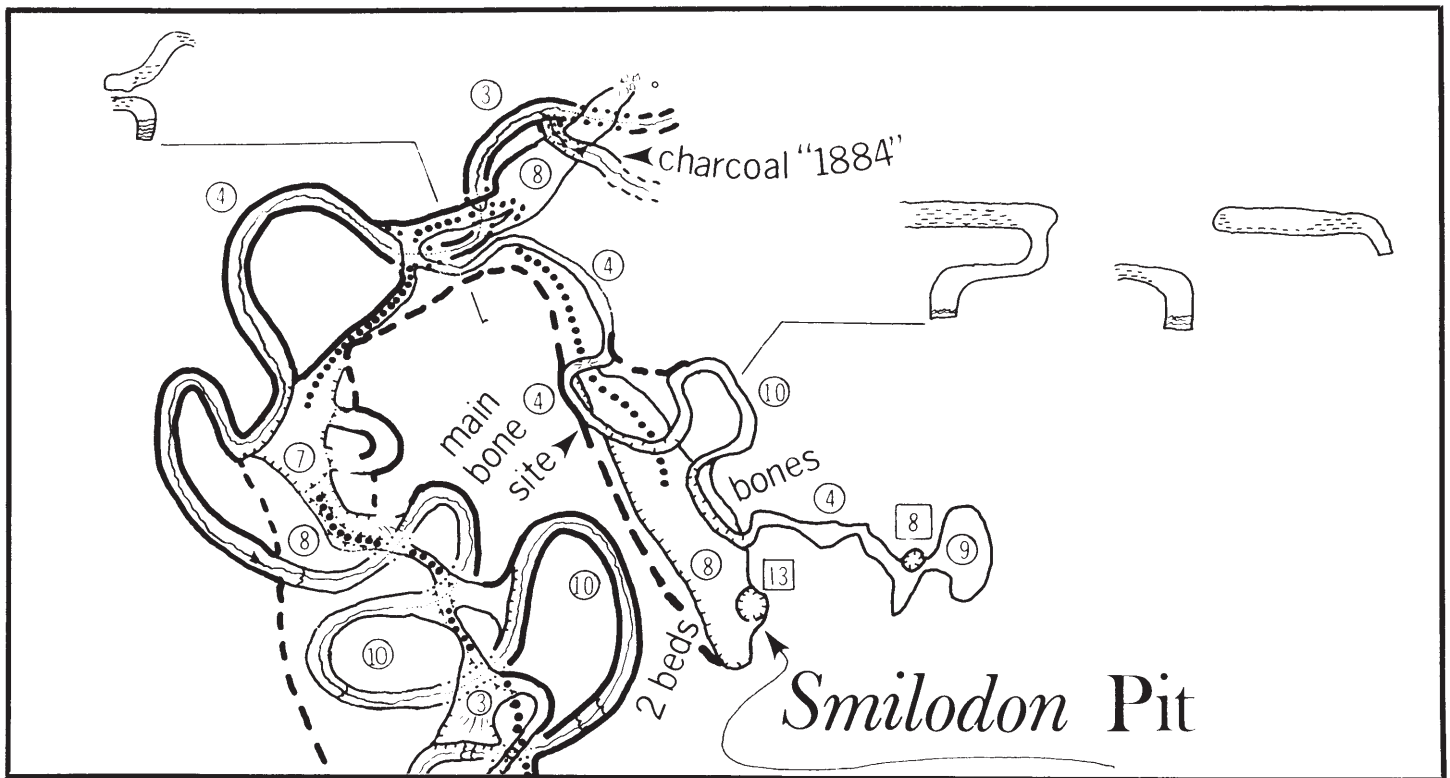


Figure 1. Map of rear portion of Hurricane River Cave with "Smilodon Pit" indicated. See Youngsteadt and Youngsteadt (this issue) for complete map.

branch. This branch appears to have had a phreatic origin that resulted in a broad, low, nearly clay filled upper level. Stream downcutting proceeded to form a narrow canyon, then a low horizontal section, and finally a second, lower, canyon. A stream flows slowly through this lower canyon over a clay bottom. Canopies and redissolved flowstone along the lower canyon walls suggest that the depth of the fill has varied several meters in the past. The stream depth is generally about 0.6 m, but varies depending on bottom configuration and rimstone dams. The stream canyon forms a tightly meandering course to the back of the cave. The upper canyon is more direct. The two canyons form a criss-cross pattern that results in an abundance of overhangs and steep ledges. Canyon depths decrease toward the back of the cave and travel there becomes increasingly difficult.

The bones were found in a 4 m deep pit at the back of the north branch, about 520 m from the entrance by a reasonably direct and likely route. By this route, about half of which is over a level walkway constructed for tours and the rest through the upper canyon, a half hour is required to reach the site if one travels at a brisk rate.

The Youngsteadts discovered the sabertooth bones in the pit in May, 1976, while making a sketch map of the cave. A femur, tibia and innominate (ilium-ischium-pubis) bones were visible at the surface as well as the outline of lumbar vertebrae just below the surface of the clay floor of the pit. Since the pit was undisturbed, they photographed it but did not

enter it. First entry of the pit was made by Hawksley in September, 1976, at which time he removed posterior limb elements and an M_1 to identify the animal. The cat lay on its left side in a semi-articulated position with the pelvic region partly under a ledge and with the vertebral column extending out and away from the wall (Fig. 2). The femur, tibia and innominates were covered by a thin coating (2 to 3 mm) of red clay. The vertebrae were more heavily coated; no other elements were visible at the surface. The matrix, which extended well below the lowest recovered elements of the animal, was primarily a red, unctuous clay with occasional small pieces of limestone and chert in it. There was no heavy breakdown material in the pit which might have damaged the bones but the more deeply buried anterior elements, including the skull, were much less intact. Portions of some bones had become so soft and friable (almost mushy) that only small fragments could be recovered.

A second trip was required to remove most of the rest of the specimen, once its identity was verified, and three other follow-up trips were made by the Youngsteadts. Their final trip, in January, 1978, involved going through the sticky clay matrix of the entire pit floor by hand. It resulted in the recovery of additional missing elements of *Smilodon* as well as a few teeth and other fragments of *Ursus americanus* cf. *amplidens*.

Numerous bears apparently entered this part of the cave and, since bear bones (*U. americanus*) were abundant in the canyon below upper level

bear beds in the vicinity of the pit (Youngsteadt and Youngsteadt, this issue), it seems apparent that the bear material found in the pit fell in, or was accidentally knocked in by other bears, from above. Based on visible remnants of bear trails leading to these beds and on the pattern of the cave relative to surface features, it is concluded that the animals reached this site from the present cave entrance.

Recovery, cleaning, preserving and re-assembling of fragments took about 18 months, but the several hundred bones and usable fragments eventually produced what appears to be the most complete specimen of *Smilodon floridanus* from the midlands to date. One hundred eighty-six identifiable items have been catalogued under No. 702 in the fossil vertebrate collection of Central Missouri State University (CMS).

Carbon dating of the specimen was attempted but unfortunately there was an insufficient amount to provide a C^{14} date.

