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Contents

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DISCUSSION of papers published in the Bulletin is invited. Discussions should be 2000 words or less in length with not more than 3 illustrations. Discussions of papers in this issue should be forwarded to the editor by July 15, 1968.

Cave-Associated Herpetozoa II: Salamanders of the Genus Gyrinophilus in Alabama Caves

By John E. Cooper and Martha R. Cooper

ABSTRACT

Both *Gyrinophilus porphyriticus* and *G. palleucus* are found in the caves of Alabama, but occupy mutually exclusive ranges. *G. porphyriticus* is found north of the Fall Line Hills but is not known from within the range of *palleucus*, which is largely restricted to the Cumberland Plateau in Jackson County north of the Tennessee River. A single specimen of the latter species from a cave in Colbert County represents a 110 mile westward range extension for the species. This is the only known record from the Highland Rim and from south of the Tennessee River in Alabama. The aquatic cave communities containing *palleucus* differ markedly in species composition from those containing *porphyriticus*. The larvae of *porphyriticus* which feed in captivity have been seen to respond immediately and voraciously to mechanical stimuli and can become sight-conditioned to the presence of observers. A single *porphyriticus* adult responded to sight stimulus in feeding, but a single *palleucus* refused to feed and displayed much less reactivity to disturbing stimuli. The latter specimen displayed an average heart-beat rate 27-28% lower than that of comparable-sized *porphyriticus* larvae from caves, kept and tested under identical conditions.

INTRODUCTION

The genus *Gyrinophilus* contains two currently-recognized species (Brandon, 1966), the neotenic, cave-adapted *palleucus* and the epigean *porphyriticus*, both of which occur in the caves of Alabama. The latter is commonly associated with this habitat throughout much of its range, but is remarkably rare in Alabama caves. The purposes of this paper are (1) to report a range extension for *palleucus* into a geomorphic region from which it is unrecorded, in western Alabama, (2) to point out the spelaean and epigean distribution of *porphyriticus* relative to *palleucus*, and (3) to supply limited ecological and other information on both species from the cave ecosystem. ACS numbers refer to the Alabama Cave Survey system of identifying and locating caves (Tarkington, *et al.*, 1965). This system is more useful and accurate than simple naming, since many Alabama caves have the same or similar names, a fact which has resulted in past confusion. All of the measurements of animals which follow are first expressed as total length, with body length and tail length in parentheses. Body lengths were measured from the tip of the snout to the anterior border of the vent, since the posterior border is not as well defined in the specimens at hand.

DISTRIBUTION

Gyrinophilus palleucus – In the literature dealing with Alabama, *palleucus* has been reported only from caves in Jackson County in the northeast corner of the state. Thus it is known from Blowing Cave, which is the lower entrance of Sauta Cave, ACS #A50 (Lazell and Brandon, 1962; cave location corrected in Brandon, 1965); Saltpeter Cave, which is the upper entrance of Sauta (Brandon, 1966); Salt River Cave, ACS #A221 (McCrady,

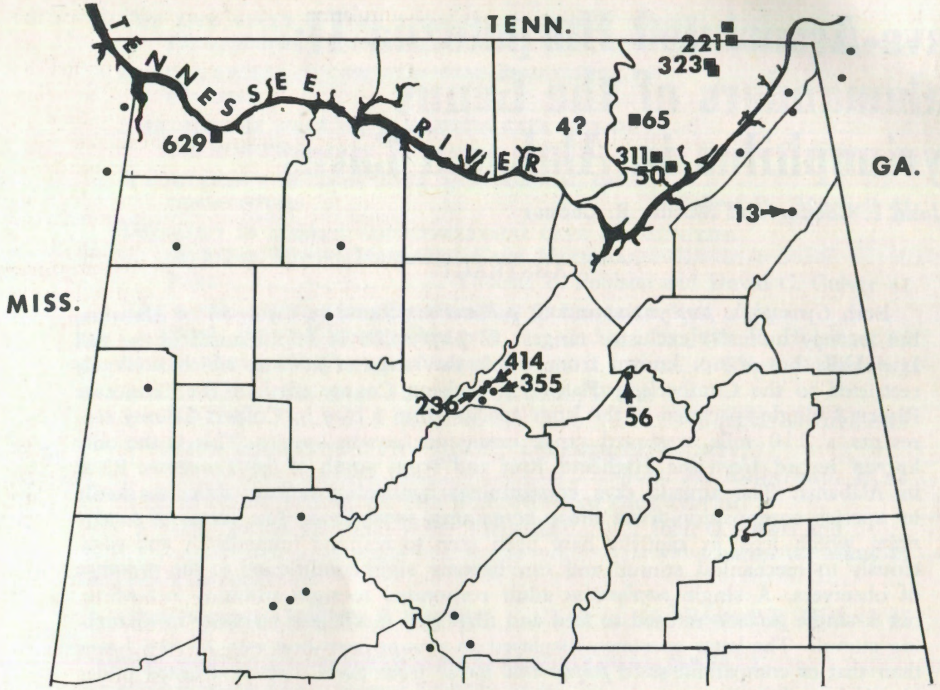

Figure 1.
Locality records for Gyrinophilus in Alabama and adjacent parts of Tennessee, Georgia and Mississippi. Circles are porphyriticus, squares are palleucus. Numbers are Alabama Cave Survey reference numbers (see text). The unnumbered palleucus locality in Tennessee is the type locality, Sinking Cove Cave; the unnumbered locality in Jackson County, Alabama, is a spring near "The Narrows," Tates Cove; and the questionable locality (No. 4) is Shelta Cave, Huntsville. Arrows indicate cave populations of porphyriticus.

