PHOLEOS

WITTENBERG UNIVERSITY
SPELEOLOGICAL SOCIETY

Volume 5(2) 1985

THE WITTENBERG UNIVERSITY SPELEOLOGICAL SOCIETY

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

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THE WITTENBERG UNIVERSITY SPELEOLOGICAL SOCIETY NEWSLETTER

Volume 5, Number 2 May, 1985

GROTTO ADDRESS

c/o H.H. Hobbs III
Department of Biology
P.O. Box 720

Wittenberg University
Springfield, Ohio 45501
(513) 327-7029

SUBSCRIPTION RATE

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EXCHANGES
Exchanges with other grottos and caving groups are encouraged. Please mail to Grotto address.

MEETINGS

Wedensday evening, 7:00 p.m., Room 206, Science Building, Wittenberg University Springfield, Ohio.

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Springfield, Ohio 45504

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John G. Fray
209 Keller Hall
Springfield, Ohio 45504

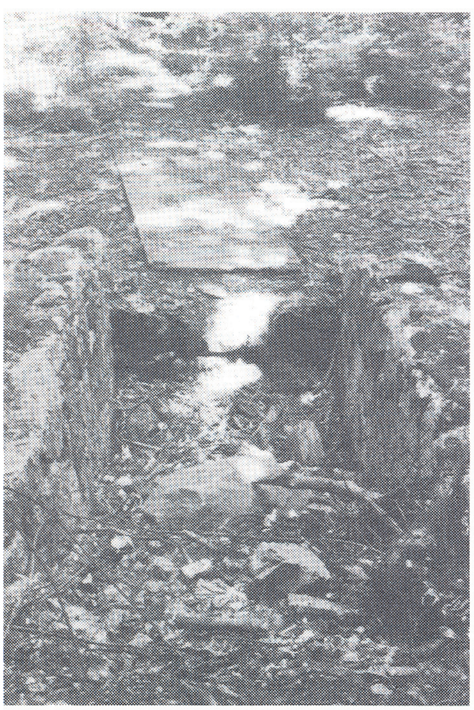
FRONT COVER: Lost Creek Cave (or Dodson Cave) White County, Tenn. Photo by H.H. Hobbs.

Editor's Note

Greetings cavers and welcome to another issue of Pholeos. Now that I have succeeded in sounding like a game show host, on to business. As you may have already noticed, this issue does not contain the write-up on the infamous Freelands Cave System as was promised in the last issue. It seems that our intrepid members have not given up on a small passage and hope to push it to it's logical (?) end at a surface sinkhole. Wish them luck. Old members: as of last reports, the club will be well represented at the NSS Convention this coming June. T-shirts and copies of Pholeos will be on sale. See you there!

Another project in the works is the much awaited Bat Cave. As of last reports, a sizable amount of survey work will have to be redone. A ten meter error in a closure is no small thing! Anyone wishing to help rectify this problem this summer should contact our grotto advisor, Dr. H. H. Hobbs.

One last comment: The drive for cave protection legislation continues on the state and national levels. Please write your Congressmen, Senators, and state representatives in support of these measures. The picture below of the entrance to Mammoth Cave of Ohio is graphic evidence of the necessity of these measures.



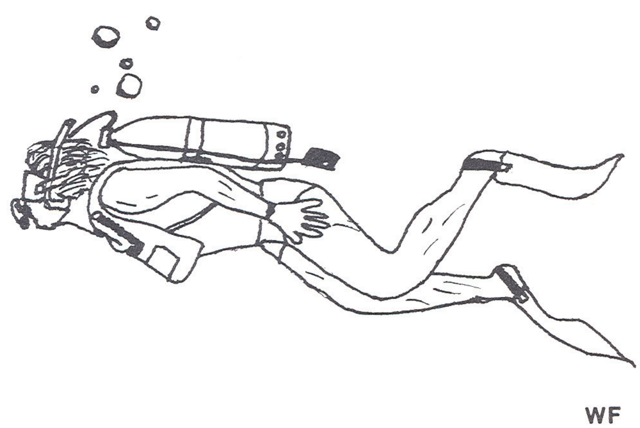
"Under Down Under"

by Francis Le Guen
Diving and Snorkeling 2(4) p.38 (6)
By William Freund

This past winter an article appeared in Diving that not only spoke of cave diving, but took you along on the expedition. Le Guen's writing was superb, invoking the spirit of adventure found in all cavers. Le Guen and the members of the French expedition were in Australia for a single purpose: to conquer Cocklebiddy Cave. At nearly six kilometers, it is one of the most grueling cave dives, considered by the Australians as the "Everest of Sumps". The Team of five divers and three tons of equipment achieved a world record, having been beneath the Australian desert for 47 hours.

During the dive several scientific finds were noted; first, mummified bats were found in one passage, proving that the cave at one point had had free air flow, secondly several unique crystal formations were observed. The cave is naturally divided into three sections separated by two air passages. These areas were used as staging areas to prepare for the assault on the next sump.

Safety is of utmost concern in any cave exploration, but especially in cave diving. Cave diving is vastly different from conventional "open water" diving. One must take along 4-5 proven sources of light, two independent air supplies, each with its own regulator and pressure gauge. One must turn back once one-third of his air has been expended. A guide line is a must. "Lastly one very good piece of advice - don't do it !" To date 240 people have died in Florida caves, 50 in Europe, and 12 in Australia.



CAVE DIVERS PENETRATE DEEPER

BERMUDA: A UNIQUE WESTERN ATLANTIC KARST*

by

H. H. Hobbs III

Introduction

The occurrence of solution caves on islands is a global feature (e.g., Japan, Sarawak, Java, Celebes, New Guinea, Tasmania, New Zealand, Australia, Madagascar, Sardinia, Majorca, British Isles, and, closer to home, Puerto Rico, Jamaica, Cuba, and Bahamas); Bermuda is no exception. More than 200 caves are known to occur (or previously existed) in the relatively young limestones of the Bermuda archipelago.

The earliest reference to caves in Bermuda was in 1623 when Captain John Smith found "...in some places varye strange, darke, and combersome Caves" (Smith 1623). Thomson (1877), Verrill (1908), Rider (1922), and Forney (1973) present discussions of the history of the caves of the islands.

The following is a brief introduction to the caves of the Bermudas, including a discussion of the origin of the islands, their geological history, solutional features, the distribution of caves, and a brief discussion of the biological, chemical, and physical factors of these anchialine environments.

Origin of Bermuda

The Bermudas are a well-known group of semi-tropical islands and islets (>150) located 1000km east of Cape Hatteras, North Carolina, USA, near latitude 32N and longitude 65W in the northwest Atlantic Ocean (Fig. 1). Although Bermuda is suggestive of an atoll in that carbonate islands, shoals, and reefs surround a central shallow-water lagoon, Stanley and Swift (1967) point out that the Bermudian shoals and reefs are not constructional but consist of eroded

* This paper is Contribution No. 1040 from the Bermuda Biological Station for Research, Inc.

Figure 1. Map of the western Atlantic indicating the location of the Bermuda Islands.

and submerged eolian limestones thinly veneered with encrusting organisms. Because of this, they propose that Bermuda is not a true atoll; however, Garrett and Scoffin (1977) present data that suggest that it is the world's northernmost coral atoll.

The topography is rolling hills up to 50m in elevation, most of the land being less than 30m above sea level (see Fig. 2). The islands proper are composed of a complex mosaic of marine and eolian, Pleistocene and Recent limestones and interlacing paleosols that sit atop a volcanic pedestal (Land et al. 1967). The Bermuda Islands are on the southeastern edge of a 116km2 platform (the top of the Bermuda Pedestal - the northernmost and largest of the three volcanic seamounts on the Bermuda Rise - see Fig. 3). The origin of the pedestal can be traced back approximately 105MY when a volcanic eruption(s) occurred along the Mid-Atlantic Ridge (Reynolds and Aumento 1974, Morris et al. 1977). The resulting lava domes gradually cooled and the erosive action of the sea began to reduce the island masses. A re-eruption 33-35MYA added sufficient lava to maintain the island above sea level (increasing the seamount by an estimated 35% - Reynolds and Aumento 1974). This was not the case for two other volcanoes to the south which, today, are merely submerged seamounts on the Bermuda Rise. The Bermuda Rise's attachment to the North American Plate has resulted in a continued westward movement since its formation. Coral reef development along the perimeter of the volcanic platform provided a source of carbonate sand. Thus, Bermuda has served as a site of limestone deposition since the Tertiary, yet, during the early Pleistocene, the volcanic platform was eroded to its present average depth of approximately 75m below sea level. During the Pleistocene, much of Bermuda's land area was alternately submerged and exposed as sea level changes of up to 100m occurred (Sayles 1931, Bretz 1960, Land and Mackenzie 1970, Land et al. 1967, Vacher 1973). These fluctuations were associated with continental glaciation and resulted in a cyclic alternation of limestones and paleosols. Coastal sand dunes (primarily carbonate sand) as high as 80m formed along the peripheral shorelines during interglacial high sea levels (Iliffe 1979), sand being supplied from beaches by onshore winds (Bretz 1960, Mackenzie 1964a). These dunes were solutionally altered (meteoric and circulating ground water dissolved calcium carbonate and recrystallized it around sand grains, producing a soft eolianite limestone -- Plummer 1970). Although there is some disagreement concerning the origin of the soils of Bermuda (see Ruhe et al. 1961; Blackburn and Taylor 1969, 1970; Bricker and Mackenzie 1970) it is generally accepted that during continental glaciations (low sea level stands) red clay "fossil" soils formed from residuum of weathered limestone and, more importantly, from an

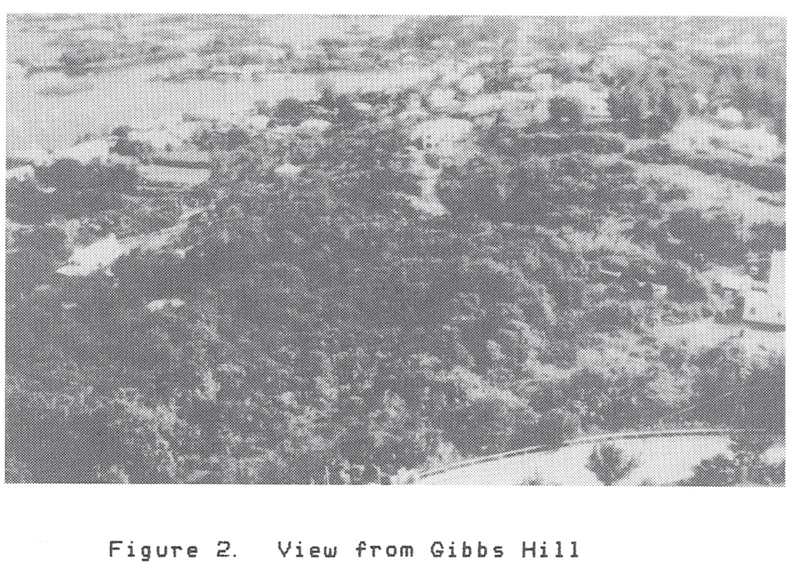


Figure 2. View from Gibbs Hill Lighthouse, looking northeast.

accumulation of atmospheric dust. This is evident since the soils contain abundant quartz that could not be derived from either the limestones or the buried volcanoes. This is further substantiated because the measurement of atmospheric dust presently landing in Bermuda demonstrates that the thickness of these soils can be accounted for simply through atmospheric accumulation (provided that the dust content of the paleoatmosphere during the Pleistocene was similar to that observed today). Additional details of the mosaic and interpretation of the depositional history and oscillating sea levels that produced the Pleistocene dunes and interlacing paleosols are presented in Bretz (1960), Land et al. (1967), and Vacher (1973). Of importance, the deepest known carbonates are approximately 75m below sea level (Schenk 1973) and, as mentioned above, are probably early Pleistocene in age.