DESCRIPTION OF THE SPECIMEN

The specimen is fully adult with moderate tooth wear. Nearly all skeletal elements (Fig. 3) are represented except some anterior regions of the vertebral column and the sternum. Dentition is nearly complete. The M^1 was not recovered, although the left maxilla contains an alveolus. The P_3 was apparently lacking since none was recovered and there appears to be no evidence of an alveolus in the mandible. At least one of each

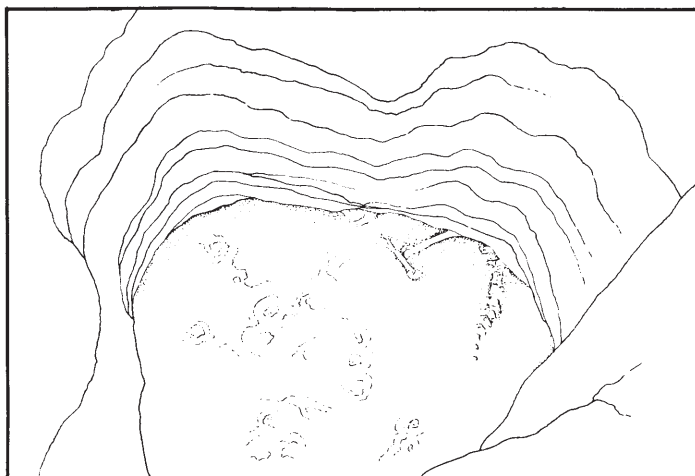


Figure 2. Sketch (from a photograph) of a 4 m deep pit in Hurricane River Cave from which sabertooth skeleton was taken. Position of the animal is indicated by the tibia, femur and vertebrae which were visible at the surface.

of the major limb bones is intact or well restored. Almost all carpal, tarsal and metapodial elements are represented though some metacarpals are missing or incomplete. Although neither the skull nor the mandibles could be completely reconstructed, major portions of the skull (left maxillary and zygomatic arch, premaxillary, frontal and temporal-mastoid-occipital areas) could be reconstructed. The left mandible is also partially reconstructed but remains in three sections which lack major contacts. Examples are shown in figures 4 and 5. A listing of the 186 catalogued elements from the specimen follow:

Cranium: right \bar{C} ; left \bar{C} (partially restored);

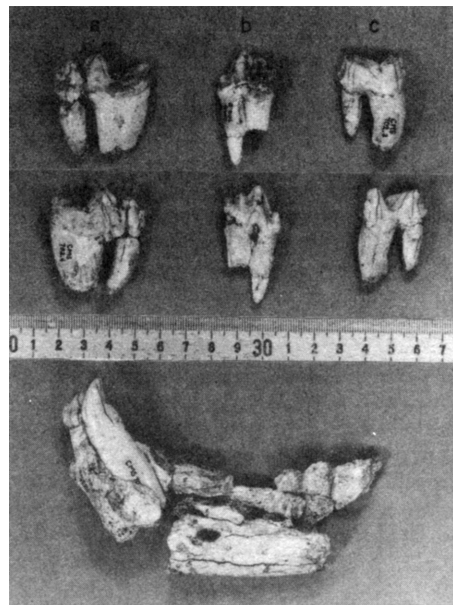


Figure 4. Top: labial views of a) right upper fourth premolar, b) left lower fourth premolar, c) right lower first molar. Center: lingual views of the same teeth. Lower: two fragments of left lower jaw with canine, incisor three and incisor two. Scale in centimeters.

left maxilla with alveolus of \bar{C} , P3, P4, zygomatic arch and mandibular fossa; premaxilla with left I3 and roots of left I2 and I3; right I1, I2 crown, P3 and P4; left I1, and I2 crown; frontal-maxilla portion with partial alveoli of upper canines; fragmental right maxilla with partial alveoli of \bar{C} , P3, and P4; left mastoid process and tympanic bulla; right mandibular fossa and mastoid process; frontal fragment; occipital condyle.

Mandible: left — anterior third with I2, I3 and \bar{C} ; mid third with partial alveoli of P4 and M1; posterior third with coronoid process and condyle; right — lower fragment and a fragment of condyle with coronoid process; left I1, P4 and M1; right \bar{C} , I1, I3 crown and M1.

Vertebral column: atlas fragment; 2 cervical centra; 2 thoracic centra; thirteenth thoracic; twelfth thoracic; first lumbar through sacrum (articulated); first caudal; 6 miscellaneous caudals; 2 miscellaneous vertebral fragments. Numerous small fragments of vertebrae are not catalogued.

Ribs: 8 partial ribs. Numerous fragments not

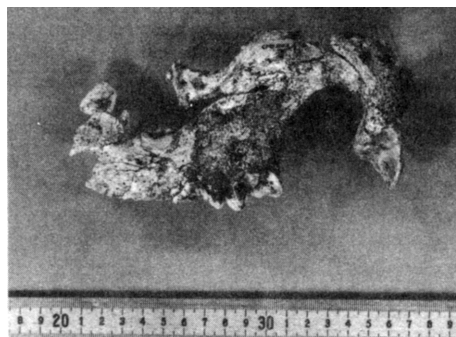


Figure 5. Left maxilla with premolars three and four (labial view zygomatic arch and mandibular fossa). Scale in centimeters.

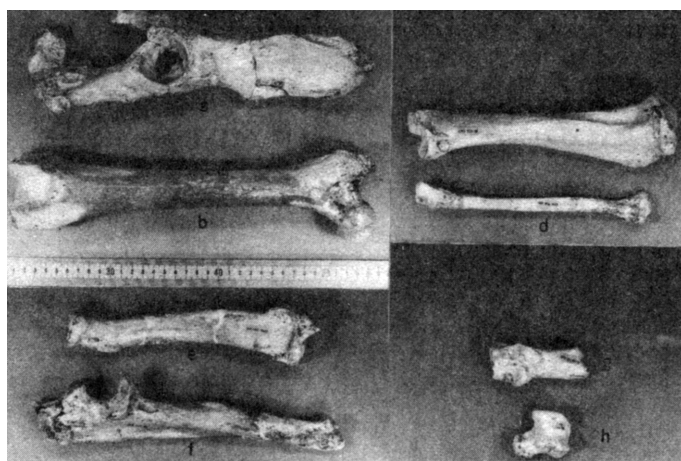


Figure 3. Selected post cranial elements of *Smilodon floridanus* (Leidy) from Hurricane River Cave, Searcy County, Arkansas: a) left innominate, b) right femur, c) right tibia, d) right fibula, e) left radius, f) left ulna, g) right calcaneus, h) right astragalus. Scale in centimeters.

catalogued.

Forelimb: 2 scapular fragments; right humerus, distal third; left humerus, distal part of shaft; 3 fragments, head of humerus; right and left ulnae; right and left radii; right and left scapholunars; right and left pisiforms; left trapezium; right and left trapezoids; right magnum; right and left unciforms; right and left metacarpals I; right and left metacarpals II; left metacarpal III, proximal end of right; left metacarpal IV, proximal end of right; right and left proximal phalanges, digit I.

Hindlimb: innominates; right and left femora; right and left patellae; right and left tibiae; right fibula, distal two-thirds of left; right and left astragali; right and left calcanea; left entocuneiform; right and left mesocuneiforms; right and left ectocuneiforms; right and left cuboids; right and left naviculars; right metatarsal series I-V; left metatarsal series II-V.

Phalanges and miscellaneous: 17 basal phalanges; 13 medial phalanges; 2 terminal phalanges; 16 sesamoids.

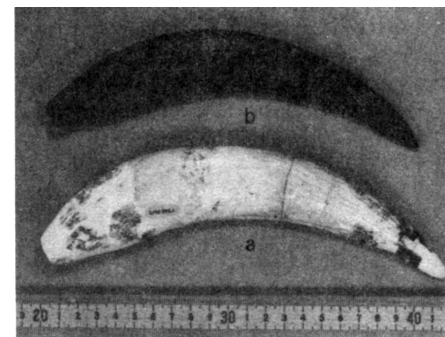


Figure 6. Right upper canine (a) of *Smilodon floridanus* (Leidy) from Hurricane River Cave, Searcy County, Arkansas compared with upper canine (b) of *Smilodon* sp. from Crevice Cave, Perry County, Missouri. Scale in centimeters.

Table 1. Dental and Cranial Measurements (in mm), *Smilodon floridanus* from Hurricane River Cave, Arkansas Compared with Specimens From First American Bank Site, Nashville, Tennessee, Crescent, Oklahoma and Rancho La Brea.