1954); Jess Elliott Cave, ACS #A323; McFarland Cave, ACS #A65; and Lim Rock Blowing Cave, ACS #A311 (all Brandon, 1966). Sauta Cave is the southernmost known locality for *palleucus*. It lies on the southeast edge of the Cumberland Plateau (Cave Mountain) overlooking North Sauty Creek. Salt River Cave is a few miles southeast of Sinking Cove Cave, Franklin County, Tennessee, the type locality of *palleucus*. Its entrance lies in Jackson County, but most of the cave lies in Tennessee. Jess Elliott Cave is in Tates Cove west of Little Coon Mountain, in the drainage of Big Coon Creek. McFarland Cave is west of Bingham Narrows on Clear Creek, part of the Paint Rock River drainage. Lim Rock Blowing Cave is in Gentle's Cove at the head of North Sauty Creek.

On three occasions we have observed a large, gilled *Gyrinophilus* (cf. *palleucus*) in Shelta Cave (ACS # A4), Madison County (Cooper, 1965) but have been unsuccessful in capturing specimens. Ronald Altig (pers. comm.) has also observed this salamander in Shelta. The cave is about 18 miles west of McFarland Cave.

On April 2, 1967, we observed a specimen of what appeared to be the nominate subspecies in open daylight in a cave-spring pool near the entrance to "The Narrows," Tates Cove, Jackson County (Hytop Quad-

rangle). Brandon (1965) reported the subspecies *gulolineatus* from an epigean situation at its type locality in Tennessee.

Our discovery of a 118 mm (66 + 54) specimen of *palleucus* in McKinney Pit (ACS #A629), Colbert County, on April 16, 1966, extends the known range of the species about 110 miles into western Alabama. It also represents the first definite occurrence for this form in the Highland Rim, and the first record for the species from south of the Tennessee River in Alabama. The specimen was found on the edge of a large, irregular pool of water, 2.5 to 4 feet deep, well within the aphotic zone of the cave at a subsurface depth of about 60 feet. When high, the water here is very still with heavy, settled silt on the bottom. In times of intermediate water levels, however, this entire area changes. A small, running stream issues from under the wall, the silt level drops and the substrate becomes a coarse gravel-silt mixture. Until recently it was thought that the cave was little affected by surface-water fluctuations. On October 15, 1966, however, following a summer drought, water level in the cave had dropped at least 4 feet and most of the open pools had disappeared.

On March 31, 1967, the water in the cave was at an intermediate level and a second specimen of *palleucus* was observed under the ledge from which the slow-flowing stream was issuing. The specimen, which was discovered by David Kramer and then seen by the authors, managed to elude capture. It is interesting to note that the original specimen from this cave was found during high water on a ledge about 2 feet directly above this point and, when disturbed, headed straight towards an opening under the ledge.

The new locality is in a timbered sink on the edge of an abandoned pasture. It is bounded some 600 yards to the north by the Tennessee River, 870 yards to the west by Dry Creek, and 2730 yards to the east by Little Bear Creek. The 30-foot entrance is about 230 yards from the nearest surface stream draining Dry Creek, and 530 yards from one emptying directly into the river (all distances estimated from topographic maps). Both the sink and the bottom of the pit contain large amounts of debris, indicating that surface runoff water occasionally enters the cave. There is no accumulation of organic debris in the cave water, however.

Lazell and Brandon (1962) interpreted the Blowing Cave (=Sauta) population as being intermediate in coloration and number of trunk vertebrae between the nominate subspecies *palleucus* and the subspecies *necturoides* of Grundy County, Tennessee. Brandon (1966) sees the Jess Elliott Cave population in the same light. The single juvenile collected by us on April 14, 1965 in McFarland Cave, which was the westernmost verifiable locality for *palleucus* prior to this paper, and juveniles from Lim Rock Blowing Cave collected on August 17, 1965 by Stewart Peck, are unidentifiable as to subspecies. The living salamander from McKinney Pit was salmon-pink dorsally and colorless ventrally, but it was noticably darker than the nominate subspecies and in this respect resembled *necturoides*. Until other specimens from this population are available, no further taxonomic comments can be made. The gills were quite long and brilliant scarlet in appearance, since the rami completely lacked the dark pigment markings seen on the rami of cave-dwelling *porphyriticus* larvae of a comparable size. In preservative, however, melanophore concentrations are visible on the rami.

Gyrinophilus porphyriticus – In Alabama, *porphyriticus* appears to be widely distributed in upland areas above the Fall Line Hills, but is known exclusively from epigean populations (fig. 1). Brandon (1966) lists 15 surface localities for the species from 11 different counties, while recording only one cave occurrence, McClendon's Cave (ACS #A56), just northwest of Whitney, St. Clair County. This latter record is based on two adults measuring 190 mm (106 + 84) and 157 mm (92 + 65), and a large branchiate specimen, all collected by Dr. J. D. McClung and presently in the collection of Dr. T. C. Barr, Jr., University of Kentucky. Brandon also lists a specimen from Ft. Payne, Dekalb County, but does not mention that it was collected at Manitou Cave (ACS#A13). It is a 143 mm (83 + 60) adult taken on April 2, 1955 by Dr. Barr. To Brandon's localities may be added Rock Bridge Canyon, Franklin County, where Richard Franz and David Kramer collected two very large branchiate individuals on March 27, 1967.

New Alabama cave populations of this species have been found, all in southwestern Blount County. On December 31, 1965, we collected a 62 mm (33 + 29) larva, and observed another of comparable size and a third considerably smaller, in Randolph Cave (ACS #A414) on the west bank of Mill Creek southeast of Blount Springs. The larger specimens were under small stones in a shallow, gravel-bottomed stream, and the small individual was in the open in about 6 inches of water. Richard Franz and Herbert Harris, Jr. visited the same cave on March 11, 1966 and found a 172 mm (107 + 65) adult under a large rock not very far inside the cave. On April 11, 1966 the authors, assisted by John E. Cooper, Jr., revisited the cave and collected two larvae, one 11 mm (61 + 50) and the other 25 mm (16 + 9). On our last successful trip to this cave, on July 7, 1966, we collected a 31 mm larva (approx. total length).