Geology

The present topography of Bermuda reflects the origin and subsequent diagenetic history of the limestones which formed as shoreline dunes (see above) and were later modified by corrosion (Bretz 1960; Mackenzie 1964a,b; Land et al. 1967; Vacher 1973; Plummer et al. 1976). These limestones are composed of three rock-stratigraphic units (Plummer et al. 1976), differing largely on account of the varying extent of their diagenetic alteration: Paget Formation (Vacher 1973), Belmont Formation (Land et al. 1967), and the Walsingham Formation (Land et al. 1967), the youngest being the Paget Formation and the oldest the Walsingham Formation (Fig. 4). Land et al. (1967) demonstrated within these formations the progressive change with time of a number of lithologic features, including cementation, mineralogy, and porosity. The Paget is largely a deposit of well-sorted calcarenitic sand (low magnesium calcites). "The eolianite ridges of the Paget consist of individual dune-shaped hills representing large acretionary mounds that merged laterally as they grew landward from the source beaches" (Plummer et al. 1976:1303). The Belmont contains many pencil-sized solution channels in the present-day phreatic zone and most of the magnesium calcite has been converted to calcite (Ristvet 1971). The Walsingham Formation is composed essentially of calcite (highly altered, Pleistocene eolianite) and is cavernous; thus, ground-water flow is virtually unrestricted. The topography of the Belmont and Walsingham Formations is "subdued" and "rolling" which "...is in striking contrast to the dune topography of the coasts" (Sayles 1931:445). The largest number of caves occurs in the Walsingham Formation, although "caves" are developed in all formations.

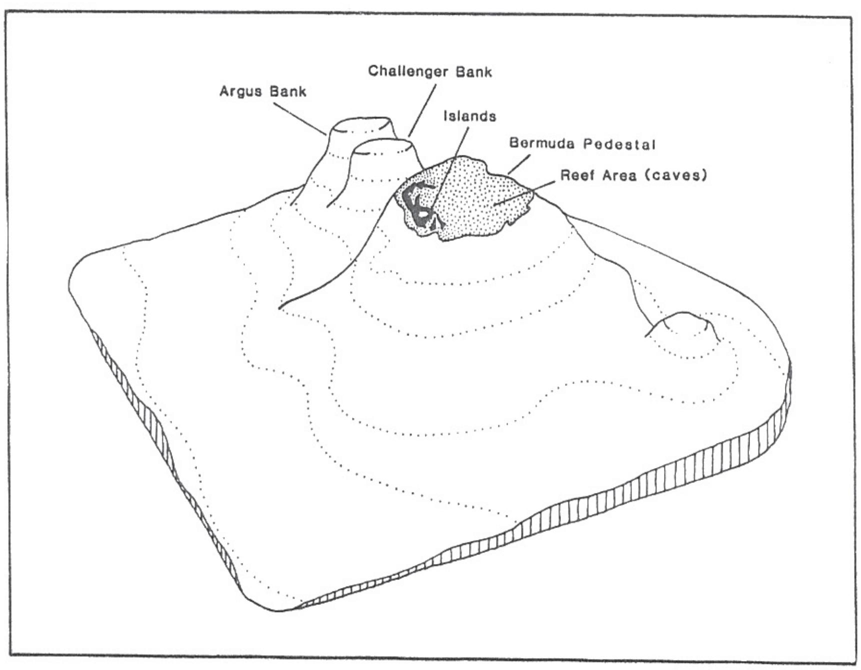


Figure 3. Generalized perspective view (from the northeast) of the Bermuda Rise (the three seamounts, the Bermuda Islands) and adjacent sea bottom (after Moore 1969).

Origin of Caves

A great deal has been written concerning the origin of the caves of Bermuda. Plummer et al. (1976:1303) state that "...much of the karst formed on the Walsingham prior to deposition of the Belmont. In some areas, the Belmont eolianites onlap a karst topography, and locally Belmont deposits breach caves in the Walsingham...the Bermudian landscape is a solution-modified dune topography; cave related karst seems principally inherited from early, pre-Belmont events." Disagreement exists concerning whether Bermuda's caves are of phreatic or vadose origin. Swinnerton (1929a, 1932) proposed that the caves were formed above the "water table" by meteoric water migrating downward along steeply dipping and intersecting joints during a period of lower sea level (see Swinnerton 1929b) in the Pleistocene (vadose origin). Davis (1930) proposed a phreatic origin for the caves and classified them as "one-cycle caverns in porous limestone" (one cycle of solutional excavation occurred below the "water table"). This is in contrast to most other caves which, he hypothesized, were formed in two cycles: a cycle of depositional replenishment took place following lowering of the "water table" when the cave became air-filled. Bretz (1960) suggested that cave formation occurred beneath the "water table" (phreatic origin) at a time when a large fresh groundwater body, supplied and maintained by rainwater, circulated horizontally. He hypothesized this elevated fresh water lens occurred on the island during low sea level stands when the islands' total landmass was approximately 13 times as large as it is at present. Since sea water does not readily corrode limestone, the existence of currently submerged solution passages strongly suggests that cave formation took place when sea levels were considerably lower and when large bodies of fresh groundwater were present. Post-glacial sea levels rose, displacing the fresh water and inundating many of the caves. Bretz stated that since the extensive fresh groundwater body presently is virtually gone from the island, cave formation has ceased. He (1960:1741) suggested that closely adjacent caves with no known air-filled connections are remnants of one former extensive and integrated cave system. Secondary deposition of speleothems in air-filled channels resulting from additional sea level lowering further contributed to their isolation.

Currently the most widely accepted theory of cave formation in Bermuda states that caves were formed by solution below the "water table" during low stands of sea level (Harmon 1974, Palmer et al. 1977). Collapse

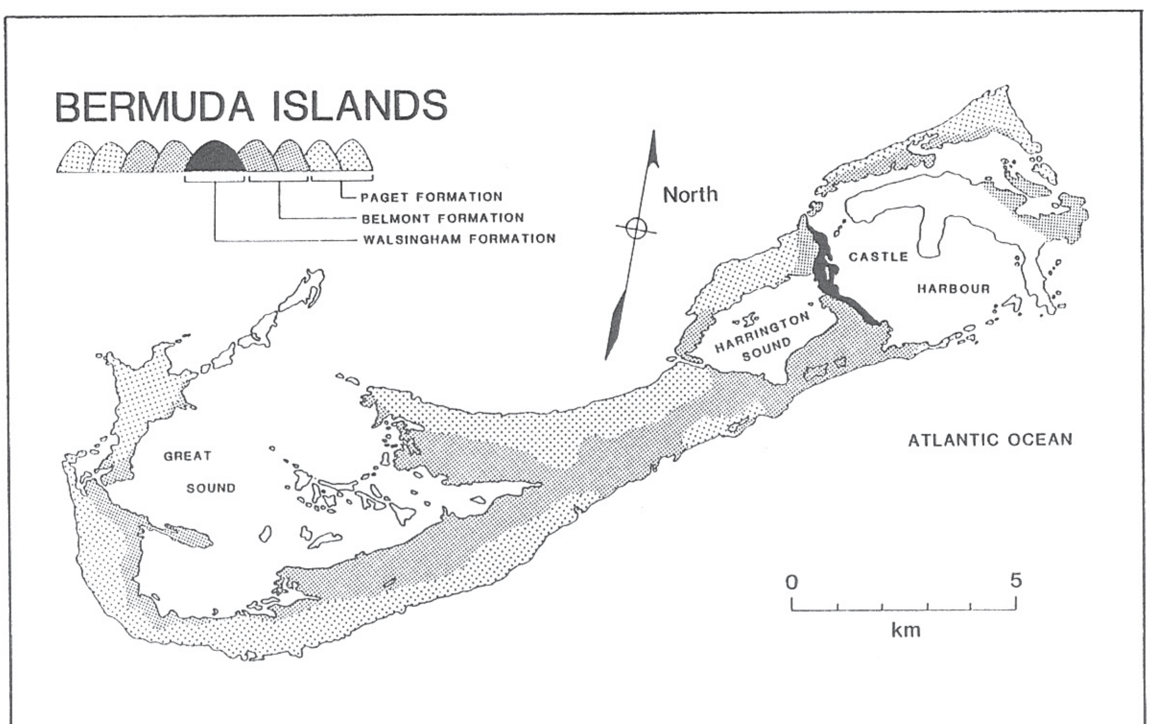


Figure 4. Geologic map of Bermuda showing the distribution of the three major rock formations (from Vacher 1974 and Plummer et al. 1976).

of overlying rock into large solutional voids gave rise to irregular rooms and fissure-type entrances that are common in Bermuda caves. While working in the Walsingham area Peckenham (1981) drilled into a cavern at a depth of 18m. The bottom of the submerged room was reached at 30m and basalt was recovered beginning at a depth of 33m. "This and other evidence indicates that major caves in Bermuda may have been formed by solution at the limestone-basalt interface and extended upwards by subsequent collapse" (Iliffe et al. 1984:175). Many large stalagmites, stalactites, and other speleothems that can form only in air, are commonly observed submerged in the majority of caves. These speleothems show little alteration by their long inundation that may be as deep as 23-24m underwater (Latham 1977, Iliffe 1981). Thorium-uranium dating has been used by Harmon et al. (1978) to obtain an age of 195,000 years for two submerged stalagmites from Crystal Cave. Home (1864), using less accurate methods, estimated the age of a large stalagmite from Admiral's Cave to be 600,000 years.

Caves

Iliffe (1981) noted that in addition to the terrestrial caves, three distinct types of submarine caves also occur on Bermuda: Reef, Collapse, and Passage caves. Reef caves are those submarine caves found along the seaward bases of fringing reefs in 10-20m of water (see Fig. 3). These caves are probably formed when voids occur in the construction of the reef and are subsequently modified by wave and surge erosion. They are generally short (tens of meters in length) and consist of cavities or roofed vertical fissures within the reef proper.