Measurement	Hurricane River Cave		Nashville, Tennessee	Crescent, Oklahoma	Rancho La Brea*		
	Right	Left			\bar{X}	O.R.	N
<i>Upper</i>							
Greatest diameter across occipital condyles	61.6				65.1	57.6 — 72.3	24
Length, anterior end P ³ to posterior end P ⁴	51.5				53.2	50.7 — 63.7	19
Length, diastema posterior C-P ³	15.0†		10.4		16.1	7.8 — 23.6	24
I ¹ , transverse diameter	6.9	7.0			6.7	5.0 — 7.6	20
I ² , transverse diameter	8.8	8.8			8.5	7.6 — 9.7	20
I ³ , transverse diameter	10.9			12.0	11.9	11.0 — 13.0	21
Canine, anteroposterior diameter	42.8		42.7		41.6	36.0 — 46.1	24
Canine, transverse diameter	20.9		19.8		20.6	16.6 — 24.1	24
P ³ , anteroposterior diameter	16.4	16.3		18.5	17.1	15.0 — 19.0	17
P ³ , transverse diameter	8.8	9.0		10.1	9.3	8.4 — 10.6	17
P ⁴ , anteroposterior diameter	39.8†	39.4	40.3	42.3	40.5	37.5 — 46.0	19
P ⁴ , length metacone	16.0	16.0	15.7		14.4	11.5 — 16.9	19
<i>Lower</i>							
Transverse width of condyle	45.0†				47.8	38.7 — 55.9	25
Greatest depth of condyle	18.0†				18.1	15.8 — 20.7	25
I ₁ , transverse diameter	4.9	4.8			4.9	4.4 — 5.6	17
I ₂ , transverse diameter		6.2	6.2		6.8	6.1 — 7.7	19
I ₃ , transverse diameter		8.6	8.2		8.4	7.5 — 9.2	20
Canine, transverse diameter	10.5	10.3	10.5		10.5	9.7 — 12.2	22
Canine, anteroposterior diameter	14.6	14.6	15.7		14.7	13.0 — 16.6	22
P ₄ , anteroposterior diameter		25.1			24.6	22.5 — 27.7	23
P ₄ , transverse diameter		11.9			11.9	10.5 — 14.6	23
M ₁ , anteroposterior diameter	27.0	27.1	29.3		28.7	25.0 — 32.1	25
M ₁ , transverse diameter	14.2	14.2	13.6		14.3	12.4 — 17.6	25
M ₁ , length protoconid	15.8	15.8	15.0		15.3	12.8 — 18.0	23

*Measurements defined and data from Merriam and Stock, 1932

†Approximate (cemented parts involved)

DISCUSSION

Measurements of the dentition afford the best opportunity for comparisons of the Hurricane River specimen with those from Crescent, Oklahoma and Nashville, Tennessee. These are presented in Table 1. As will be noted, all measurements fall within the observed range of specimens from Rancho La Brea given by Merriam and Stock (1932). Although only four measurements are available for the Oklahoma specimen, they are consistently larger than the comparable measurements for the Hurricane River and Nashville specimens. With few exceptions, dental measurements of the Hurricane River and Nashville specimens are strikingly similar.

Although Oesch (1969) did not assign the upper canine from Perry County, Missouri to species, he remarked that the measurements of the tooth fell "within the ranges given by Merriam and Stock (1932) for *Smilodon californicus*" (= *floridanus*). Actually, the anteroposterior dimension is below the minimum observed range given

for Rancho La Brea and the other measurements are close to the minimum. When this Missouri specimen is viewed side by side with the canine from Hurricane River Cave (Fig. 6), it is not only smaller but appears much less robust in form.

The P₄ has the large tubercle on the postero-internal region of the cingulum mentioned by Merriam and Stock (1932) as being present in many cases. The M₁ shows both the small heel on the posterior border of the cingulum and the small but distinctly separated cusp on the anterior border of the paraconid (Fig. 4). Both of these features, which Merriam and Stock indicate are present in nearly all cases at La Brea, appear to be missing in the M₁ from Nashville figured by Guldaway (1977). If the absence of the accessory anterior cuspule is indeed a "late evolutionary innovation" (Guldaway, 1977), then the Hurricane River sabertooth may be older than the specimen from Nashville which has a C¹⁴ date of 9,410 ± 155 years B.P.

Detailed comparisons, in tabular form, of post cranial measurements with those from Rancho La Brea would serve little purpose, but since the Hurricane River specimen provides the most

complete set of measurements for a midwestern specimen to date, the post-cranial measurements are presented in Table 2. Nashville measurements are included where available.

Only 10 of the 132 post cranial measurements fall outside the observed ranges for Rancho La Brea and some of these are only slightly outside. Since they may represent new extremes for the species, they are indicated in the table by asterisks. Only two (anteroposterior diameter of the fibula shaft; length of MT I) are above the upper limits for La Brea. The MT I may be aberrant since in the dorsal view it looks more like the MT I for *Felis atrox* figured in Merriam and Stock (1932).

In spite of the similarity in the size of teeth from Hurricane River Cave and Nashville, comparison of skeletal elements seems to indicate that the latter specimen was slightly larger.

One of the most interesting features of the Hurricane River sabertooth is the occurrence of sacralization similar to that found by Moodie (1930) in five of 1034 sacra from Rancho la Brea which he examined. Moodie describes the phenomenon as "the exaggerated development of the transverse processes of the last lumbar vertebra until they look like parts of the sacrum." Moodie found that in all five examples from La Brea that co-ossification was on the right and that all the anomalous sacra showed a right lateral curvature. The Hurricane River specimen differs in two respects (Fig. 7:a-d). Fusion of the lumbar vertebra and sacrum is not complete, though the articulation is very rough and may have been lightly fused in the center in life. The co-ossification is on the left rather than the right, but there is still a pronounced lateral curvature to the right!

The Hurricane River sabertooth provides another anomaly in the fusion of the ectocuneiform and mesocuneiform (Fig. 7:e and f). Fusion is on the right, only. The left elements appear to be quite normal. Merriam and Stock (1932) mention fusion of the mesocuneiform with the navicular and fusion of various other tarsal and carpal elements but not of ectocuneiform and mesocuneiform.

On first examination, we assumed we had an aberrant unciform but, upon closer examination, determined that figures 86E and 87E for the dorsal views of the unciform in *Felis atrox* and *S. californicus* must be reversed in Merriam and Stock (1932).

Guldaway (1977) makes a suggestion, based on known locations in Tennessee for jaguars (*Panthera onca augusta*) and machairondontine cats, that jaguars may have been restricted to the mountainous areas and the machairodonts to the more western portions of the state by some ecological break that resulted in the differential distribution of preferred prey species. However, the evidence from the Missouri and Arkansas Ozark plateaus does not seem to support this since *Smilodon* sp. has been reported from three locations and *P. o. augusta* is known from at least five locations in the region. Three of the jaguar

Table 2. Post Cranial Measurements (in mm), *Smilodon floridanus* from Hurricane River Cave, Arkansas Compared With Available Measurements of Specimen from First American Bank Site, Nashville, Tennessee.