On April 12, 1966, again accompanied by J. E. Cooper, Jr., we captured a 119 mm (66 + 53) larva in a quiet pool about 2 feet deep in the lower, stream-passage section of Bryant Cave (ACS #A355). Another, slightly smaller specimen was observed in a similar nearby pool of the same stream. A great deal of water was flowing through the cave on this date.

A single larva, probably of this species, was observed in a small but deep body of standing water known as Crystal Lake in Rickwood Caverns (ACS #A236) by Harris and Franz on March 11, 1966. Two successive efforts on their part to capture the animal were unsuccessful, and a trip to this cave by the authors on April 12, 1966 failed to turn up the species. Rickwood Caverns and Bryant Cave are practically on an east-west line less than 1.5 miles apart, two to three miles southwest of Randolph Cave.

Summary of distribution – Current knowledge of the distribution of these salamanders in Alabama indicates that not only is *porphyriticus* absent from caves within the range of *palleucus*, where it logically could not compete with the better adapted troglobite, but also that the two forms occupy totally exclusive ranges. There is only one authenticated record for *porphyriticus* from Jackson County, a specimen from Long Island Creek near Higdon, collected by Dr. B. D. Valentine (Brandon, 1966). An old record from "Sand Mountain," Jackson County (Holt, 1924) is cited in Dunn (1926) and was probably the basis for Bishop's (1947) inclusion of Alabama on his range map for the species. The specimens collected by Holt were apparently deposited in the Biological Survey collections in the U.S. National Museum, but cannot be located (Dr. James A. Peters, pers. comm.). Both the Holt and Valentine localities are east of the Tennessee River and outside the known range of *palleucus*. There are no *porphyriticus* records from Colbert County, although Ferguson (1961) reported the species from nearby Tishomingo County, Mississippi, and we have recently (March 17, 1967) taken it there also, along U.S. Highway 72 southeast of Iuka.

As previously mentioned, *porphyriticus* is decidedly rare in the cave habitat in Alabama as compared to its incidence in caves of Kentucky, West Virginia and Virginia, where it appears to be much more frequent and numerous in caves than above ground. In Alabama, however, it is not impossible that this situation is more apparent than real, since systematic investigation of the biota of Alabama caves is far from complete. This fact may also account for the apparently discontinuous range of *palleucus*, which currently exhibits a considerable hiatus through the scarce-investigated limestone areas of north-central Alabama and adjacent Tennessee. In this respect, it is of interest too that there are as yet no records for *porphyriticus* from Lauderdale, Limestone, Madison, Marshall, Morgan or northern Lawrence Counties. One or the other of the two species should show up in these areas.

Ecological Associates

The communities containing *palleucus* differ markedly in species composition from those containing *porphyriticus*, especially in troglobite members. In all of the caves of the Cumberland Plateau in Jackson County where it has been found, *palleucus* is associated with two widespread troglobites, the crayfish *Orconectes pellucidus australis*, the adults of which are the largest and most abundant members of the aquatic communities, and the isopod *Asellus alabamensis*. In many of the Jackson County caves, and in Shelta Cave, the blind fish *Typhlichthys subterraneus* occurs. This is true also of McKinney Pit in Colbert County. Here, too, there is a cave isopod, as yet unidentified, and a crayfish fauna consisting of a new troglobitic form presently being described by Dr. Horton H. Hobbs, Jr., a troglobitic *Cambarus* (cf. *jonesi*) and a very large, pigmented and eyed *Cambarus* (cf. *cahni*) which is the largest and most abundant animal in the cave. Two days after collection of the *palleucus* from McKinney Pit it expelled the exoskeleton of a small crayfish chela, apparently from a juvenile of the pigmented *Cambarus*.

In McFarland Cave, *palleucus* is associated with a troglobitic amphipod of the genus *Crangonyx* (*antennatus*) group). In Shelta, in addition to *O. pellucidus*, there are two species of troglobitic crayfishes, *Cambarus jonesi* and a new *Orconectes* which we are currently describing elsewhere. The community in this cave also includes an unidentified troglobitic flatworm and an amphipod (Stewart Peck, pers. comm.). The salamanders *Eurycea lucifuga* and *Plethodon g. glutinosus* have been found in all of the *palleucus* caves, but only the aquatic larvae of the former could constitute important food items. *Pseudotriton r. ruber* has been taken in Lim Rock Blowing Cave by Stewart Peck, and larvae of this form were found in the stream flowing from McFarland Cave by Richard Franz and David Kramer. We found larvae of this species to be extremely abundant in the previously-mentioned cave-spring near Tates Cove, along with *Desmognathus f. fuscus*, *Eurycea b. bislineata* and a single, large *Rana catesbeiana*.

In the Blount County caves, *porphyriticus* is associated with an aquatic troglobitic isopod of the genus *Asellus*, and an undescribed amphipod of the genus *Stygobromus* (*exilis* group). In Randolph Cave and Rickwood Caverns there is a scarce troglobitic crayfish of the genus *Cambarus* (cf. *hamulatus*). In Bryant Cave there is a large population of epigean crayfish, *Cambarus striatus*, which has also been taken from Rickwood. The adult *porphyriticus* collected in Randolph Cave by Franz and Harris expelled partial appendages of a troglobitic crustacean, either a crayfish or an isopod. The terrestrial fauna of this cave is quite rich, both in diversity of species and abundance, including phalangids, spiders, isopods, millipedes, pseudoscorpions, crickets and other invertebrates. The salamanders *P. g. glutinosus*, *E. lucifuga* and *E. longicauda guttolineata* are also found here in number.