Collapse caves are located primarily in the Walsingham area (located between Harrington Sound and Castle Harbour -- see Fig. 5) and are characterized by large collapse chambers and fissure entrances. Iliffe (1981:161) suggests that these large chambers may "...have resulted from collapse into deeper passages lying at the limestone-basalt interface. This interface may be as shallow as -35m in the Walsingham area (Newman, 1959). During periods of lower sea level, ground water would penetrate the very porous eolianite limestone until reaching the

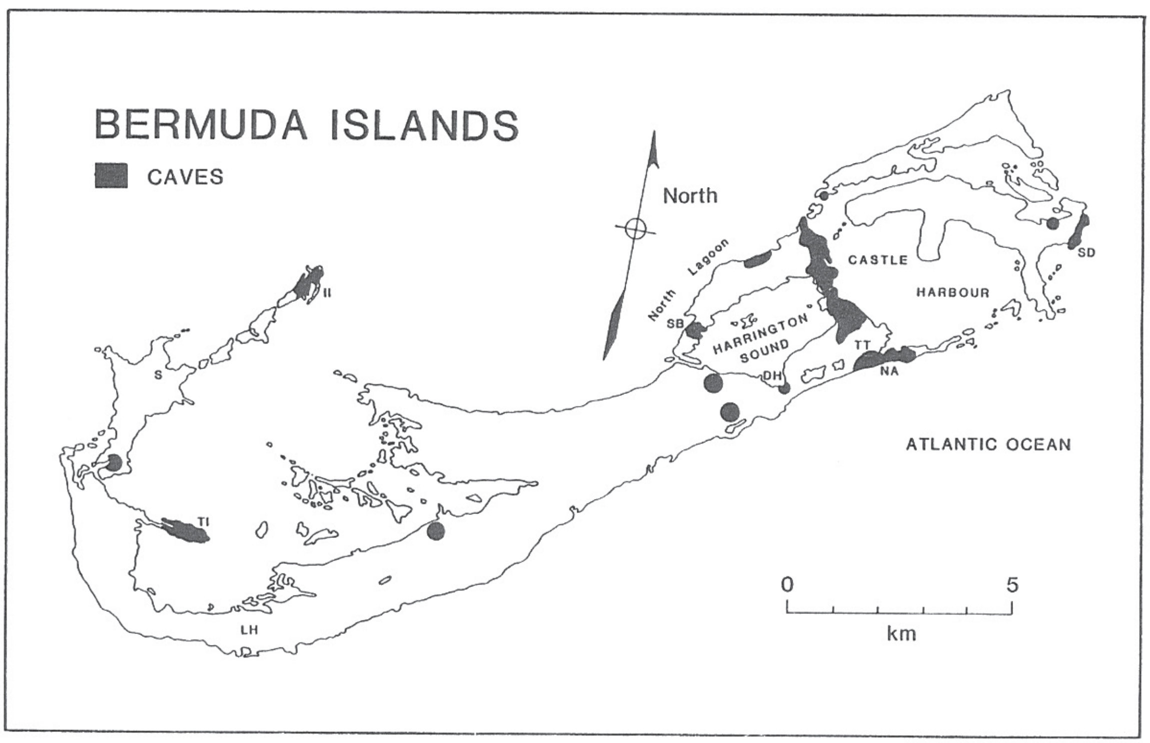


Figure 5: Map of the Bermuda Islands indicating the location of cave areas (■) and other significant features (S = Somerset; TI = Tucker's Island; II = Ireland Island; LH = Gibb's Hill Lighthouse; SB = Shelly Bay; DH = Devil's Hole; TT = Tucker's Town; NA = Natural Arches; SD = St. Davids).

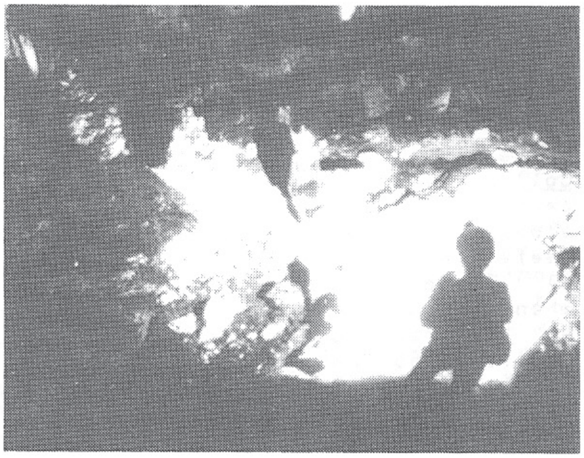


Figure 6. Admiral's Cave, developed in the Walsingham Formation.

impermeable basalts. At the interface, horizontal transport of the ground water would likely have formed large solutional cave passages. The underwater portions of the Walsingham caves closely resemble the terrestrial morphology found in the same caves, even to the variety of large speleothems found at all depths within the caves."

"Passage caves" are inland caves in the Shelly Bay area (Fig. 5) and tend to be long, nearly horizontal, anastomosing passages extending from Harrington Sound to the North Lagoon (although direct connection has never been made by diving). These caves probably served to transport water between Harrington Sound and the North Lagoon or possibly the North Rim of the Bermuda Pedestal, 15km distant to the north. Iliffe (1981) points out that the 18m mean depth of these caves corresponds to the depth of the main reef terrace, indicating that both may have formed during a stationary sea level stand at this position. The longest cave in Bermuda is a "Passage Cave" and is developed in the Belmont Formation in the Shelly Bay area: the Green Bay Cave System (nearly 2km of totally submerged passages and two entrances -- see Iliffe 1981).

The highest concentration of caves is found along the Harrington Sound-Castle Harbour isthmus in the Walsingham Formation. Iliffe (1981) reports 100-150 caves in this region and he (1978:75) pointed out that nine caves "...in a 2 mile section of the isthmus..." at some time were shown commercially: Admiral's (see Fig. 6), Castle Grotto, Cathedral, Crystal, Island (=Prospero's, Cheek-to-Cheek), Leamington, Shark Hole, Walsingham (see Fig. 7), and Wonderland (see Fig. 8) caves. Only Crystal and Leamington caves are currently open commercially to the public; the former contains a tidal pool spanned by a pontoon bridge and divers have descended a steeply sloping fissure to a depth of 23m where another steeply up-sloping passage opened into a large room with no surface connections (Latham 1977). Forney (1973) reported that Devil's Hole, the deepest part of Harrington Sound, was Bermuda's first (1843) commercial tourist attraction. Devil's Hole is actually a collapsed cave and is currently operated as a natural fish-pond. Blue Grotto is also a collapsed cave and is the site of commercial dolphin shows. Island (more popularly called "Cheek-to-Cheek") Cave's notoriety centers around an underground bar and dance floor, and a tidal pool in the small but well decorated Cathedral Cave is occasionally used as an "indoor swimming pool." Admiral's Cave has a large entrance in a prominent sinkhole (see Fig. 9) and is a beautiful show cave. Like most of the caves in this area, salt water pools flood the lower portions of this cave. In 1819 a large stalagmite, (11 feet long, weighing nearly 3.5 tons) was removed by Admiral Sir David Milne. It was shipped to the University of Edinburgh Museum in Scotland for display. One of his sons, Sir Alexander Milne, measured the amount of newly deposited stalagmitic material on the stump, 44 years after the stalagmite was removed. Another son, David Milne Home, used these data (as mentioned above) to estimate that the original stalagmite was 600,000 years old (Home 1864). Wonderland Cave is well-decorated with a large tidal pool and extensive dry passages (see Bowman and Iliffe 1983 for a description). Several other caves in the isthmus are Callabash Cave, Sink

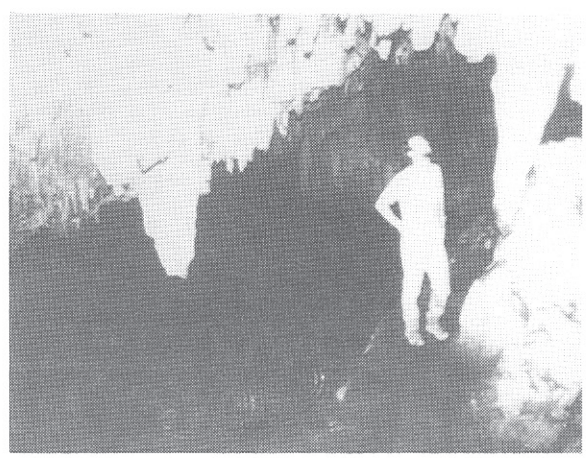


Figure 7. Walsingham Cave located in the Walsingham area and formerly commercialized.

Cave (these two caves are connected beneath the surface water and are probably a remnant of the cavern that occupied present day Walsingham Pond -- Iliffe, pers. comm.), Walsingham Sink Cave, Cherry Orchard Cave (an upper level remnant of Walsingham Sink Cave?), Church Cave (see Bowman and Iliffe 1983 and Iliffe et al. 1984 for descriptions of the cave), Deep Blue Cave (one of the nicest cavern dives on the island -- Iliffe, pers. comm.), Shop Cave, Horse Shoe Cave, Staff Quarters Cave, Fern Sink Cave (steep slope to water level with dry upper passages and skylight), Government Quarry Cave (refer to Iliffe et al. 1984 for a description), Sibley's Cave (quite extensive dry cave, muddy, tidal pools), and two small caves, Shrimp (Fig. 10) and Roadside, are of particular faunal interest. Southeast of the isthmus near Tucker's Town and Natural Arches is Tucker's Town Cave, a feature in the Belmont Formation. The entrance is a 13m drop into a sandy-floored, beautifully decorated chamber containing a large, oval tidal pool, the floor of which lies approximately 21m below the surface of the pool. This submerged chamber is connected to an adjacent room through a spectacular arch-like passage (see Hart and Manning 1981 for further discussion). East of Castle Harbour are five caves which open on to the sea cliffs at St. Davids. These caves are developed in the Belmont Formation and do not have saline tidal pools, however, one cave is unique in that it contains a relatively extensive body of fresh water. Some of these caves are choked with speleothems.

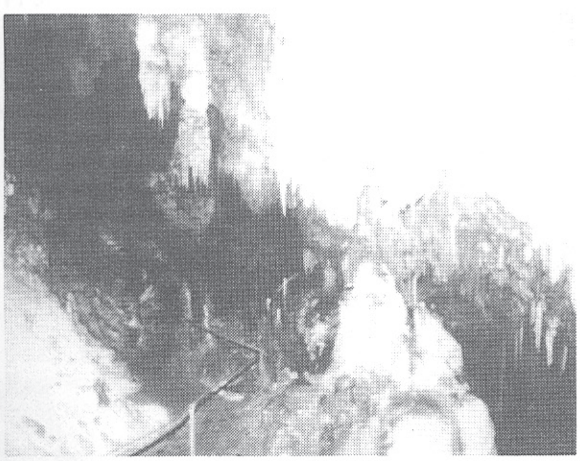


Figure 8. Wonderland Cave, a former commercial cave; an 18m deep tidal lake is to the right of the photo (note railing for scale).

Figure 9. Entrance to Admiral's Cave (note palmettos for scale).

Cave Water Analysis

The clear, blue, saline cave pools are at sea level and are found in most of the known caves and, except for their location in the interior of caves, are typical of what Holthuis (1973:3) termed anchialine habitats. He defined these as "...pools with no surface connection with the sea, containing salt or brackish water, which fluctuates with the tides." By popular favor, Holthuis' term has been extended to include the unique Bermuda cave habitats. These pools, which rise and fall with the tides, are distinctively constant chemically and physically the year round (Iliffe et al. 1983, Iliffe et al. 1984). Some small differences occur seasonally in the upper 3m but the absence of changes in the cave water column below this depth indicates that the deeper cave waters are probably well isolated from the open sea. Tidal currents generally become more diffuse with increasing distance from the sea and Ilife et al. (1984) estimated the water residence time in Church Cave to be approximately one year. Iliffe et al. (1983) indicated that the tidal range is 40% that of the surrounding ocean and has a lag time of about 107 minutes.