Measurement	Hurricane		FABS	Measurement	Hurricane		FABS
	River Cave	Left			River Cave	Left	
Vertebral Column				Thickness of shaft at middle			
Twelfth thoracic, length of centrum		37.6		Greatest width of distal end		18.9	55.8
width, posterior epiphysis		43.4		Greatest thickness of distal end		54.2	
depth, posterior epiphysis		28.5		Scapholunar			
Thirteenth thoracic, length of centrum		42.7		Greatest transverse diameter		47.3	54.5
width, posterior epiphysis		42.5		Greatest dorso-palmar length		36.4	40.8
depth, posterior epiphysis		29.1		Proximal-distal diameter		27.8	27.8
First lumbar, length of centrum		45.0		Pisiform			
width, posterior epiphysis		44.8		Greatest length		42.0	
depth, posterior epiphysis		29.3		Long diameter, articulating end		23.7	
Second lumbar, length of centrum		46.8		Trapezium			
width, posterior epiphysis		42.9		Greatest dorso-palmar length		24.2	
depth, posterior epiphysis		30.0		*Greatest proximal-distal diameter		18.2†	
Third lumbar, length of centrum		47.8		Greatest width of proximal surface		19.5	
width, posterior epiphysis		44.6		Trapezoid			
depth, posterior epiphysis		30.4		*Greatest dorso-plantar width		20.8	
Fourth lumbar, length of centrum		49.3		Greatest transverse width		24.3	24.6
width, posterior epiphysis		46.8		Greatest proximal-distal diameter		13.4	13.4
depth, posterior epiphysis		30.6		Magnum			
Fifth lumbar, length of centrum		50.8		Greatest proximal-distal diameter		24.3	
width, posterior epiphysis		46.0†		Unciform			
depth, posterior epiphysis		31.9		Proximal-distal diameter		27.6	
Sixth lumbar, length of centrum		47.8		Dorso-palmar diameter		29.1	
width, posterior epiphysis		48.0		Greatest width of dorsal surface		27.0	
depth, posterior epiphysis		39.6		Metacarpal I			
Seventh lumbar, length of centrum		44.4		Greatest length		35.0	
width, posterior epiphysis		48.7†		Greatest width of proximal end		23.3	
depth, posterior epiphysis		37.8		Metacarpal II			
Sacrum, greatest length		113.0†		Greatest length		84.2	83.3
Sacrum, greatest width, anterior end		94.5		Transverse diameter, proximal end		21.1	
Sacrum, greatest width between				*Dorso-ventral diameter, proximal end		27.3	
anterior zygapophyses		49.0		Transverse diameter of shaft		17.3	18.0
Sacrum, width across post. zygapophyses				Metacarpal III			
of third sacral vertebra		15.8		Greatest length		89.0	93.9
Sacrum, depth of centrum of first				Transverse diameter, proximal end		25.9	26.3
sacral vertebra		25.0		Dorso-ventral diameter, proximal end		24.2	
Humerus				Metacarpal IV			
Least anteroposterior diameter of				Greatest length		87.3	
articulating surface for ulna	27.9			Transverse diameter, proximal end		22.1	21.8
Ulna				*Dorso-ventral diameter, proximal end		22.1	22.1
Greatest length	302.0			Transverse diameter of shaft		15.5	
Greatest transverse width of				Dorso-ventral diameter of shaft		13.5	
greater sigmoid cavity		50.0		Metacarpal V			
Anteroposterior diameter, posterior to				Greatest length		69.9	
top of coronoid process	66.6†	66.2		Transverse diameter, proximal end		21.0	
Anteroposterior diameter of shaft at			34.7	Transverse diameter of shaft		14.7	
proximal end of tendon scar		37.2					
Transverse diameter of shaft at proximal							
end of tendon scar		25.4					
Radius							
Length, along internal border		236.5	241.0				
*Long diameter, proximal end	41.0	41.2	46.9				
*Greatest diameter, taken at right angle							
to long diameter of proximal end	31.6	31.8	34.8				
Width of shaft at middle	31.0	30.4					

(table 2, continued)

		Hurricane		FABS			Hurricane		FABS
		Right	Left	Nashville,			Right	Left	Nashville,
Measurement				Tennessee	Measurement				Tennessee
Innominate					Entocuneiform				
Total length			312.0		Proximal-distal diameter		22.2		
Length of symphysis			101.4		Greatest width		14.2		
Diameter of acetabulum	46.0		45.2		Mesocuneiform				
Long diameter of obturator foramen	73.4				Greatest long diameter	24.0	24.3		
Femur					Width of metatarsal surface	10.4	11.0		
Greatest length	338.0				Ectocuneiform				
Transverse diameter, proximal end	86.2		91.1		Dorso-plantar length	36.6	37.1	39.9	
Antero-posterior diameter of head	40.6	41.0			Proximal-distal diameter	17.4	17.8	15.8	
Transverse diameter of shaft at middle	34.3	34.8			Width across metatarsal facet	25.0	25.3	27.3	
Antero-posterior diameter of shaft					Cuboid				
at middle	31.7	30.2			Proximal-distal diameter	25.7	26.5		
Greatest width of distal end	74.8				Transverse diameter	27.5	28.6		
Antero-posterior diameter of distal end	68.5				Dorso-plantar length	29.9	30.3		
Patella					Navicular				
Proximal-distal diameter	48.0				Dorso-plantar length		40.5		40.1
Transverse diameter	37.8				Transverse diameter		30.8		
Tibia					Rudimentary Metatarsal I				
Greatest length	255.5	256.5	256.0		*Greatest length	23.0			
Transverse diameter of proximal end	76.2	75.0			Metatarsal II				
Transverse diameter, shaft at middle	25.6	26.4			Greatest length	80.2	80.8		
Transverse diameter of distal end	54.1	54.8			*Transverse diameter of proximal end	14.2	14.5		
Antero-posterior diameter, distal end	38.3	38.1			Dorso-ventral diameter, proximal end	28.1	27.8		
Fibula					Metatarsal III				
Greatest length	224.6				Greatest length	91.4	91.9		
Antero-posterior diameter, proximal end	34.0				Transverse diameter of proximal end	23.6	23.8	25.9	
Antero-posterior diameter, distal end	23.0	22.1			Dorso-ventral diameter, proximal end	30.7	31.0		
Transverse diameter of distal end	29.0				Metatarsal IV				
*Antero-posterior diameter of shaft					Greatest length	93.1	93.2		
at middle	13.3				Transverse diameter of proximal end		18.2		
Transverse diameter, shaft at middle	11.8	11.5			Dorso-ventral diameter, proximal end		27.1		
Astragalus					Metatarsal V				
Greatest length	53.0	53.2			Greatest length	76.1	75.7	76.6	
Greatest width	47.8	48.5			Dorso-ventral diameter, proximal end	27.3	27.2		
*Least distance across neck	22.8	23.8							
Greatest diameter of head		29.6							
Calcaneum									
Greatest length	94.3	93.1	93.1						
Greatest width across astragalar facets	42.5	43.0							
Greatest width across cuboid surface	33.3	34.2							

*Measurements which are outside observed ranges for Rancho La Brea (Merriam and Stock, 1932)

†Approximate (cemented parts involved, or slight erosion of surface)

locations were noted by Oesch (1969) when he reported the *Smilodon* canine from Crevice Cave, Perry County, Missouri. One was from Crevice Cave itself, a second from nearby Berome Moore Cave and the third from Bat Cave (erroneously reported as Pulaski Co.) in Shannon County, Missouri. Two other locations are represented by jaguar specimens in the Central Missouri State University collection though they have not been previously reported in the literature. They consist of the head of a humerus (CMS 567, det. J. Guilday) from Ozark Underground Laboratory, Taney County, Missouri and a scapholunar (CMS 560, det. B. Kurtén) from West Cave, Pulaski

County, Missouri. The latter was associated with *Megalonyx jeffersoni* and other extinct forms.

Paleoecological information for northwestern Arkansas is sketchy at best and since the age of the Hurricane River sabertooth cannot be determined, it is impossible to reach specific conclusions about its habitat. Recently, Gonyea (1976a) has compared claw retractile mechanisms and body proportions between modern felids and sabertoothed felids. He concludes that body proportions for *Holophoneus* and *Smilodon* were similar to modern forest felids and suggests that there was habitat compatibility of these cats to "high structured dense forest" but that *Dinictis*

and *Machairodus* were better adapted to occupy open terrain such as "open woodland, meadow". In another paper dealing with adaptive differences in the body proportions of large felids, Gonyea (1976b) indicates that the modern jaguar (*P. onca*) is morphologically adapted as an exclusively forest dweller and is thus found in the same densely structured habitats mentioned for *Smilodon*. He does, however, also state (Gonyea, 1976a) that *Smilodon*, like modern lions (*P. leo*), may have adapted to open habitats by forming prides.

Gonyea's conclusions do not necessarily conflict with Guilday's suggestion, since dense forest

could have existed in any of the Ozark or Tennessee locations, and they seem to be supported by the fact the *P. o. augusta* and *Smilodon* occurred together or in close proximity in Missouri and Arkansas. In view of this, we may indeed be dealing with a time in which, as Guilday (1977) suggests, *Smilodon* was being forced into a losing competition with other large carnivores due to the extinction of the large herbivores which had previously been its prey.