Miscellaneous Observations

In captivity, the 62 mm *porphyriticus* larva taken in Randolph Cave on December 31, 1965, fed readily and voraciously on enchytraeid worms. It reacted immediately to anything which touched the water and would even bite bare forceps, thus suggesting that mechanoreception is more important in feeding responses than chemoreception or sight in these larvae. Worms were snapped from forceps or sucked from the water by a quick pharyngeal intake. Surface feeding was accompanied by a loud popping noise. After several days in captivity this larva would detect and react to a person entering the room several feet away by moving alertly to the near rim of the bowl. This behavior was observed both during hours of daylight and when an artificial white light was turned on in the animal room. The large adult from Randolph Cave also ate readily from the beginning, responding by sight and picking food (tenebrio larvae and adults, earthworms, enchytraeids) from forceps or the side of the bowl with explosive thrusts of the tongue. The eyes receded deeply when swallowing. All of the Randolph larvae maintained in captivity ate readily, employing the same technique as the one mentioned above. The larva from Bryant Cave, however, would not eat at all during the seven weeks of captivity. When disturbed, it would roll over and over and thrash its body from side to side.

The *palleucus* from McKinney Pit consistently refused all offers of food, and responded to no stimulus tried except direct touch. This same specimen showed an average heart-beat rate 27-28% lower than that of two comparable-sized *porphyriticus* larvae collected about the same time from Alabama caves and kept under the same conditions following capture. The rate was measured in each case at a water temperature of 25 degrees C. by the unsophisticated technique of counting the number of erythrocyte surges per minute through gill and foot capillaries viewed under a dissecting microscope. Further observations on the comparative physiology of these salamanders are contemplated.

ACKNOWLEDGEMENTS

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This paper is Contribution Number 2 from the Biological Survey of Alabama Caves, a research project of the National Speleological Society.

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Institute of Speleology and Dept. of Zoology
Univ. of Kentucky
Lexington, Kentucky 40506

and

Dept. of Biochemistry
Univ. of Kentucky
Lexington, Kentucky 40506

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The Role of Gravity Sliding in the Development of Some Montana Caves

By Newell P. Campbell

ABSTRACT

Recent studies of high mountain caves in Montana indicate that a surprising number of these caves have been formed by gravity sliding. Massive limestones resting on shale have been deeply dissected by erosion, allowing large blocks to "slide" down dip. Where these blocks break from the main mass, deep fissures are formed. Caverns formed in this manner show almost no solution features and their longitudinal axes usually parallel nearby cliffs.

Many other vertical caves in Montana, long thought to have been formed entirely by solution, occupy positions paralleling walls of deep canyons. Gravity sliding may have been the force responsible for initiating development of these caves before normal solution enlarged them.

INTRODUCTION

The majority of caves found in Montana and northern Wyoming are located at elevations of 4,000 to 9,000 feet, in carbonate rocks that cap or rim isolated mountain ranges. About sixty percent of these caverns can be classified as vertical and significant numbers of them contain no horizontal passages. Many seem to be narrow and "crack-like" fissures rather than the randomly oriented solution pits normally associated with sinkhole and karst topography.

Investigations from 1960 to 1966 show that a number of these "caves" are directly formed by gravitational sliding. Others may be indirectly formed by a sliding process.

FISSURES DIRECTLY FORMED BY SLIDING

Montana mountain ranges such as the Little Belts, Big Snowy, Pryor, and Mocassin mountains are capped or flanked by limestones of Mississippian and Cambrian age (fig. 1). Many of these massive units are dissected by deep canyons exposing vertical limestone cliffs up to 1000 feet in height. In some cases, especially in Cambrian formations, a thick massive limestone rests on shale. Where this condition exists, it is not uncommon to find deep vertical caves which reach depths of over 200 feet. These fissures are often located roughly parallel to an adjoining cliff face and as far as one-half mile behind it. The fractures generally become narrower with distance from the escarpment.

Figures 2 and 3 show the relationship between the fissures and cliff face. Separated and broken blocks of limestone lying on shale near the escarpment grade to talus with distance down dip. Some large blocks have moved only a short distance from the cliff face. A map of a typical fissure system (fig. 4 which has been explored to a depth of 220 feet reveals slumping in two directions. Two sets of cracks intersect at nearly right angles. Surface depressions allow individual fractures to be recognized at the surface where underground explorations is not possible. These fissures have "roofs" which are caused by debris consisting of vegetation and small limestone blocks falling into the top of the crack and sealing it off. This is partially caused by the collapse of the upper 5 to 10 feet of the walls. The resulting depressions can be traced along the ground surface.

Descending these fissures, one often reaches the shale-limestone contact. Some solution ac-

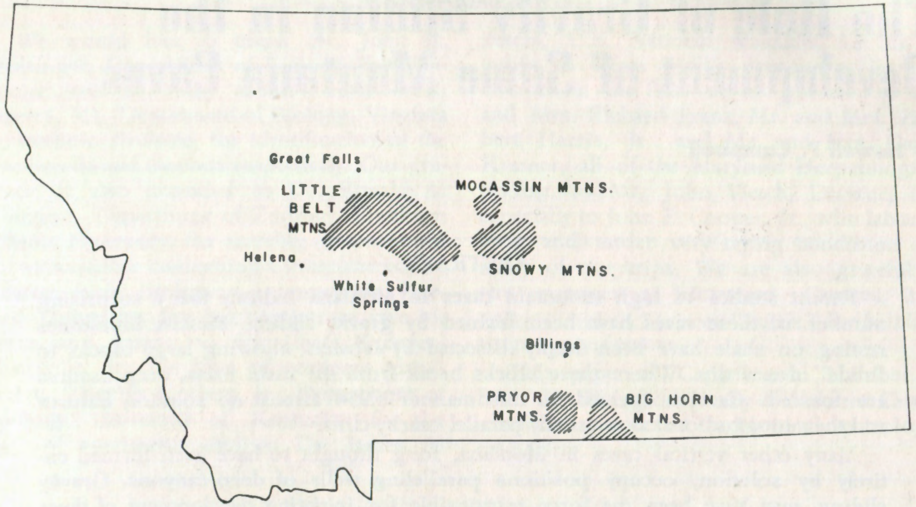

Figure 1.
Location map of Montana.