The source of saline water to the caves is ultimately the Bermuda inshore waters (see Bodungen et al. 1982), whereas freshwater inputs occur at the surface of cave pools from soil percolation, from vadose water percolating through open fractures, or from lateral transport of fresh groundwater occurring as a lens in less porous, generally younger limestones (Plummer et al. 1976, Frantz 1970). Since there is virtually no wind or wave action, vertical mixing is minimal, resulting in the establishment and maintenance of a highly stratified cave water column; this is what can be described as a meromictic environment. According to Iliff et al. (1984), most far inland cave pools contain a thin (<1m) brackish surface layer which varies in salinity from 0 to 25ppt, depending on freshwater input, surface water evaporation rates, and degree of water perturbation from tidal currents (minimal, particularly with increasing distance from the sea). Beneath this brackish layer is a sharp halocline which is underlain by waters that gradually show increases in salinities with increasing depth (to values near those observed in the surrounding Bermuda inshore waters -- >35ppt); see Figure 11 for representative salinity profiles.

Water temperatures demonstrate similar steep gradients with depth: coolest waters remain at the surface while temperatures increase markedly through the halocline and then more gradually with increasing depth (see Fig. 11 for representative temperature profiles). In this warm temperature range, warmer waters are less dense than cooler waters and should reside high in the water column but, due to increased salinities, densities are high in the warmer, deep waters inspite of the thermo-density relationships; thus, a temperature inversion is characteristic of Bermuda cave pools. Iliffe et al. (1984) proposed that natural geothermal heat flow could account for temperature increases below the halocline (seasonal temperature variations are minimal).

Oxygen levels in cave surface waters are near saturation (>90% -- see Fig. 12) primarily because air exchange (diffusion) and drip waters maintain oxygen supplies. At the halocline, oxygen drops sharply and remains fairly constant throughout the deep waters (not lower than 55% saturation in the seven unpolluted caves sampled by Iliffe et al. 1984). As one might anticipate, BOD (biochemical oxygen demand) levels are very low (<0.25 ml O_2/l) in cave waters (Iliffe et al. 1984). They report a small BOD maximum in the halocline and note that it is probably the result of the entrapment of surface derived particulate organic matter at the pycnocline.

Of interest and concern, preliminary investigations demonstrate that many species of cavernicoles (see discussion below) are found in the polyhaline water zone which has a markedly low oxygen content. Some of this low oxygen concentration is "natural" while some such conditions are man-induced (see discussion below). In some cave passages in which certain animals apparently thrive optimally, oxygen levels have been extremely low (ppb). The physiological significance of this low oxygen tolerance has not been determined but warrants further study.

Like the Bermuda groundwater, cave waters have high nitrate but low ammonia, nitrite, and phosphate concentrations (Iliffe et al. 1984). The levels of nitrate and phosphate in the deep cave waters are approximately five times higher than inshore waters of comparable salinity (Bodungen et al. 1982), probably due to biological utilization in the latter environment. Iliffe et al. (1984) indicated that all trace metals analyzed (cadmium, copper, iron, manganese, nickel, and zinc) demonstrated similar distribution patterns: highest surface water concentrations which drop sharply at the halocline and then remain fairly constant with depth at concentrations similar to those found in Bermuda inshore waters.

Cave Fauna and Flora

Amazingly, only recently have marine caves been recognized as a habitat within the marine environment. Many western Atlantic islands have been explored and extensive inland cave systems containing marine or brackish waters have been discovered (also on the Ascension Islands, Canary Islands, Hawaiian Islands, Maui

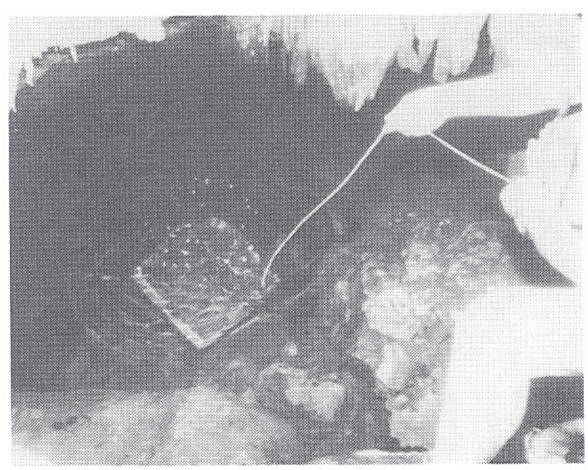


Figure 10. Shrimp Cave; baited trap being lowered into tidal pool inhabited by <u>Barbouria</u> <u>cubensis</u> (von Martens).

Islands, etc.). Lucayan Caverns on Grand Bahama Island currently is the world's longest (10km, totally submerged) underwater cave (Dennis Williams and Jill Yager, pers. comm.). Gradually these caves are being found to host rich and diverse biological communities.

Prior to the 1970's very little research had been conducted in the caves of Bermuda. Britton (1915) noted that a number of mosses are restricted to cave entrances. Britton (1918) reported two endemic ferns were known primarily from the entrances to caves and crevices located in the Walsingham area.

The fauna of the caves proper is quite diverse, species richness being influenced heavily by aquatic organisms. The terrestrial fauna is very poor and is limited to regions in a cave where organic debris is available in "suitable" amounts. Fewer than 20 species of invertebrates are known and the lack of any evidence of cave-inhabiting bats or their fossil remains indicates that cave-inhabiting bat species were never resident in Bermuda (Van Gelder and Wingate 1961). In addition, there are no known cave crickets or other ecologically similar animals, thus, there are no species that could serve as carriers of food into the cave interior (no "enrichers").

In contrast with the impoverished fauna of the terrestrial environment of Bermuda's caves, the submarine passages and inland tidal pools of these same caves are inhabited by a rich and highly diverse marine fauna. More than 100 species of marine macroinvertebrates have been collected from inland caves and over 35 represent new species (Sket and Iliffe 1980). *Atlantasellus cavernicolus* Sket (1979) an isopod representing a new family, *Bermudalana aruboides* Bowman and Iliffe (1983) a new genus and species of cirolanid isopod, two new shrimps *Typhlatya iliffei* Hart and Manning (1981) and *Somersiella sterreri* Hart and Manning (1981), *Mitocarsi halope* Bowman and Iliffe (1985) a new peracarid crustacean, *Mesonerilla propsera* Sterrer and Iliffe (1982) a new ardiannelid polychaete *Miostephos leamingtonensis* Yeatman (1980) a new calanoid copepod, and *Apseudes bermudeus* Bacescu (1980) a new hermaphroditic tanaidecean are some of the new troglobitic species recently described from Bermuda.

An interesting find has been the discovery of a high species richness of cavernicolous shrimps in Bermuda's cave waters (Hart and Manning 1981, Manning and Hart 1984). The new genus of hippolytid shrimp *Somersiella sterreri* (see above), the hippolytid *Barbouria cubensis* (von Martens), a new species of atyid, *Typhlatya iliffei* (see above), and the alpheid *Automate dolichognatha* De Man have been observed in the water of Tucker's Town Cave. Another alpheid, *Synalpheus sanctithoma*, and an undescribed species of *Procaris* have been collected in the Green Bay Cave System.

The origin of the Bermuda cave fauna is probably quite complex and certainly poorly understood. A number of new species are considered relics of formerly widely distributed groups that have become extinct or considerably reduced in geographical range. Some species may be recent invaders via the Gulf Stream from the Caribbean, while some species may have their derivation traced back to the separation of the African and American continental masses. Some may be Tethyan relicts and still others are probably of deep sea origin; the reader is referred to Hart et al. (1985) for further discussion. Much additional research is required prior to a full understanding of how and when these diverse cavernicoles (or their ancestors) came to dwell in the crevicular habitats ("...those aquatic habitats formed by crevasses in and among rocks" -- Hart et al. 1985:291) of subterranean Bermuda.

Man's Impact on Caves

A discussion of the caves of Bermuda would be incomplete without mention of some of the threats that exist to these karst features. Certainly "time" is an "enemy" and Bretz (1960:1744-1745) pointed out "cave failures" in various locations. Needless to say, the caves have had a history of collapse. More pertinent to this discussion is the damage that has been caused by the activities of man. Iliffe (1979:184) reported four primary threats to caves: filling and quarrying activities, water pollution, dumping and littering, and vandalism. Forney (1973) reported Wilson's Cave, Peniston's Cave, and Wilkinson Quarry Cave as being destroyed by quarrying. Kindley Field Cave was discovered during excavation for a playground; it was explored and immediately filled (Ibid). Tucker's Island Caves (one was once shown commercially by boat -- Verrill 1908) were destroyed during the construction of the U. S. Naval Annex and North Bastion (on Ireland Island) Cave was destroyed during construction of fortifications (Nelson 1837). Cave Island was buried during construction of an airport (Ibid) and Iliffe (1979) noted that numerous other caves have been filled or destroyed during construction of hotels, golf courses, and private residences.

An unnamed cave was discovered by workers digging a cesspit for the Bermuda Telephone Company (Forney 1973) and incorporated as part of the sewage facility since it greatly increased the volume of the cesspit!! Bassetts Cave, located near Somerset and at one time said to be Bermuda's largest at more than 1.5km in length, has been used by the U. S. Navy for dumping waste fuel-oil and raw sewage. Forney (1973) also reported that extensive dumping at Sears Cave may have destroyed a rare fern for which the cave was once noted. Cans, bottles, garbage, and other litter are all too commonly seen in many of the better known, non-commercial caves. Vandals have broken and removed irreplaceable speleothems (recall the work of Admiral Sir David Milne!! -- see above) and defaced cave walls. Although the severity of pollution of ground waters on Bermuda is not fully understood, Iliffe et al. (1984) reported some of the physicochemical characteristics of Government Quarry Cave, a dumping site. Figure 12 graphically compares the percent oxygen saturation of this polluted cave water with water from unpolluted Church Cave. BOD levels in the upper 10m of the water column of the polluted caves are 10-60 times higher than those in Church Cave. The maximum levels occur in the region of the halocline, reflecting the entrapment of organic matter released from submerged portions of the rubbish pile. Organic pollution is extremely serious in these marine cave environments because it leads to oxygen depletion and, because of very long residence times of water, ultimately, to anoxic conditions. Since many of Bermuda's cavernicoles are endemic and are often restricted to only one cave or a single cave system, pollution of these habitats can result in their extinction. Another poorly understood problem of local, as well as global, concern is the increased acidity of predipitation. Acids present in rainfall are almost entirely sulphuric with a small nitric acid contribution (Jickells et al. 1982).