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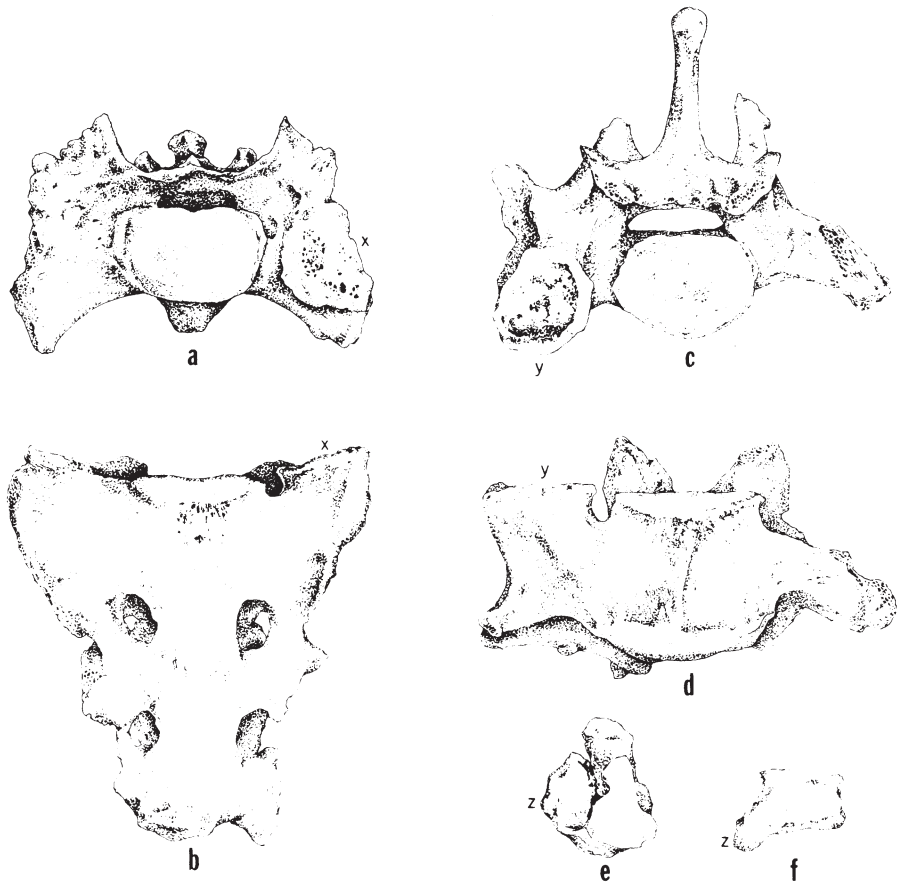


Figure 7. Sacralization and fusion of tarsal elements in *Smilodon floridanus* from Hurricane River Cave: a) sacrum, anterior view, b) sacrum, ventral view, x) area of exaggerated development, c) seventh lumbar vertebra, posterior view, d) seventh lumbar vertebra, ventral view, y) anomalous growth of transverse process; ectocuneiform with fused mesocuneiform (z) shown in distal view (e) and in dorsal view (f). One-half life-sized. Drawings by Phillip A. Schroeder.

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CAVE LOCATION AND EXPLORATION IN SCHOHARIE COUNTY, NEW YORK

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ABSTRACT

Cave location in Schoharie County, New York is often carried out on an inferred basis, because the bedrock is generally mantled by a thick cover of glacial sediment which plugs active insurgences and resurgences and buries abandoned ones. Standard techniques such as dye tracing, flood pulse monitoring and analysis of the bedrock structure allow the delineation of potential cave systems by remote means.

Actual entry and cave exploration involves competing with glacial sediment and water for use of the active insurgences and resurgences. Because of stream derangement by glaciation, influent and effluent passages are usually small and immature with a large water flow (average temperature 6°C). Digging is often required for entry. Exploration of cave conduits is impeded by glacial sediment which blocks the abandoned upper levels and causes water to pond in the lower, active passages. These obstructions also promote overflow-passage formation, but increase the risk of flooding for the explorer. Coarse glacial deposits (cobbles, etc.) permit water flow but strain out cavers. Both cave diving and cave digging have proved successful in extending or discovering caves. Notable examples of cave discovery and extension include McFails Cave, Cage Caverns, Schoharie Caverns, Single X Cave, Caboose Cave and Westfalls Cave.

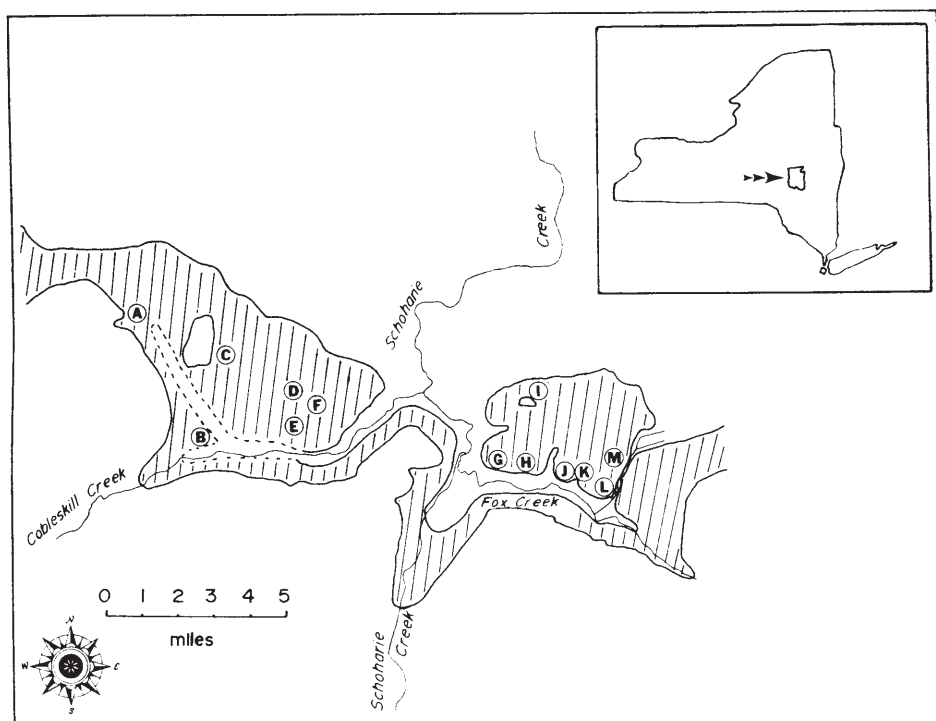


Figure 1. New York State, showing the location of Schoharie County (inset) and the limestone outcrop (striped area) in northern Schoharie County; major streams and cave locations within the limestone area mapped. A — Cave Mistake, B — Doc Shauls Spring, C — McFails Cave, D — Mystery Pits, E — Single X Cave, F — Gage Caverns, G — Westfall Cave, H — Schoharie Caverns and Tufa Cave, I — Spider Cave, J — Caboose Cave, K — , L — , M — .

INTRODUCTION

SCHOHARIE County is located in East-central New York. Cavernous limestone (Upper Silurian-Lower Devonian) crops out in a band across the northern part of the county (Fig. 1). The limestones form a uniform surface, dipping 1 to 2° SSW, the Helderberg Plateau, which is the northerly edge of the Allegheny Plateau. It is basically undeformed, although scattered minor faulting is present. The Helderberg Plateau has formed as a separate unit of the Allegheny Plateau because it is a thin layer of resistant carbonates sandwiched between thick but more easily eroded clastic rocks (Table I). The plateau has been deeply incised by Schoharie Creek and its two main tributaries, Fox Creek and Cobleskill Creek, providing the hydrological environment necessary for large-scale cavern development (Fig. 1). The karst geology and hydrology of Schoharie County has been well studied recently (Kastning, 1975; Baker, 1976; Mylroie, 1977; and, Mylroie and Palmer, 1977).