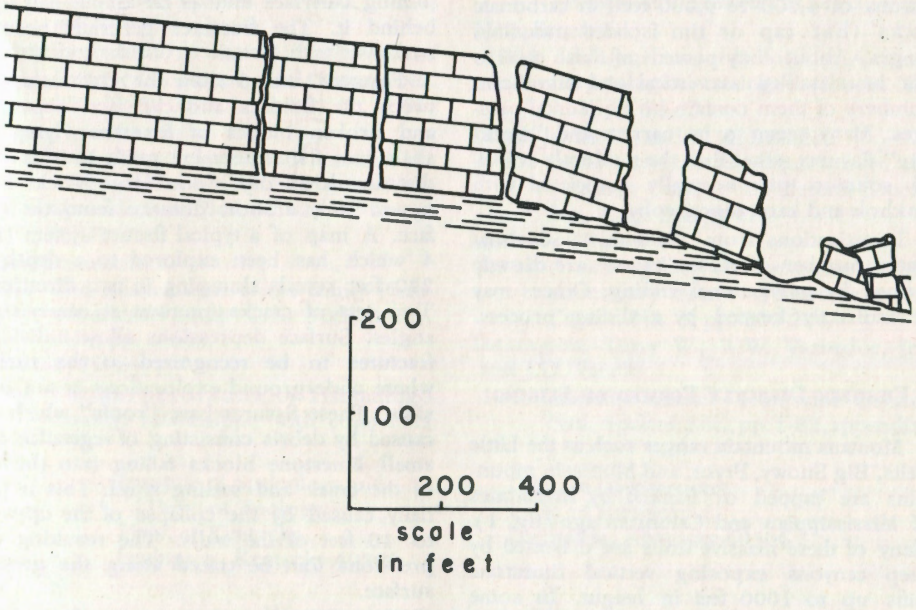

Figure 2.
Cross section showing formation of vertical cracks and fissures by gravity sliding.

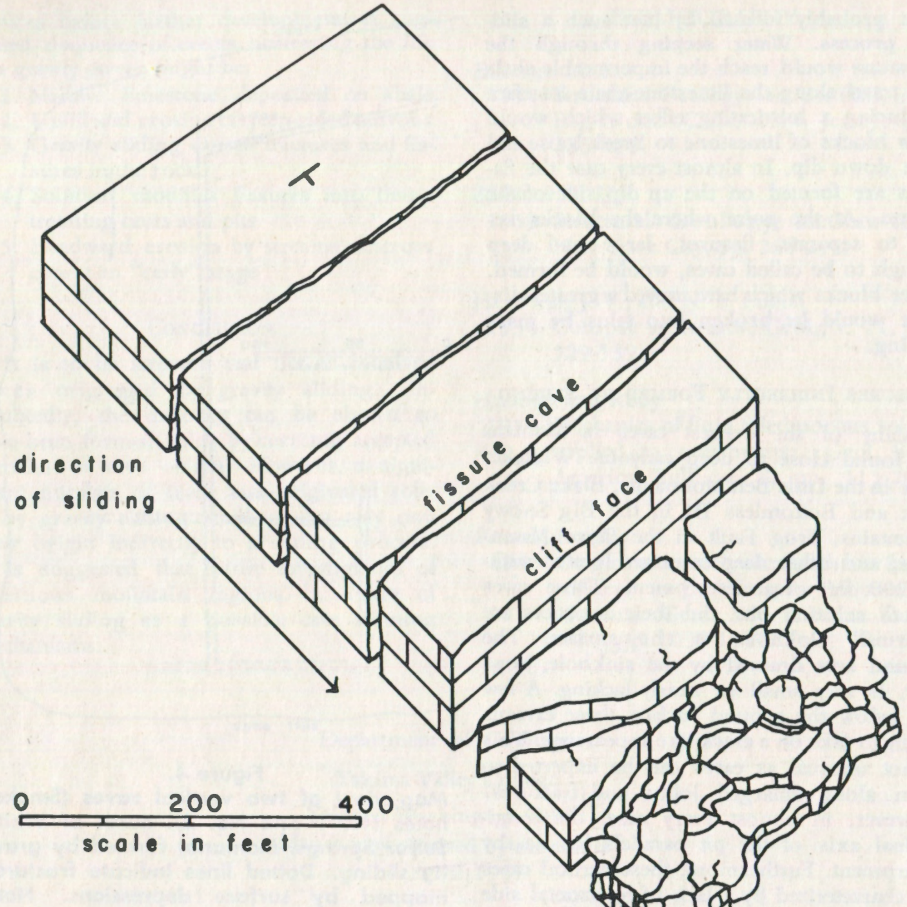

Figure 3.
Idealized view of fissures formed by gravity sliding showing parallel alignment of fissures and escarpment.

tivity is evident in the fissure walls but is only secondary in the development of these caves. The primary force responsible for opening these fissures has been the gravitational sliding (and breaking) of massive limestones along a lubricated shale surface.

Many authors have recognized gravity sliding as a non-tectonic force capable of moving large masses or rock. Reeves (1946) explains a series of shallow thrust faults radiating 25 miles out from the Bearpaw Mountains, Montana, as due to gravity sliding of a mass of igneous rock. Harrison (1934) describes many examples of "collapse structures" – overturned beds, landslides, and slumping – all caused by gravity sliding. Hubbert and Ruby (1959) have applied fluid mechanics to the problems of moving large masses of rock long distances. They point out that a body of rock lubricated and partially buoyed up by water will travel along a surface having a dip of only one or two degrees.

The cave in figure 4 and others like it

were probably formed by just such a sliding process. Water seeping through the limestone would reach the impermeable shale and travel along the limestone-shale interface producing a lubricating effect which would allow blocks of limestone to break loose and slide down dip. In almost every case the fissures are formed on the up dip side of the canyon. At the point where the blocks began to separate, fissures, large and deep enough to be called caves, would be formed. Other blocks which have moved a greater distance would be broken into talus by mass wasting.