Summary

Bermuda consists of a group of small islands (>150) situated atop a volcanic seamount in the northwest Atlantic Ocean. The islands proper are composed of marine and eolian, Pleistocene and recent limestones entirely capping the volcanic pedestal. These limestones are divided into three distinct formations: Paget, Belmont, and Walsingham. Although many theories exist for the origin of Bermuda's

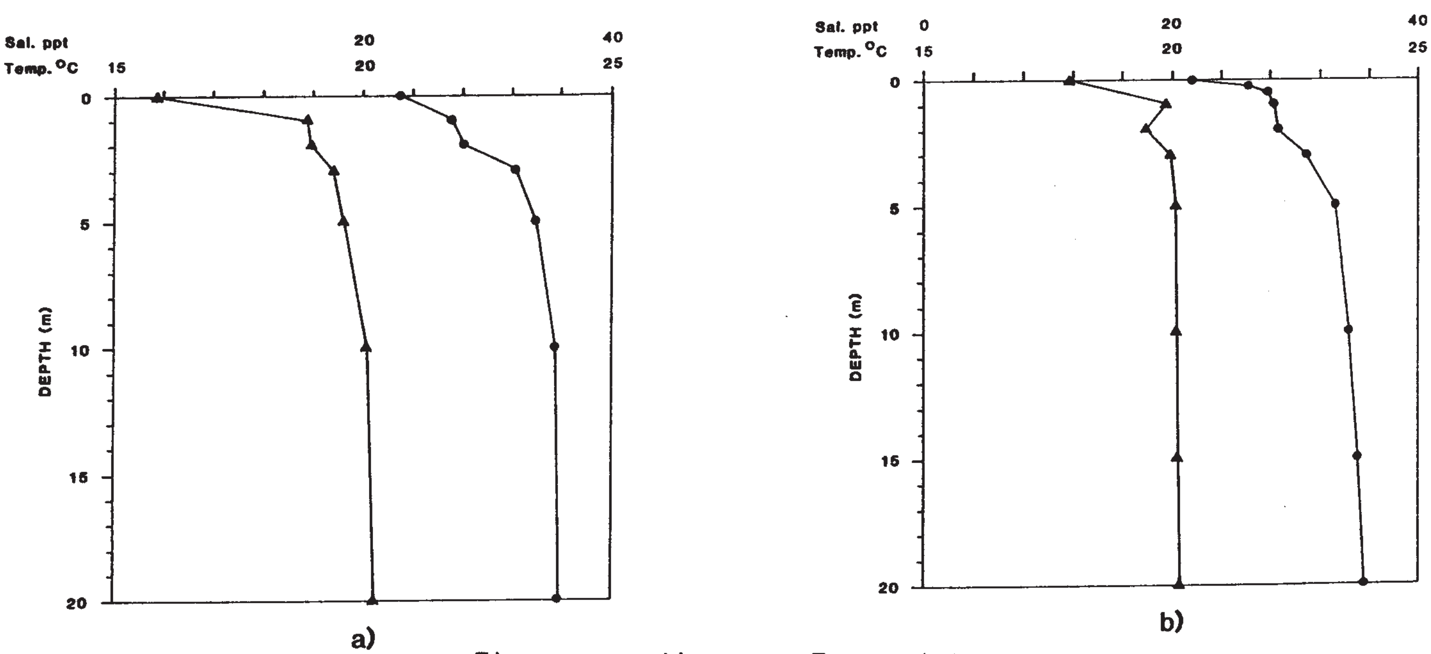


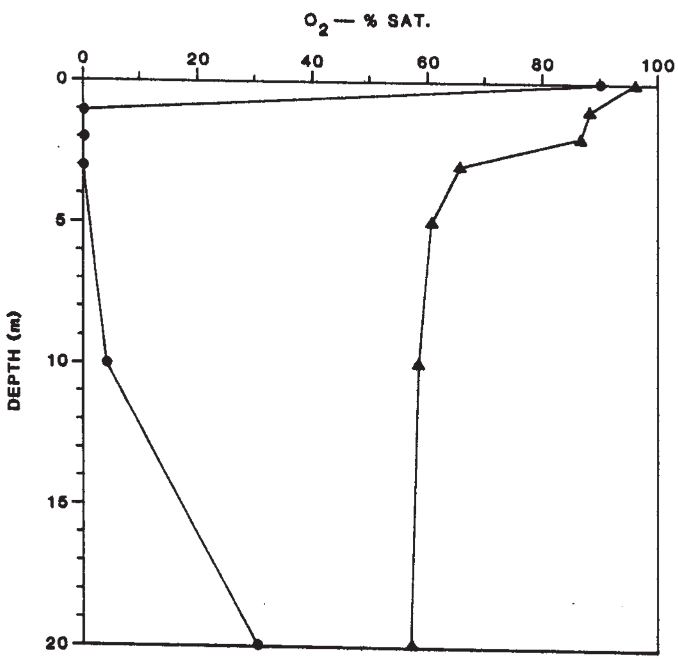
Figure 11. Temperature (triangles) and salinity (circles) profiles in Church Cave. a, 28 February 1982; b, 11 July 1982 (data from Iliffe et al. 1983).

caves, the most current hypothesis proposes that the caves have a phreatic beginning during low sea level stands. Some of the major caves may have been formed by solution at the basalt-limestone contact and further "growth" extended upwards by subsequent collapse. Certainly collapse of overlying rock into apparently large solutional chambers gave rise to the characteristically irregular rooms and fissure-type entrances.

In addition to terrestrial (air-filled) caves, three distinct types of submarine caves also occur: reef, collapse, and passage. "Collapse" caves are most numerous and are usually developed in the Walsingham Formation, whereas the longest cave is a "passage" cave and is found in the Belmont Formation.

The clear tidal pools of the caves (anchialine habitats) are generally well isolated from the open sea, do not experience comparable tidal fluctuations with inshore waters, and tides tend to lag behind those of the surrounding ocean. High nitrogen levels but low concentrations of ammonia, nitrite, and phosphate are common characteristics of these waters. A sharp halocline exists usually within the top 3m of the water column and due, in part to geothermal heating, temperature increases occur

Figure 12. Oxygen saturation profiles from unpolluted Church Cave (triangles) and polluted Government Quarry Cave (circles) (data from Iliffe et al. 1984 -- no sample date given).



below this density gradient. Typically oxygen levels are near saturation in the surface waters but drop sharply at the halocline, normally remaining above 55% saturation.

A depauperate cave fauna is found in the terrestrial environment of Bermuda's caves but a rich invertebrate community is supported in the marine cave pools. More than 100 macroinvertebrates, at least 35 of these are undescribed species, have been recognized. The origin of these organisms is complex and not fully understood. Some species have originated from stocks from the Caribbean via the Gulf stream; some may represent groups that survived on emergent and submergent seamounts along the Mid-Atlantic Ridge since the middle Mesozoic, some are probably relict deep sea fauna, and others may be Tethyan relicts.

Recent investigations have shown that some cave waters have been/are contaminated, altered, etc. by the activities of man. Conservation, legislation, and importantly, education concerning these anchialine habitats is of utmost and immediate concern -- these vulnerable resources must be preserved.

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Thoughts of a First-Time Caver

L. Elisa Shepland

As I looked into the hole that I knew I had to enter, I thought, "Do I really want to do this?" "This" was caving, something I'd never done before. The only experience I'd had with caves was being led through large, well-lighted commercial caves by a guide who kept saying things like, "To your left is a stalactite, on your right you can see--." Buckner's Cave in Monroe County, Indiana was certainly no commercial cave! I had been told that after I went down the hole I faced a 600-foot belly crawl; if I were lucky I'd be able to be on hands and knees. I really wasn't looking forward to this experience, but I was too stubborn to give up. I knew I'd make it through this cave if it killed me!

Looking back, I know that my first trip through a cave could have had some serious results if I hadn't had people around me who knew what they were doing. I survived the belly crawl--there had really been no question in my mind about that--and even lived through wading the ice-cold (as it seemed to me) stream which we encountered. I was sitting with my back up against a rock, changing the carbide in my lamp, when I felt as though the insides of my bones were shivering. That unnerved me for a moment, because I knew that this was not normal. I debated between going farther into the cave, or mentioning the fact that I was becoming extremely cold. I realized that if I continued any farther into the cave, I'd have that much farther to return. Besides, before we had gone into the cave, we were told that if we felt cold, tired, or panicked we should tell someone so that we could get out. I told Tom Keller that I was very cold. He immediately went and told John Fray what I had said, and events seemed to go very quickly from there. John determined that yes, I <u>was</u> unusually cold and that I should be as warm as possible before being taken back through the stream. So there I was--sitting down with a plastic garbage bag over my head and two carbide lamps underneath my legs. I was told that this was an effective method to raise body temperature. Someone gave me some food which I tried to eat, but I wasn't really hungry. As soon as I felt a little warmer, Chip Freund, John and Tom began to take me back through the stream. At first I didn't think I could make it; at one point both of my feet slipped into the water and I just sat there for a minute or two. But I knew that staying in one place wasn't going to get me any warmer so I moved on.

As soon as we got out of the stream, the whole group stopped and we decided what to do. Chip and John were going to take me out of the cave. The rest of the group wanted to explore a part of the cave we hadn't been in yet. Chip went in front of me and John was right behind me; they both gave me encouragement in the form of jokes and by teasing me. If they hadn't been there, I know that, although I probably would have been able to get out by myself, it would have been much more difficult. On the way out we had to stop a couple of times because I felt very tired and there were a couple of times when I wanted to stop right where I was and go to sleep. When that happened, the three of us stopped to rest, with John on one side and Chip on the other so I wouldn't get any colder than I already was. We finally got through the 600-foot passage which led back to the entrance of the cave. When we were at the hole I had been looking down several hours earlier, Chip was already out and ready to give me a hand up. I said no, I was going to get out by myself, and jumped up out of the hole. After we were back at the van, I changed into dry clothes, curled up in a sleeping bag on the front seat of the van and drank several cups of hot chocolate. I was slowly getting warmer and eventually slept.

My first experience in a cave was not the best that someone could have and at first I thought that it was mostly my fault. However, Chip, John and other members of the club told me that it wasn't. It was true that I wasn't properly prepared for the trip--I hadn't worn any long underwear or wool socks and wore canvas sneakers instead of boots. Since I had never been on a caving trip and there were a few other people who had also never been in a cave, I was told that my lack of preparation wasn't entirely my fault; I should have been more informed as to what to wear and what to expect while in the cave. This information made me feel less stupid. I am also more determined than ever to have an uneventful next trip. Yes, I am planning on going down again, and it won't kill me this time either!