Schoharie County differs from the Paleozoic limestone Ozark plateau of the Midwest in that it has been glaciated. Similar areas exist in the upper Midwest, but they have not been as thoroughly studied by scientific and sport cavers as have the Northeastern caves. The alpine karst of the American West is also similar to Schoharie County in having been glaciated, but the inaccessibility of the alpine areas, the great vertical relief and the large scale tectonism make accurate comparisons difficult. The Yorkshire, England area is also somewhat similar to New York, especially in terms of caver population pressure and glaciation, although the geologic structure there is more complex. In all these areas, glacial modification should be considered and understood by the cave explorer in order to have significant success in exploration.

The cave exploration history of Schoharie County began in the middle 1800's when Howe Caverns and Gage Caverns were discovered and described. Cooke (1906) and Grabau (1906) studied the area and described many caves and their geology. Cooke's maps were especially

accurate and detailed, and provide valuable data concerning caves later closed or destroyed. In the 1920's, a small cave exploration group headed by Arthur Van Voris began the first large-scale sport caving in Schoharie County, and his manuscript describing these efforts was published by the Mohawk-Hudson Grotto of the NSS (Van Voris, 1970).

Organized caving came to Schoharie County in the years following World War II, with the early grottoes of the then-new National Speleological Society. Perry (1948) discusses these formative years and reviews earlier events and legends. In the 1950's the NRO (Northeastern Regional Organization of the National Speleological Society) was established and provided still better organization for caving efforts in the NE. It concentrated mostly on the prime caving areas of Albany and Schoharie counties, New York and published a series of reports, *The NRO Bulletin*. The NRO also published the "*Schoharie Guide*" (Schweiker, *et al.*, 1958) and *Caves of Schoharie County* (Davis, *et al.*, 1966). However, a more regular publication was needed, and, in 1968, the *New York Caver* was launched. It was renamed after one year the "*Northeastern Caver*" and has provided the basic medium of caver communications in the NRO. With the advent of the 1970's the New York Cave Survey was formed. It has published a series of bulletins on caves and karst areas in the state.

Initial cave discoveries in Schoharie County were, as in most areas, the open and obvious cave entrances. As time progressed, thorough searching of the Plateau turned up the most readily enterable caves. The exploration of known caves went rapidly in easily accessible passages, and improvements in techniques and equipment, such as vertical skills and wetsuits, allowed further sections of caves to be entered. The cold cave water (5 to 8°C), accompanied by the tightness of many of the cave passages, made even short caves a test of endurance. As with the perfection of vertical skills in the Southeastern United States, the perfection of anti-exposure equipment and techniques led to further discoveries in known caves in New York. Even with these improvements, caves "ended" all too often in sumps, breakdown, tight passages, or sediment obstructions, and means had to be devised to successfully bypass these obstructions. Digging was utilized more and more as a means of entering new caves. Through theoretical and empirical work, some basic principles of cave entry and extension were developed, and several notable successes were achieved.

EXPLORATION PROCEDURES

The most basic procedure in exploring caves is locating them. This is often achieved by consulting past literature and interviewing local residents. To be truly comprehensive, there is no substitute for extensive and thorough ridge-walking of the limestone areas. This type of work readily leads to "passive" exploration (the

Table 1. Stratigraphic Column in the Helderberg Plateau area, northern Schoharie County, New York.

Data compiled from Gregg (1973), Kastning (1975), Rickard (1975), Baker (1976) and Mylroie (1977).

System	Group	Rock Unit	Thickness at Howe Cave (ft)
Quaternary		alluvium sand and gravel (outwash) lacustrine sediments till and tillite	20 ± 0-20 0-100 0-100 +
	Hamilton	mainly sandstones and shales	340
		Onondaga Ls.	100
Devonian	Tristates	Schoharie Fm. (limy ss.)	8
		Carlisle Center Sh.	40
		Esopus Sh.	50
		Oriskany Sandstone	6
	Helderberg	Alsen Ls.	8
		Becraft Ls.	20
		New Scotland Fm. (shaly ls.)	—
		Kalkberg Ls.	104
		Coeymans Ls.	54
		Manlius Ls.	36
		Rondout Dol.	37
		Cobleskill Ls.	9
Silurian	Salina	Brayman Sh.	40
Ordovician		Indian Ladder Fm. (sandstone and shales)	100
		Schenectady Fm. (sandstone, graywackes, and shales)	1800- 2000

discovery of open and accessible caves). Careful observation during this process will record possible sites for "dynamic" exploration (digging). Such items as blocked or impassable sinkholes and resurgences or insurgences should be catalogued for later study. In Schoharie County, New York, glaciation resulted in extensive alteration of the karst: glacial sediment plugs sinkholes, insurgences, and resurgences. Many shallow caves and karst features were crushed or quarried away.

The unequal deposition of glacial sediments on the land surface has deranged the surface drainage. Many large, pre-glacial insurgences are blocked with sediment, and their streams deflected to small, immature, post-glacial insurgences. These tight, small and wet input passages often lead to large, mature, well-established cave networks. The problem in Schoharie County lies not only in finding entry points into the caves, but also in demonstrating that the caves exist at all, due to the glacial rearrangement of the landscape.

To successfully enter and explore a cave system in Schoharie County, existing open entrances are first utilized and the accessible cave segments explored and mapped. Additional data from the ridge walk catalogue are plotted on a base map, along with the limits of limestone exposure. Well logs and field measurement by resistivity, gravity and seismic methods help determine the glacial sediment distribution and thickness so that the true limestone contours can be determined (see Fig. 1). Dye tracing from insurgences to resurgences, and water budget studies help to determine probable subsurface flow paths.

The final result is a base map that shows the plot of surface karst features and the hypothesized or actual flow paths of the cave conduits that connect them. From this map, the best areas to dig or dive become apparent. A sinkhole taking water, but located in an area of exceedingly thick glacial drift is not as promising a dig site as a sinkhole taking water where only a few feet of glacial drift covers the limestone. Springs regionally alluviated by large quantities of sediment, like Doc Shauls Spring (Fig. 1), are poor dive sites as compared to Youngs Spring (Fig. 1) which is only locally alluviated.

The effectiveness of digging is maximized by determining, through these studies, those locations most likely to yield accessible cave passage with the least amount of work. Actual digging techniques are fairly standard, although glacial sediment occurs in a wide variety of shapes, sizes, and compositions. To gain entry, bedrock passage may also be artificially enlarged, usually by chiseling or blasting. The glacial events in Schoharie County provided several consistent hinderances. Sediment was introduced into the caves with the ponding and flooding during ice advance, still-stand and retreat. In active passages, where normal stream flow was re-established after glacial withdrawal, much of this sediment was removed. Abandoned upper level passages, however, had no such sediment removal and remained blocked by sediment. In Schoharie

County, it is a general rule (with some exceptions) that abandoned upper levels are inaccessible due to sediment obstruction. Excellent examples exist in Howe Caverns, McFails Cave, Secret Caverns, Gage Caverns and Caboose Cave.

The large sediment loads of the active streams during glaciation often resulted in constricted passage dimensions, or impeded water flow resulting in ponding and/or sumping. Where coarse-grained glacial sediments (such as gravels and cobbles) abound, water can pass through easily but cavers are strained out. These sediment obstructions or other obstructions such as collapse, promote the development of overflow passages, as in Caboose Cave, McFails Cave and Single X Cave. While these passages often allow troublesome obstructions to be bypassed, they indicate increased risk of flooding in lower cave passages during exploration.

Glacial or post-glacial sediments can pond water in the cave passages to varying degrees. Doc Shauls Spring, the resurgence for McFails cave, is a large spring deeply blocked by regional glacial alluviation of Cobleskill Creek forming a sump in the main passage of McFails Cave 4,200 ft to the NE. Obstructions of a more local nature, such as at Single X Cave and Schoharie Caverns, have resulted in the bypassing of the blocked resurgence and the formation of a small, immature tapoff passage drainage water from the main cave to a small, nearby resurgence. Tapoff passage development is a common feature associated with caves around the world. In Schoharie County, abandoned resurgence passages are often sealed by glacial drift, and tapoff passages have to be forced for access to the main cave. Similarly, insurgences, tributary passages and flood overflow passages are often small and tight with much water, but negotiating these segments of cave passage is necessary to gain access to larger, older passage. In many cases, flood overflow passages lead directly to surface flood resurgences, such as at Caboose Cave, and can provide access to an otherwise unenterable cave.