Fissures Indirectly Formed by Sliding

Many of the deepest caves in Montana are found close to deep canyons. Whitaker Sink in the Little Belt Mountains, Blake Creek Sink and Bottomless Pit in the Big Snowy Mountains, Frog Fault in the Pryor Mountains, and other deep caves are located within 200 feet of an escarpment. These caves are all solution pits and their entrances are "normal" sinkholes at the surface. The ground area drained by the sinkhole, however, is very small or nearly lacking. A few feet below the ground surface, these caverns begin to take on a crack-like appearance. This is not unusual as caves can be expected to form along enlarged joints and fractures. However, in almost every case, the longitudinal axis of the pit parallels the nearby escarpment. Furthermore, these vertical caves are characterized by a lack of horizontal side passages; most of these caves consist of a single vertical drop with no side leads. If side leads are encountered they invariably follow the fissure-escarpment directional trend.

After studying these fissure caves one obtains the distinct impression that they must in some way be related to topography and nearby steep-sided canyons. Although at this time conclusive proof is lacking, it is suggested that gravity sliding of limestone blocks has been responsible for creating open fissures which were subsequently modified and enlarged by processes of solution.

A gravity sliding theory would then explain: 1) the preferred orientation and "crack-like" nature of the caves and, 2) lack of well developed horizontal passages.

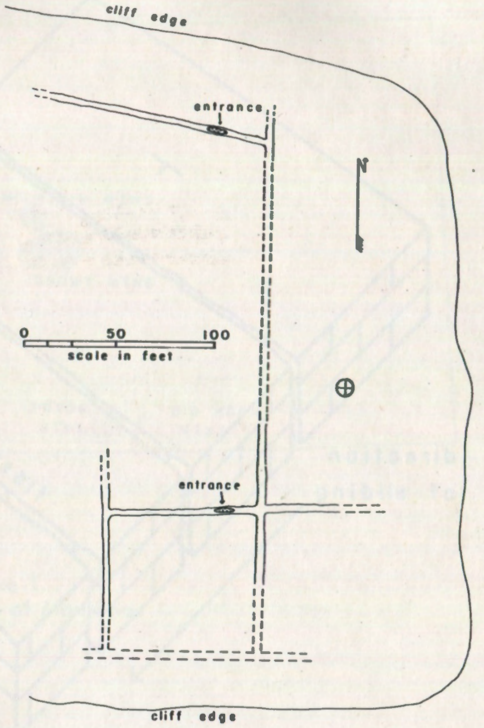

Figure 4.
Map view of two vertical caves (Smokeholes No. 1 and No. 2), north of White Sulfur Springs, Montana) formed by gravity sliding. Dotted lines indicate fractures mapped by surface depressions. Note parallel alignment of cliff face and fracture pattern. Depth of this fissure system reaches nearly 220 feet.

Horizontal passages would not be expected to develop for several reasons. Because the limestone has been extensively dissected by erosion, only a small amount of surface water would be available for solution. Also, water would enter the "gravity' opened" fractures and follow the linear trend already established. Caves which do exhibit a normal network of horizontal passages are generally situated on undissected plateaus with larger drainage areas. The Pryor Mountains of Montana are a good example. It is also probable that headward stream erosion and continued sliding may destroy many gravity

fissures before further development. A suggested dequence of events portraying the life of a gravity cavern might be:

1. Massive limestone deposited on shale
2. Uplift and erosion of steep-sided canyons
3. Gravity sliding causes fractures and fissures in the rock
4. Solution modifies fissures into linear trending caves and pits
5. Headward erosion by streams destroys cave at an "early" stage

Conclusion

It is to be stressed that not all Montana caves originated by gravity sliding. Undoubtedly, the majority can be shown to have been formed solely by currently accepted theories of cave origin. However, a significant number of caves have originated solely by gravity sliding while others may owe their origin indirectly to a sliding process. It is suggested that future investigators of cavernous mountain regions be aware of gravity sliding as a possible cave forming mechanisms.

Department of Geology
Yakima Valley College
Yakima, Washington 98901
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Proceedings of the Society

MEETING IN BIRMINGHAM, ALABAMA, JUNE 1967
BIOLOGY SESSION

THE OCCURRENCE OF PROTOZOA IN CAVES, WITH SPECIAL REFERENCE TO PINE HILL CAVE, ROCKCASTLE COUNTY, KENTUCKY

James R. Reddell and Stephen M. Gittleson
Department of Zoology,
University of Kentucky,
Lexington, Kentucky

Although cave Protozoa were first described from Mammoth Cave, Kentucky (T. A. Tellkampf, 1845, New York, J. Med., 5:84-93), only about 25 species of the more than 250 species known from caves throughout the world have been reported from North America to date. An examination of water from six stations in Pine Hill Cave, Rockcastle County, Kentucky, on April 9, 1967, revealed the presence of at least 21 species of Protozoa, including six organisms not reported previously from North American caves. The cave waters contained between 11 and 900 microorganisms per ml, while a surface stream which feeds the cave stream contained between 9,000 and 13,000 organisms per ml. Small flagellates and ciliates were the principal inhabitants of the cave stream, while diatoms and other algae constituted more than 90% of the non-bacterial surface stream microbiota.

Water temperature of the surface stream was 18.0°C, while the cave stream temperature was 11.1°C. Chemical analysis showed that cave and surface waters contained no free CO_2., had a pH of about 8.0, and contained 13.4 to 14.6 and 16.2 ppm of dissolved oxygen respectively. Absence of solar energy apparently plays a major role in determining the number of species which can survive in the cave. Further identification of North American cave Protozoa in comparison with surface forms is needed in order to determine if troglobitic Protozoa exist.

SEASONAL ABUNDANCE OF THE GROTTO SALAMANDER, *TYPHLOTRITON SPELAEUS*, CORRELATED WITH REPRODUCTIVE ACTIVITY

Ronald A. Brandon,
Southern Illinois University,
Carbondale, Ill.

Presented by title only.

NATURAL HISTORY OF ALABAMA CAVE PTOMAPHAGUS BEETLES: A PROGRESS REPORT

Stewart B. Peck
Biological Laboratories,
Harvard University,
Cambridge, Mass.