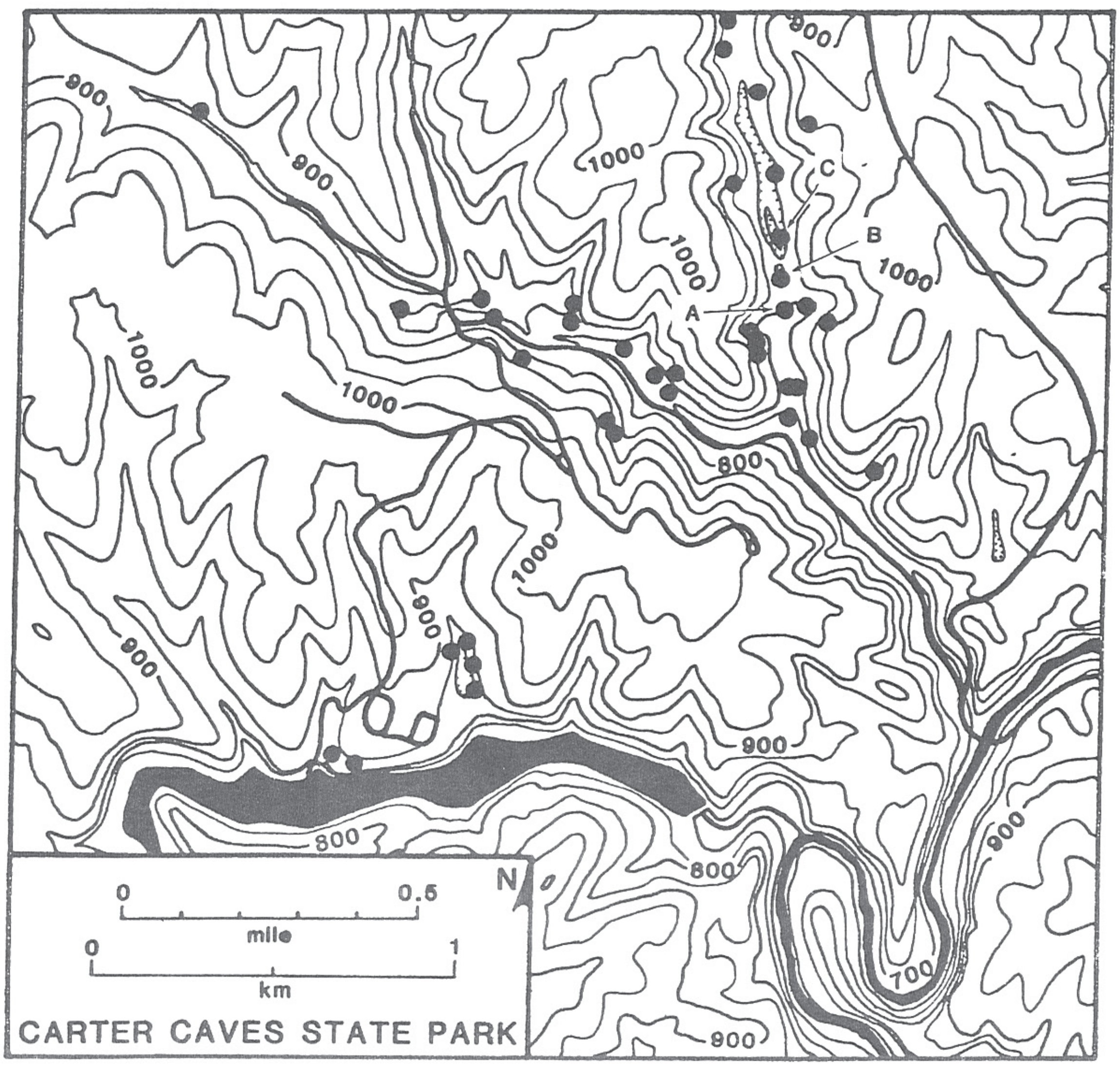
THE HORN HOLLOW CAVE SYSTEM, CARTER COUNTY, KENTUCKY

by
H. H. Hobbs III and M. M. Pender

Introduction:

Carter Caves State Park is located in the northern portion of the Eastern Coal Field in north-central Carter County, Kentucky. This hilly region of the state is capped by the Pennsylvanian Lee Sandstone which is underlain by Mississippian limestones (e.g., Lower Chester, Ste. Genevieve, and St. Louis). Numerous caves, sinkholes, pits, bridges, and sinking streams are found within the boundaries of the Park (see Fig. 1). Cave Branch, a tributary to the major stream in the area (Tygarts Creek) sinks beneath the surface and reappears three times prior to its confluence with Tygarts Creek. It flows ESE through the Park, passing through Bat Cave and emerging to flow beneath Carter Caves Bridge, and then disappears under X Cave. It emerges on the east side of the X Cave ridge and continues southeasterly as a surface stream. Horn Hollow receives runoff from a large area to the north of the Park, carries water that drains into Cave Branch, and is a "classical" karst valley, its waters disappearing and reappearing several times as they move down slope. That it also is a "hanging valley" is most obvious near its junction with Cave Branch where it is situated approximately 15m above that surface stream in the eastern portion of the Park.

Figure 1: Map of Carter Caves State State Park. Filled circles represent one or more cave entrances. A= Main entrance to Horn Hollow Cave; B= Entrance to Rimstone Cave; C= Upstream entrance to Horn Hollow Cave. Elevation is in feet.



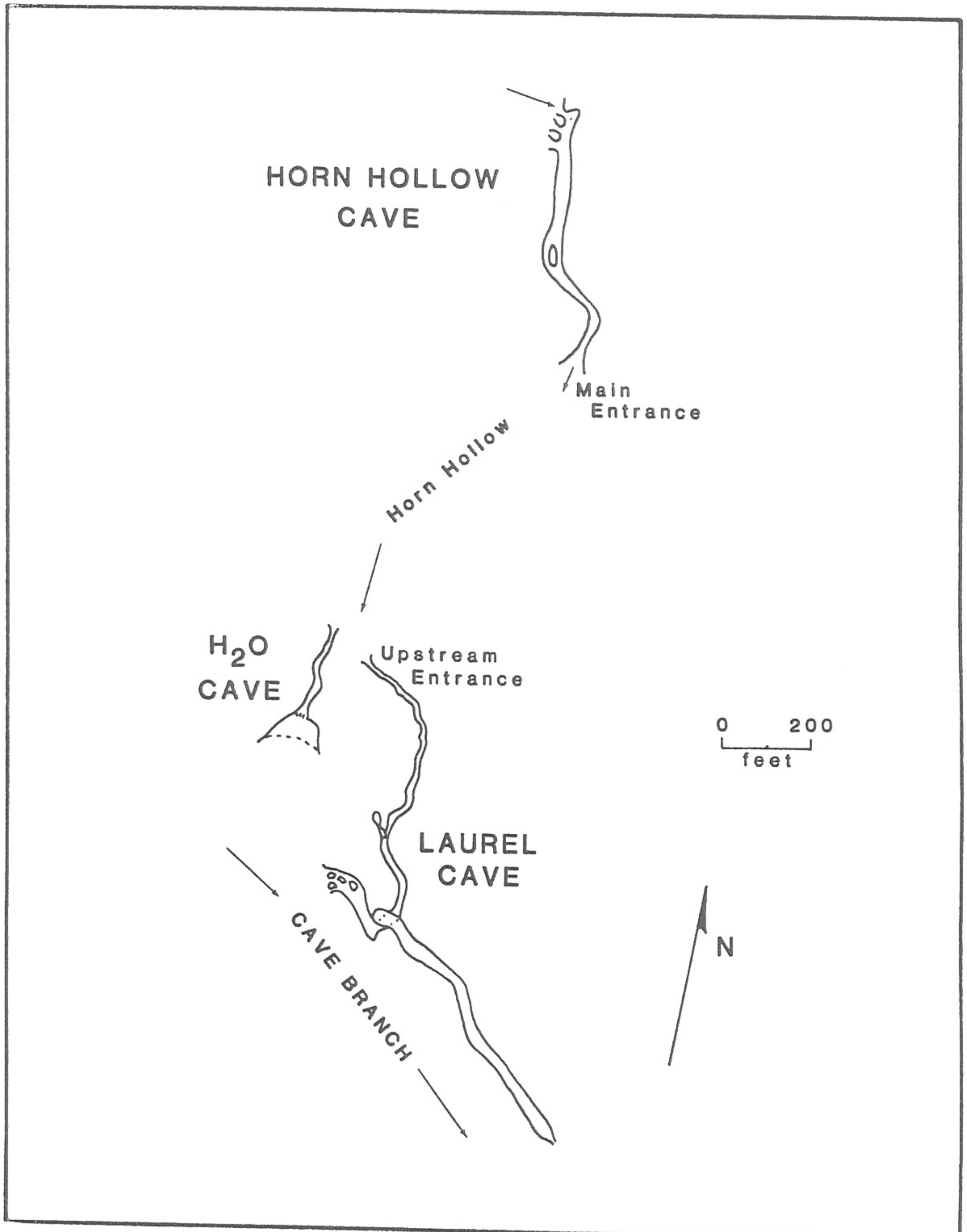


Figure 2: Southern part of Horn Hollow showing relative location of three caves (map redrawn from Keller: see text).

It is within Horn Hollow that the Horn Hollow Cave System is located. A series of subterranean passages is developed in the Ste. Genevieve Limestone and consists of two caves having four entrances and two "windows;" a total of 601m (1973 feet) has been surveyed. Rimstone Cave (also known as Boundary Cave) is the smaller of the two caves, having a total horizontal length of just under 100m and lacks an active stream. Horn Hollow Cave is considerably longer and is the penultimate subterranean route taken by water in Horn Hollow prior to joining Cave Branch (after flowing through Horn Hollow Cave most of the water passes through Laurel Cave and then merges with Cave Branch).

A map of Laurel and Horn Hollow caves produced by Robert Keller circa 1960 (see Fig. 2) and a description by McGrain (1966) indicated that Horn Hollow Cave was a tube-like stream passage that extended up the valley for approximately 180m. Our initial trip to the cave on 4 February 1984 was a pleasant surprise as it became apparent that not only was there considerably more than the stream passage but a crawlway lead to Rimstone Cave, the entrance to which we had done little more than enter on an earlier date.

Description:

The main entrance to the cave system is quite picturesque and is located in a 5.5m high limestone face (Fig. 3). The stream exits the cave at this point and flows into a surface pool and then disappears below the normally dry streambed to appear again in the upstream area of Laurel Cave (see Pfeffer et al. 1981). During periods of heavy rainfall flood waters exit Horn Hollow Cave, travel down the surface valley, and flow directly into the upstream entrances of Laurel Cave and also H20 Cave (Fig. 4).

The walk-in Horn Hollow Cave entrance is approximately 4.5m high; the floor rises steeply and withing 25m the height of the passage is reduced to 2m. The eliptical tube continues to the west and north with dimensions varying from 5 - 10m wide and from 1.4 - 2m in height until the upstream entrance is encountered. At this point the surface stream enters the cave and flows beneath breakdown (twenty meters south of the Upstream Entrance is an additional "stoop"

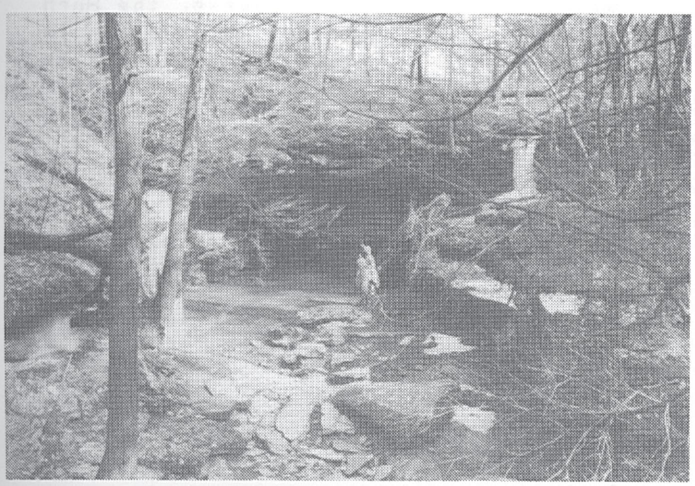
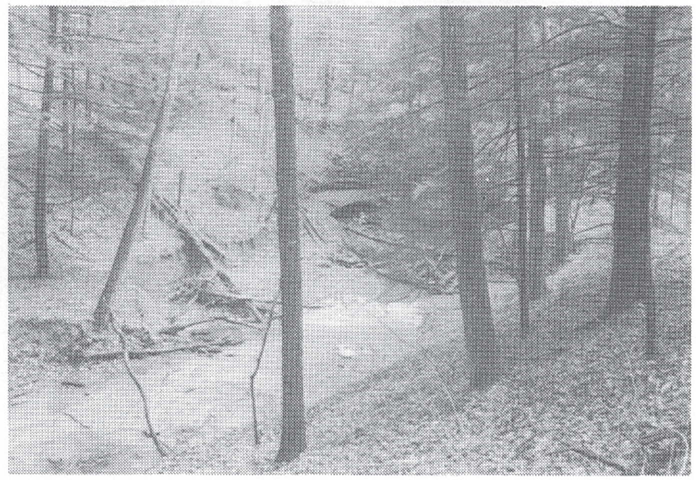


Figure 3: Main entrance to Horn Hollow Cave System.