SELECTED EXPLORATIONAL CASE HISTORIES

The following case histories are some examples of cave entry and extension in Schoharie County, New York, made possible in recent years by refinements in exploration techniques.

Cave Entry

Mystery Pits. Mystery Pits is a small pit cave complex northeast of Howe Caverns (Fig. 1). It has a large, open entrance that was discovered in the early 1970's by an extensive and detailed ridge walking operation led by Bill Gregg. Even though Schoharie County is one of the most intensively explored cave areas in the country, and numerous reports exist about the area, Gregg's work (which

located other caves as well) demonstrates the need to actively examine all areas of a limestone outcrop. Mystery Pits is mentioned in particular because it is obvious in the field, but not detectable on maps.

Cave Mistake. Cave Mistake is an immature insurgence cave located northwest of McFails Cave (Fig. 1). The cave is basically a small series of cobble- and debris-choked joints in a 100-ft-long limestone outcrop abutting on a large glacially-constructed swamp. The swamp is a closed basin. Cave Mistake is in the only bedrock outcrop on its entire margin. The swamp drains into the outcrop. In 1977, a group led by Jack Middleton succeeded in gaining access to a series of small, tight, cobble-filled crawlways that eventually led to a large chamber blocked by breakdown. Although an extensive, deeper breakthrough has not been made as yet, Cave Mistake is a classic example of entry into a mature cave system by determined forcing of small, immature, post-glacial inputs that have formed due to glacial rearrangement of surface drainage.

Single X Cave. Single X Cave is a large, mature cave entered by way of a small, immature, tapoff passage (figs. 1 and 2a). The tapoff passage drains the cave and has formed to carry water around an extensive obstruction of glacial debris in the original resurgence. Even though early reports (Gurnee, *et al.*, 1961) said that the present resurgence appeared unenterable, the volume of water discharged indicated that a negotiable passage might exist.

In spring, 1974, a team excavating talus and debris in front of an abandoned dam succeeded in uncovering an opening 6 inches high. This was later forced to reveal 350 ft of 2½ ft diameter tube. A push team negotiated a further 120 ft of flatout belly crawl in the stream to another 350 ft of 2½ ft diameter tube. From this point a narrow shaft lead upward 12 ft to a canyon-and-tube complex that in turn lead upward into the main cave (at a chamber 200 ft long, 75 ft wide and 40 ft high). Later explorers followed a large passage 2000 ft upstream (north) to a sump. This was forced in 1977 by T. Cook and associates to a submerged breakdown obstruction. The downstream continuation of the cave becomes choked with glacial sediment as it approaches its original resurgence.

The main passage in Single X Cave is floored with mud, breakdown and glacial cobbles, and examination of the passage walls shows glacial cobbles cemented to the walls by flowstone up to 20 ft above stream level. This is an indication of the amount of glacial sediment input into the cave during glacial episodes, as well as a measure of the ability of the active cave passages to clear themselves of sediment. The amount of sediment still covering the floor is unknown, as bedrock floor is seen only in the drain and tapoff complex.

Westfalls Cave. Westfalls Cave is an example of the complications that can arise in trying to

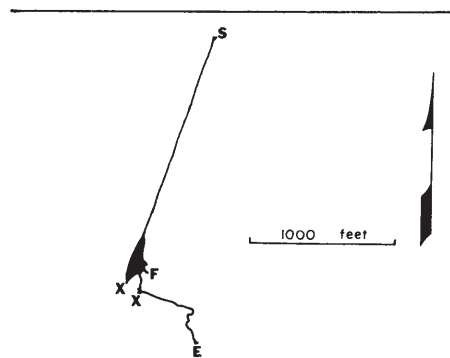
predict and anticipate cave location in a glaciated area. Located a few miles east of Single X Cave (Fig. 1), it was initially believed to be a tapoff drain for a larger, older conduit. The spring was excavated of its blocking talus in the spring and summer of 1975 in a massive effort by three teams, and entry was gained in the fall. The entrance slumped shut before exploration was finished, and it wasn't until the spring of 1977 that exploration and surveying were completed in the readily accessible areas.

The cave was believed to drain a larger passage extending from insurgences 6,000 ft to the north (Mylroie, 1977). Dye tests and water budget studies by Dimbris and Wood (1977) later demonstrated this to be unlikely. The cave is very dendritic, with five separate tributary streams in its 500 ft length. It appears to be post-glacial, developed as a result of glacial stripping of clastic rocks from a narrow band of limestone exposed above the escarpment in which the cave resurgence is developed. The cave receives limited recharge from shales immediately north of the limestone outcrop via a series of small, independent tributaries. The feeder passages unite, in a small, immature trunk passage leading 400 ft to the resurgence.

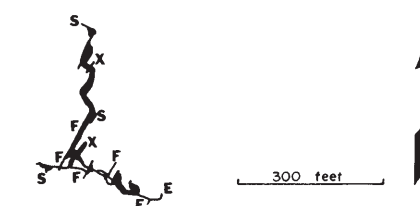
A tremendous amount of excavation went into opening this cave, and while 500 ft of virgin passage were discovered, perhaps better results would have occurred if this effort had been diverted to a more likely prospect. The excavating team was encouraged by the author, who was premature in drawing conclusions about the cave's potential. Glaciation, while it does bury large cave systems, also uncovers new, small limestone exposures by glacial quarrying that result in new, small caves. The dye and water budget studies performed later by Dimbris and Wood (1977) show that this possibility could have been predicted in advance.

Caboose Cave. Caboose Cave is a case of access through flood overflow passages. The cave is 900-ft segment of passage at the downstream end of a large system obtaining its water from areas at least 1 mile away (Dimbris and Wood, 1977) (fig. 1 and 2b). The cave entrance, a small sinkhole at the end of a long dry gulley, was located in fall, 1974, during field work by the author. The sinkhole is located in the Coeymans Limestone (Table 1) and was believed to be too far above the base of the limestone to act as a normal resurgence. It was hypothesized to be a flood-water or overflow resurgence. The sinkhole was cleared of trash and debris and entered a few weeks after its discovery.

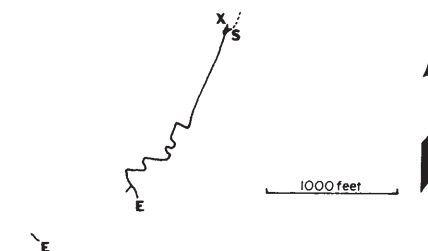
The entrance series of passages are a flood overflow route for a stream in a large master cave located 300 ft back into the hill. It is not clear if the entrance passages formed as an overflow route, or if they represent abandoned upper levels now rejuvenated for this purpose. The cave has a large abundance of glacial sediment, from clay to cobbles. The cobbles act as a strainer that allows water to pass freely but effectively stops cavers.



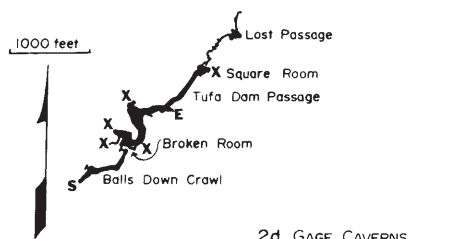
2a. SINGLE X CAVE



2b. CABOOSE CAVE



2c. Tufa CAVE (left), SCHOHARIE CAVERNS (right)



2d. GAGE CAVERNS

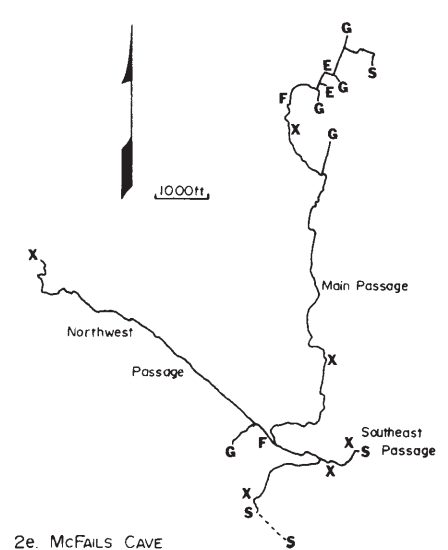
This cobble deposit causes backflooding and a forceful discharge of water out of the entrance at an elevation 37.5 ft above normal stream level. Exploration of the cave has been hampered by its flood potential. The upstream sump was passed in 1976 by Brad Smith, who reported that the cave ended in a breakdown and cobble choke.