Most of the cave beetles of the United States belong to the families Carabidae, Catopidae, and Pselaphidae. All three families contain representatives living in Alabama caves. Of these, the catopid genus *Ptomaphagus* is the most abundantly available for study. Seven troglobitic species are known from a total of 55 Alabama caves, and two troglobitic species from 12 caves.

This paper is a summation of the past three years of study of the troglobitic Alabama *Ptomaphagus.* A map is presented showing the ranges of the species and their relationship to the regional topography. Data gained from populations in Cathedral Caverns and Barclay Cave indicate that the first few hundred feet of a cave supports the largest populations. The beetles apparently feed upon yeasts or fungi growing in this section of the cave. Salamanders are the only presently known predators of the beetles. Parasitic fungi of at least two types can take a heavy toll of the populations.

The biology of the cave populations, as inferred from trapping, is compared with populations grown in the laboratory. Preliminary data are presented on the life cycle stages of individuals raised in a laboratory cold box. This data is compared with some known life cycles of European cave catopids.

DISCOVERY OF THE FIRST NORTH AMERICAN BLIND TRECHINE BEETLE FROM AN EPIGEAN ENVIRONMENT

Thomas C. Barr, Jr.,
Institute of Speleology,
University of Kentucky,
Lexington, Ky.

Although blind, depigmented trechine beetles (Carabidae, Trechini) have been known for many years from deep soil environments in mountainous regions of Europe and Japan, the first North American species was not discovered until April, 1967. It is an undescribed species of *Pseudanophthalmus* closely related to *P. fuscus* Valentine, a cave species from the Greenbrier valley of West Virginia. The new epigean species occurred under stones embedded in wet gravel beside a small brook at the southeast corner of Kennison Mountain, near the Cranberry Glades, elev. 1000 m., Pocahontas County, West Virginia. Three specimens were obtained. Since the locality is 200 m above and 7 km from the nearest limestone exposures, and is in a different drainage system, the possibility is precluded that the beetles washed from a cave. The new species is additional evidence that many of the regressive evolutionary modifications of cave trechines may have occurred first during adaptation to life in humus and upper soil strata in cool forests, prior to colonization to caves.

HABITAT DIVERSITY IN NORTH AMERICAN SUBTERRANEAN AMPHIPODS OF THE FAMILY GAMMARIDAE

John R. Holsinger,
Dept of Biology,
East Tennessee State University,
Johnson City, Tenn.

North American subterranean amphipods of the family Gammaridae occupy a number of distinct but closely related habitats which can be grouped into three broad categories: (1) caves and associated solution channels and fissures developed in limestone and dolomite; (2) interstices developed in metamorphic and other non-carbonate rocks and in overlying mantle deposits; (3) interstices developed in loosely consolidated sedimentary deposits. Although observations and collecting have revealed that occupancy of a particular type of groundwater biotope may depend to some extent on geographic distribution, few species have been found in more than two of the three major habitats given above, and only about 20 percent of all presently recognized subterranean species occur in as many as two of the three groups. Those species which occur in predominantly limestone regions are seldom found outside of these regions and are most often encountered in cave waters.

Of the approximately 85 presently recognized subterranean species (including both described and undescribed species distributed unequally among seven genera), about 50 are known exclusively from caves, 14 exclusively from seeps and springs, and 16 from caves, seeps, and springs. Approximately five species are known only from collections made from wells and are not included in the above breakdown.

In caves, amphipods are either found in small, shallow, mud-bottomed pools frequently fed by seepage and/or drippage, or in relatively shallow, moderately slow flowing streams with either silt or gravel bottoms. Species of *Apocrangonyx* and *Stygobromus* are largely inhabitants of the former habitat; species of *Stygonectes* are usually associated with the latter habitat; while species of *Crangonyx* appear to occupy both kinds of habitats with about equal frequency. It is believed that many of the species that are found in small drip and seep pools in caves also inhabit crevices, fissures, and solution channels which are, at one time or another, saturated by groundwater.

THE CLASSIFICATION OF CAVERNICOLES

Elery Hamilton-Smith
South Australian Museum,
Montmorency, Victoria,
(Read by Martha R. Cooper)

A seven-category system for the classification of cavernicoles is proposed, primarily on the basis of Australian experience.

Parasites are separated from the Schiner-Racovitza categories to form a separate category; it is suggested in line with some other workers that the term trogloxene should not be used for accidental species; threshold species not found within the dark zone are also separated, but the complexity of the threshold fauna is emphasized.

The dark zone fauna is thus separated into four categories: trogloxenes and troglobites as in the Schiner-Racovitza system, with troglophiles divided into two levels, being those species also occurring in the epigean environment (first level) and those confined to caves (second level).

PRELIMINARY COMMENTS ON A NEW GENUS AND SPECIES OF CAVE FISH FROM ALABAMA

John E. Cooper,
Institute of Speleology,
University of Kentucky,
Lexington, Ky.

Presented by title only.

GEOMORPHOLOGY OF THE NAKIMU CAVES, GLACIER NATIONAL PARK, BRITISH COLUMBIA

D. C. Ford and M. F. Goodchild,
McMaster University,
Hamilton,
Ontario, Canada

The Nakimu Caves, the most extensive known in Canada, are located at an altitude of 5,600 feet in the heavily-glaciated Selkirk Mountains. Aggregate passage length exceeds three miles; the system has been explored to a depth of 850 feet.

The caves are developed in rather massively bedded, steeply dipping eo-Cambrian limestones which rest upon a base of phyllites. The contact is reached in the lowest area. Neither primary porosity nor the marked lithological variation of the limestone has played any significant role in the cavern genesis. Most passages are guided by one of three major structural features:

1) A group of vertical faults trending normal to the direction of dip.
2) Two bedding planes, each evidencing differential slippage.
3) A set of great strike joints. Cave development is predominantly down true dip or along true strike of the bedding planes and joints. The faults are utilized for linking purposes and quickly abandoned.