Figuer 4: Dry bed of Horn Hollow and upstream entrance to Laurel Cave.



access to the cave marked "Entrance" on the map). A small tributary enters from a low crawlway to the north. The source of this small stream is in the top of Surprise Dome approximately 50m northeast of the Upstream Entrance. This is a 6m high dome and is the site of a future climb to gain access to an apparent small-sized upper level (the amount of overburden in this part of the ridge is minimal and it is unlikely that much additional cave will be found).

Approximately 60m south of the Upstream Entrance is a side recess extending 15m northwest from the main passage. The floor continually rises and this crawlway terminates in rubble with a "window" to the surface. This window (marked "hole to surface" on map) is in the bottom of a conspicuous surface sinkhole situated between the entrance to Rimstone Cave and the Upstream Entrance.

Approximately 65m north of the Main Entrance an elevated mud-floored passage joins the main stream level. This tunnel soon becomes a 0.5m high dusty crawl that is one of two connection routes to Rimstone Cave. The crawlway bends to the west and within 30m opens into Rimstone Cave proper. This point essentially represents a junction room as passages continue to the left (south), to the right (northeast), and directly ahead (northwest). The passage to the north of the crawlway soon is blocked with sediment fill but also a low, dusty tube loops back (east) to the crawlway. The passage to the south of the crawlway opens to a 1.3m high avenue that becomes a wet, muddy crawlway, terminating in a collapse room within 65m. This is the southernmost extension of the system and is at the edge of a hillside; a window overlooking the Main Entrance to Horn Hollow cave is located in the southeast region of this terminal passage (this might be an accessible entrance for very skinny people!!).

By returning to the connection crawlway one continues straight (northwest) and up slope to the sinkhole entrance of Rimstone Cave (Fig. 5). The sinkhole is about 10m wide and slopes steeply into the entrance room. A very tight crawlway extends beneath the entrance and connects to an upper-level hands-and-knee crawlway trending north. This is the second passage connecting the two caves; 30m from the Rimstone Cave entrance it bears to the east and intersects the main passage of Horn Hollow Cave.

A stoop passage to the right (west) in the entrance room of Rimstone Cave leads to a small room floored by a pool and with flowstone and rimstone decorating parts of the walls and floor. By climbing up a breakdown slope the upper level of the cave is intersected. To the south (left) the passage extends 25m as a muddy crawlway decorated with some columns, flowstone, and a prominent stalgmite and terminates in a small dome. To the north (right) a sandy-floored, generally 1m high avenue extends for approximately 55m to a speleothem-choked passage. This end of the cave has several columns and a spectacular series of small rimstone terraces (origin of name of cave - Fig. 6). In this upper level near the breakdown slope are two active domes, one of which supports a large, impressive mass of flowstone (Fig. 7). No passages are found in the upper section of these domes and water seeping from the surface drips continuously from them.

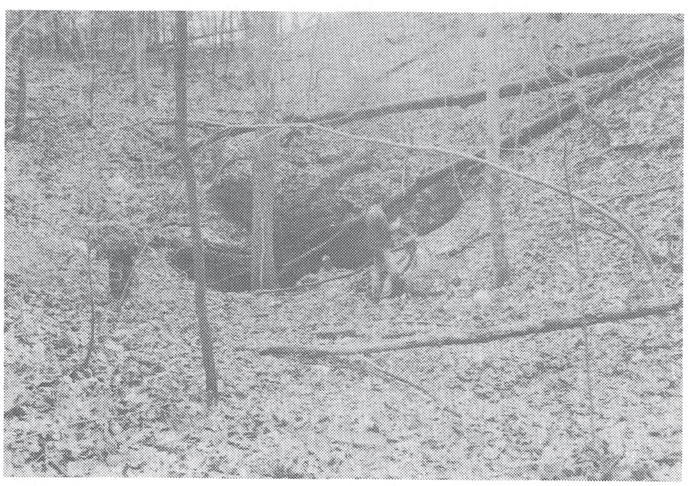


Figure 5: Sinkhole entrance to Rimstone Cave.

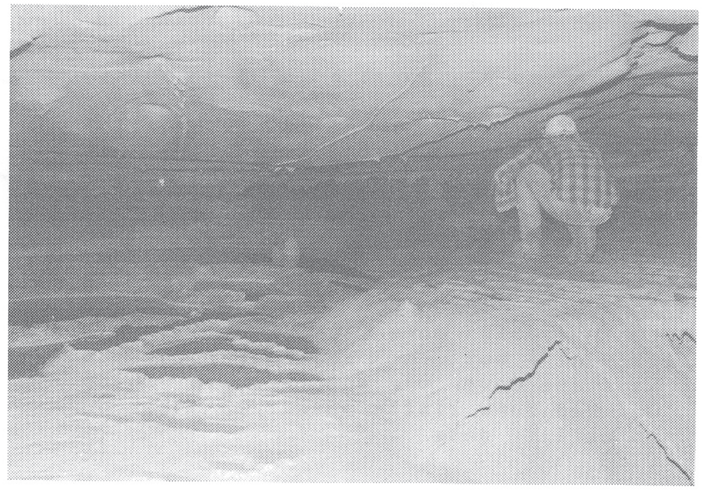


Figure 6: Rimstone terraces and pools in upper level of Rimstone Cave.

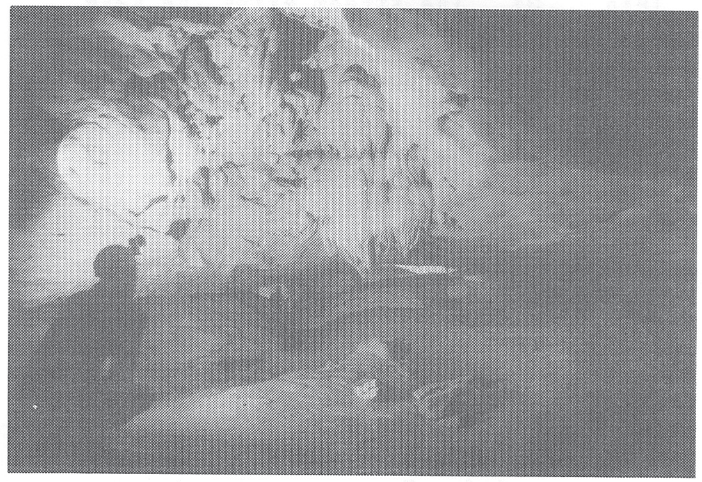


Figure 7: Dome with flowstone in upper level of Rimstone Cave.

Although not a lengthy or difficult cave to traverse, the Horn Hollow Cave System provides a diversity of passage types as well as a few good areas for photographic work. CAUTION: during periods of heavy rainfall, the Horn Hollow Cave portion of the system floods and should not be entered.

Numerous additional caves are found along Horn Hollow proper (e.g., Rhododendron Pit - see Hobbs 1985) and descriptions and maps of these will appear in future issues of Pholeos.

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We would like to thank the following members of the Wittenberg University Speleological Society for their help in the exploration and

Screaming Willie entrance to
Sloans Valley Cave, Kentucky

Frost Cave, Pike County, Ohio

Frying Pan Cave, Adams County,
Ohio

survey of the Horn Hollow Cave System: R. Baker, L. Brockhuis, R. Davenport, S. Flynn, T. Herp, T. Keller, N. Pfeffer, S. Rose, P. Simon, and W. Simpson. As always, John Tierney, Park Naturalist, was most helpful in numerous aspects concerning the continuing study of the caves within the Carter Caves State Park.

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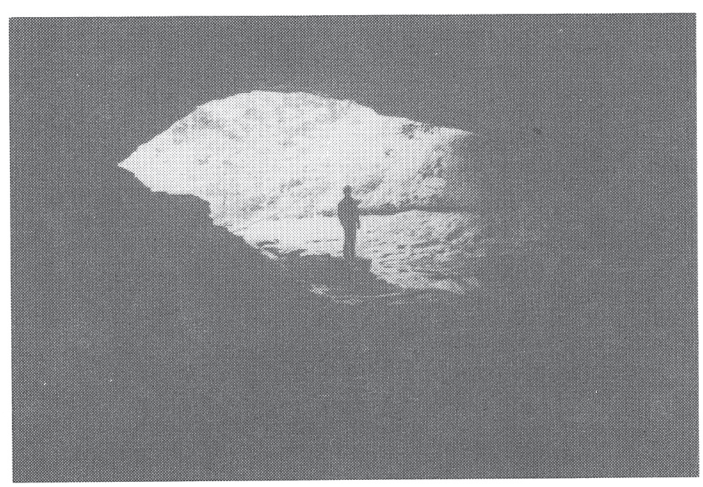
McGrain, Preston. 1966. Geology of the Carter and Cascade Caves area. Kentucky Geol. Surv. Sp. Publ. 12(Series X), 32pp.

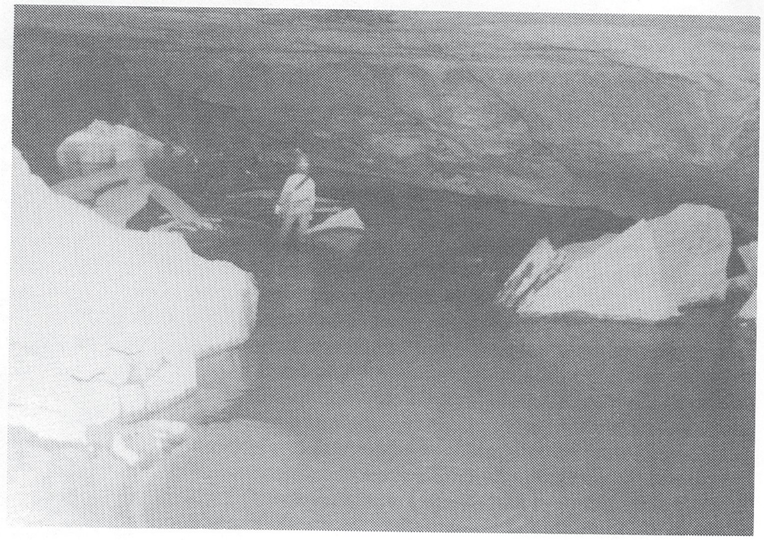
Pfeffer, Nathan, T. J. Madigan, and H. H. Hobbs III. 1981. Laurel Cave. Pholeos, 2(1):10-13.

Falls in entrance sink, Lost Creek Cave, White County, Tennessee

This is Melvin the Cave Cricket here to tell you to stay tuned! Freelands is coming in our next issue! If you miss it, five million of my cousins are going to splorp themselves all over your cars windshield!