Many cave systems have overflow passages and resurgences, but in glaciated areas the normal stream channels and springs often are more susceptible to blocking and restricted water flow, leading to overflow passage formation. In Schoharie County, overflow passages may provide the only available access into a cave system.

Cave Extension

McFails Cave. McFails Cave is the largest cave in Schoharie County, New York as well as the largest in the Northern United States (figs. 1 and 2e). The original entrance, McFails Hole, was open intermittently from the 1850's to the mid 1960's, when bedrock collapse and slumping glacial material sealed the lower shaft. Access to the cave today is gained via a nearby pit, Acks Shack, where a low crawl has been dug out to connect with the main cave. NRO reconnaissance in the late 1950's and early 1960's revealed about 2,000 ft of passage immediately upstream and downstream of the entrance area. Fred Stone, following a breeze through a long, low water-crawl, opened up the main part (over 20,000 additional ft) of the cave. The new section of the cave leads to three major passages: the Northwest Passage, the Southeast Passage, and the Main Passage. The Northwest Passage ends in break-

Figure 2. Stick maps of selected caves. 2a — Single X Cave, 2b — Caboose Cave, 2c — Schoharie Caverns and Tufa Cave, 2d — Gage Caverns, 2e — McFails Cave. Passage features shown by letters: E — entrance, F — flood overflow passage, G — drift-filled resurgence, S — sump, X — sediment-blocked upper level.



2e. McFails CAVE

down and glacial fill, the Southeast and Main passages end in sumps.

The end of the Northwest Passage is an excellent area for cave extension, as the stream seen at its terminus originates over 6,000 feet up-dip to the north (Myloie, 1977). To dig in this area requires transporting workers and equipment through 3¼ mi of cave; 6½ mi round trip, by the shortest route. Even though most of this passage (3 mi) is of walking height, the trip requires much scrambling, with total immersion in one area and nearly total immersion in two other areas. This, combined with the extremely tight entrance shaft and crawl, provides logistic and endurance problems that have prevented a determined attack on the Northwest Passage.

The Main Passage sump was passed by divers in 1968 and 800 ft of air-filled stream passage was located. Attacking this sump was a poor risk, as the rise pool at Doc Shauls Spring is over 30 ft deep and does not reach horizontal passage, yet is at the same elevation as the sump in the Main Passage 4,200 ft NE. The dip of the limestone in this area is 1.5° (135 ft/mi) SSW, and the cave passage would have to migrate stratigraphically upwards if it were to follow a horizontal datum. Since it has been demonstrated that Doc Shauls Spring is in a valley that has been glacially alluviated over 100 ft (Lafleur, 1969), it is probable that the conduit continues down the dip to an older, lower resurgence and has piped upward through the glacial sediment. The 800 ft of passage discovered was due to a change in trend of the passage to the SE, along the strike of the beds. The potential for more air-filled passage in this location does not seem to warrant the vast expenditure in manpower which would be necessary to sustain additional diving operations.

The Southeast Passage also ends in a sump from which a small stream flows towards the Main Passage. Evidence has shown (Egemeier, 1969; Baker, 1976) that floodwater flows southeast from McFails Cave to Howe Caverns. The Southeast Passage may be part of that flow route, and as the flow route is along the strike to the SE, a dive attempt might have significant results.

McFails Cave has resisted significant extension primarily because of the length of cave that must be traversed to reach promising areas, plus exposure and endurance problems.

Schoharie Caverns. Schoharie Caverns is a cave very similar in format to Single X Cave (figs. 1 and 2c). The present entrance was evacuated by bulldozer during an abortive commercialization attempt. Until this opening was made, the cave stream utilized a tapoff drain passage to nearby Tufa Cave (Fig. 2c). This route is impassable, although the stream still uses it in times of flood. Schoharie Caverns trends, 2,000 ft NNE, first as a winding canyon, then as a straight fissure to a terminal sump. Divers penetrated this sump in 1968 (Allen, 1968) and again in 1975 (Cook, personal communication), both times reaching air-filled passage. About 300 ft of passage is known to exist beyond the sump. Neither dive was made in sufficient force to assure a complete

examination, and the description of the passage found in the two dives differs, so the total extent of the accessible passage beyond this sump is unknown. The cave is trending up dip, gaining 135 ft/mi, making it unlikely that a given sump (a horizontal water surface) can continue for any great distance. The water for the cave is derived from areas at least 5,000 ft north of the upstream sump, so great potential exists here. The dye and water budget studies of Dimbris and Wood (1977) indicate a possible overflow passage to Spider Cave (Fig. 1), 5,000 ft southeast.

The sump in Schoharie Caverns, as opposed to the one in the Main Passage of McFails Cave, is readily accessible and in a geologic situation which will prohibit long, flooded sections of passage as the route is pushed up dip.

Gage Caverns. Gage Caverns (figs. 1 and 2d) is one of the oldest and most traveled caves in Schoharie County. Its historic entrance is a vertical shaft 50 ft deep. The cave is easily accessible from the Square Room to the Broken Room (Fig. 2d), although swimming or a boat is needed to traverse the Tufa Dam Passage. Sometime before 1936, an individual(s) lowered the water in the upstream sump leading north out of the Square Room and, with only 3 in of air space, entered the Lost Passage. Later explorers (Gurnee, *et al.*, 1961) found a bottle with the date 1936 at the end of the Lost Passage. This passage ends almost at the up dip limit of the Helderberg Plateau, so the discovery of further significant passage is not expected.

Downstream, a succession of abandoned upper levels criss-cross over the stream passage. These upper levels are sediment-choked after they get more than a few feet away from the main stream. Sporadic digging had been done in this area before 1975, but without success. In 1975, a group working in a sediment-plugged crawlway leading south out of the Broken Room accidentally poked a choked side crawl and unexpectedly broke into the Balls Down Crawl. The main stream here flows southwest in a low, wide passage 500 ft to a sump (later dived and found to be impassable).

The extension in this case was gained by returning to the water as soon as possible. The main stream traveled under the Broken Room through breakdown, and it could be seen and heard in places. A more direct route through this breakdown would have led to the passage continuation sooner and easier.

The terminal sump is perched 200 ft above resurgence level. It probably will be forced in the future, although digging in the plugged upper levels may be required to bypass this sump and loop back to the main channel downstream.

CONCLUSIONS

The complexities introduced by glaciation in Schoharie County have resulted in the formulation of a few simple rules for entering or

extending caves:

1. When digging, attempt to get to the active or flood-overflow passages, as they are the only ones consistently negotiable for any distance.
2. Attack blocked resurgences when the blockade appears local, like talus at a cliff base, but ignore deeply alluviated springs.
3. Push small passages carrying a fair amount of water, as they are often immature passages bypassing an obstruction in an older, larger cave passage.
4. Determine the height of a sump above the regional water table before diving it. In other cave regions, diving water table sumps may result in access to upper level passages beyond the sump, but this is rare in New York where upper levels are usually sediment-blocked. Perched sumps due to local obstructions (often glacial) are more likely to yield to a dive attempt.

These rules are not rigid, but experience has shown that they will lead to a better success rate than does a guesswork approach. Some of the rules, such as those dealing with regional alluviation and high water volume in small passages have application in most caving areas. The most consistent difference between caves in Schoharie County, New York and those in most other areas in the country is the inaccessibility of abandoned upper levels and abandoned entrances because of inwashed glacial sediments. This forces continued use of active stream ways, often partly choked themselves, with the associated problems of exposure, flooding, wet digs and sump dives. Effective use of surface field work can lead to the location of areas with high probability for cave entry or extension.

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