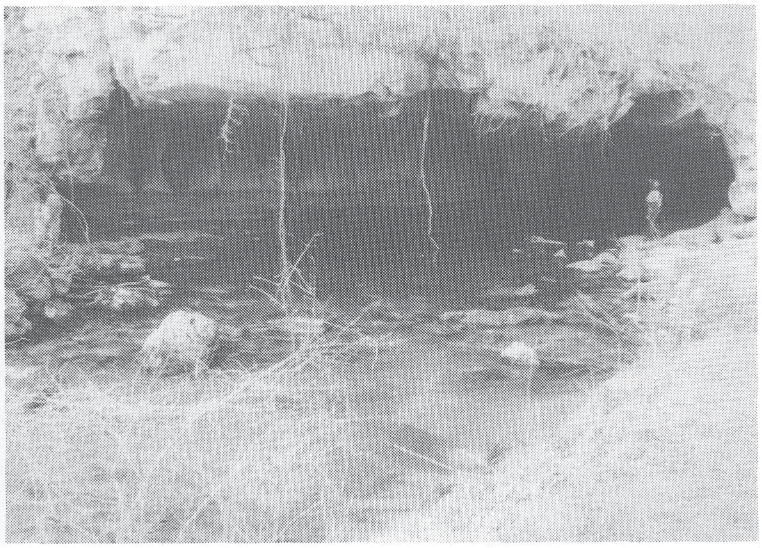
Natural Tunnel Cave, Carter County, Kentucky

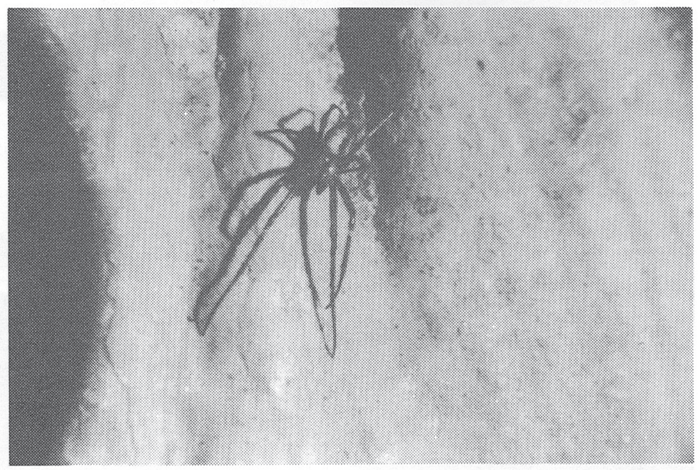


Mill Cave in Grassy Cove,
Cumberland County, Tennessee

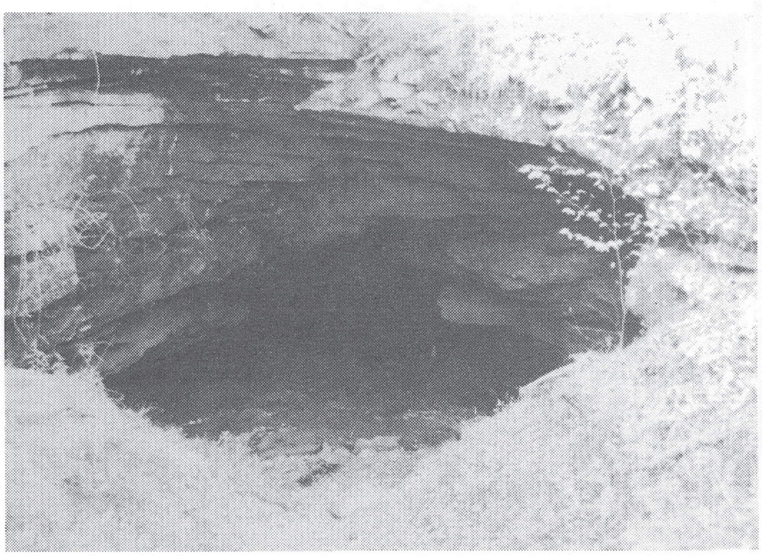
Russell Cave, Jackson County,
Alabama

Echo River Spring, Flint-Mammoth
Cave System, Edmonson County,
Kentucky





<u>Meta</u> <u>menardi</u> from White Cave, Edmonson County, Kentucky

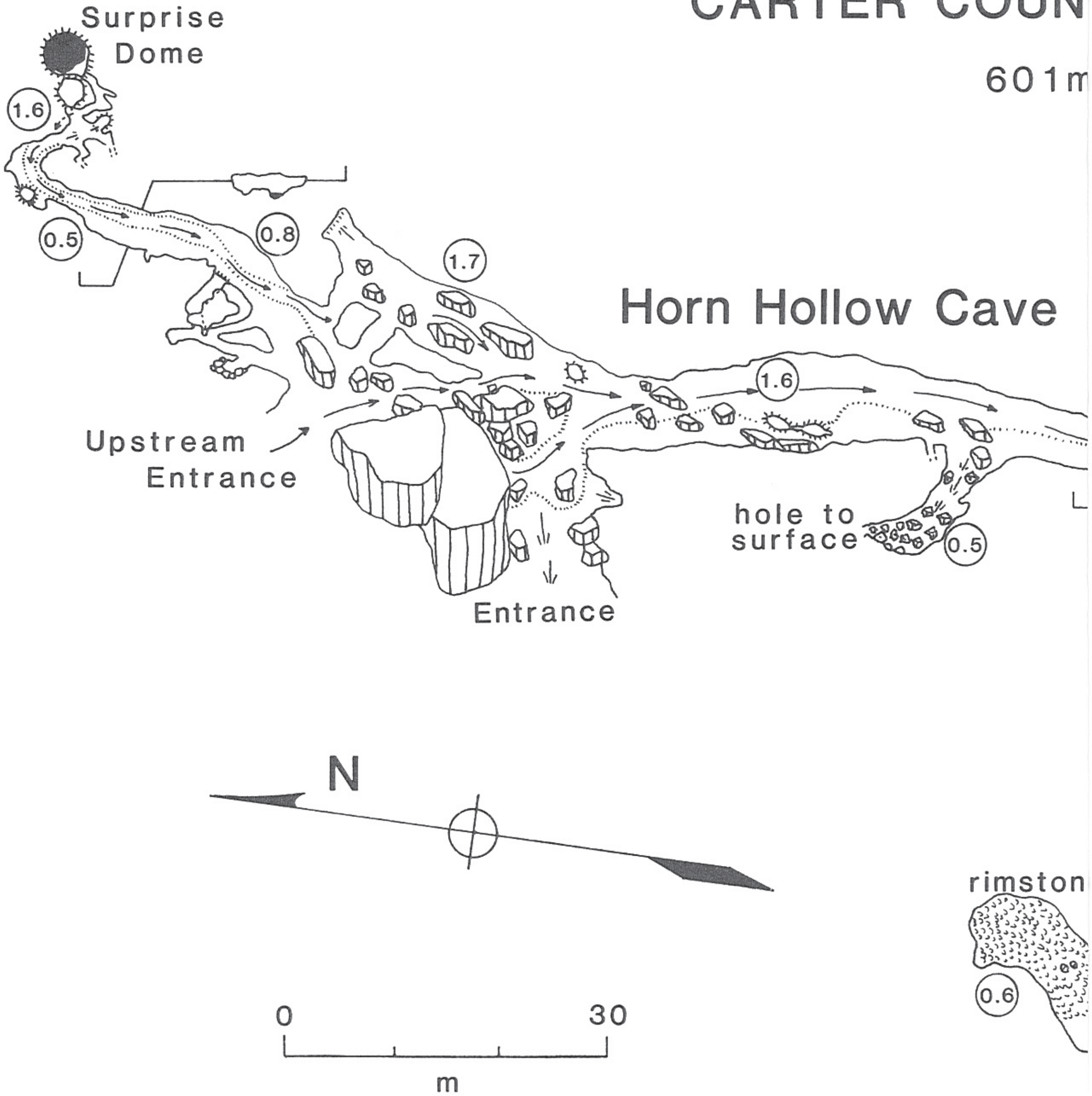


Mingo Cave I, Tishomingo County, Mississippi

HORN HOLLOW

CARTER COUN

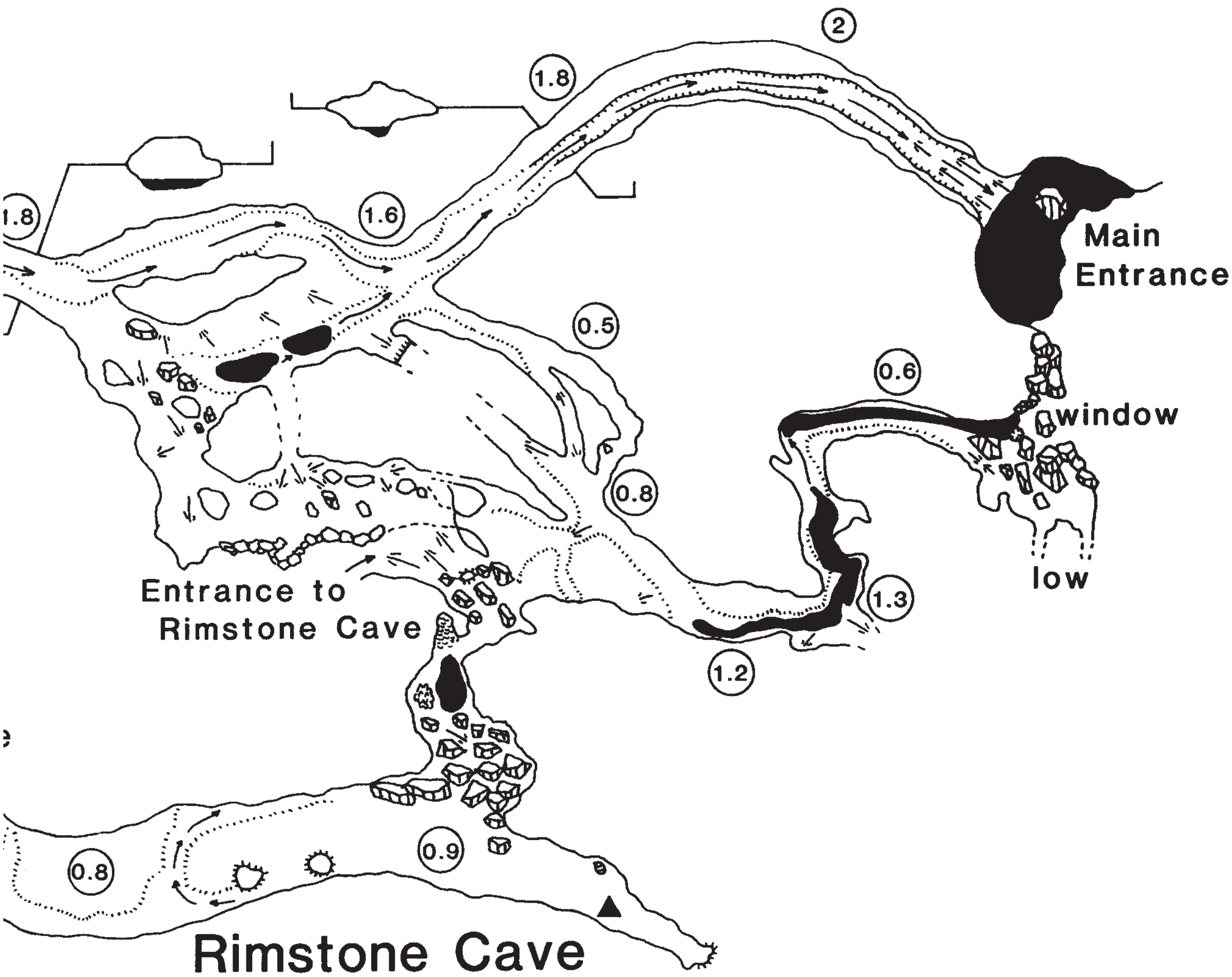
601m



CAVE SYSTEM

TY, KENTUCKY

THC



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HHH