Development of the caves may be divided into five phases:

1) A phreatic phase with the development of large elliptical passages to a depth of at least 250 feet beneath the water table, passing to -
2) A phase of steadily-falling water table stabilizing in para-phreatic conditions 300 feet below the first real level.
3) A vadose entrenchment with the recession of a nickpoint of 60 feet amplitude into the preserved system.
4) Infilling of almost the entire cave with clastic debris comprising a graded bed nearly 400 feet deep that lies unconformably upon an initial varved deposit. The succession marks a short glacial advance followed by recession and then infilling and prolonged burial beneath an alpine glacier of the last Glacial. All passages became filled with effectively static water.
5) A modern phase of fluvial re-excavation and the development of a lower series of vadose chutes and trenches to a depth of 600 feet below the phase 3 level. Phase 5 is C14 dated to greater than 4,350 years B.P. but is unlikely to be older than 8,000 years. Routine sampling of solutes reveals that at a July base flow rate of 60 cm-feet/sec., the principal meltwater creek is dissolving 12 cubic feet of limestone per day in its passage through the Caves.

HYDROLOGY OF THE CAVERNOUS LIMESTONES OF SCHOHARIE AND ALBANY COUNTIES, NEW YORK

Victor R. Baker,
Rensselaer Polytechnic Institute,
Troy, New York

In a study conducted as part of a special topics course in karst hydrology, the author has investigated anomalous hydrologic conditions in the limestone uplands of the Allegheny Front where it intersects Albany and Schoharie counties, New York. A detailed study was made of the upper Silurian and lower Devonian carbonates and their water-bearing properties. The results of this study were combined with quantitative discharge measurements on springs and disappearing streams, and also with quantitative data from time of travel studies utilizing Rhodamine B, a fluorescent dye.

It was found that the thin-bedded, closely jointed Manlius Limestone (joint spacing 1 to 5 feet) formed cavernous openings acting as conduits for seasonal-varying discharges. Protected by the massive, thickly bedded, overlying Coeymans Limestone, these conduits in the Manlius have been observed to discharge as much as 35 cubic feet per second at the Doc Shaul's Spring gaging site. The time of travel studies provided for injection of a dye into a disappearing stream and for measurement of the time required to detect this dye at the resurgence of the underground system. It was found that travel times varied from 40 hours for the two-mile run from Thompson's Lake to Pitcher Farm Spring, to only four hours from Skull Cave Sinkhole to Beaverdam Springs. Moreover, travel times varied remarkably with the discharge through the cave system. A travel time of four hours through the Skull Cave System (approximately one mile in length) at a discharge of 15.1 cfs contrasts with a 25 hour travel time through the same system at 4.1 cfs. Dye studies have also revealed unusual hydrologic conditions caused by the blocking of pre-Pleistocene cave resurgences by glacial deposits. The result of the latter event has been the flooding of the entire lower portion of a Manlius cave system and the formation of the well-like Doc Shaul's Spring, which is fed by water under hydrostatic head, conditions very similar to artesian ones. All results above are combined with data concerning known cavern systems in the area to construct a regional hydrologic picture, emphasizing the significance of dip, lithology, nearby stream valleys, and escarpments on the development of karst drainage networks.

KARST INVESTIGATIONS ALONG THE NORTHERN MARGINS OF THE CENTRAL INLIEN, JAMAICA

M. C. Brown *and* D. C. Ford,
Department of Geography,
McMaster University,
Hamilton, Ontario, Canada

During its six-month stay in Jamaica, the British Karst Hydrology Expedition of 1965-66 mapped over 100,000 feet of virgin cave, and successfully traced four major sinking rivers to their risings up to 13 miles distant. Lycopodium spores were proved useful in their first tropical application as tracers. A new type of cave feature was noted, and extensive chemical analysis of solute concentrations at risings was carried out. Analysis of relations between cave passages and surface features and spectral analysis of rising water heights, is still in progress.

DRIP POCKETS IN GYPSUM

James F. Quinlan *and* A. Richard Smith,
University of Texas,
Austin, Texas

The Kirschberg Evaporite is a horizon of gypsum within the Lower Cretaceous Edwards Limestone of south-central Texas. Formerly the gypsum was present throughout almost a thousand square-mile area, and locally it had a maximum thickness of at least 11 m, but most of it has been solutionally removed from beneath the overlying limestone by interstratal karstification (*unterirdische Verkarstung*) until it now occupies just a few tens of square miles. In the Fredericksburg Gypsum Co. quarry, nine miles north of Fredericksburg, the gypsum is 0 to 5 m thick and it contains vertical shafts, drip-pockets, two types of solution breccias, and small caves filled with travertine. Most of these karst features are overlain by genetically-associated subsidence structures in the gypsum and overlying 5 m of limestone and dolomite; such structures may or may not have topographic expression.

Drip-pockets (small vertical shafts that are typically 2 to 10 cm wide and 20 to 200 cm deep) are tubular cavities that are solutionally "drilled" by water dripping from a point source. They generally develop independently of jointing and they are enlarged laterally by water that trickles as a film along the walls. Drip-pockets may coalesce to form vertical shafts that are typically 1.5 m wide and 3 m deep. The drilling and coalesence also separates the bedrock into isolated and semi-isolated columns and blocks that can rightly be considered as cores. The gypsum of such cores commonly parts along bedding planes to form core blocks with a length and diameter usually less than 40 cm. Some of the vertical shafts are completely filled by a solution breccia of core blocks that have collapsed and subsided to various degrees. Drip-pockets also occur in gypsum fills on the floor of Carlsbad Caverns and several other New Mexico caves, in a gypsum karst of Mexico, and in limestone that is undergoing interstratal karstification in Wales.

WATER-SOLUBLE MINERALS IN THE CAVE SEDIMENTS OF THE CENTRAL KENTUCKY KARST

Craig S. Peterson *and* William B. White
Materials Research Laboratory and Department of Geochemistry and Mineralogy
Pennsylvania State University
University Park, Pennsylvania

Abstract not received.

MEETING IN NEW YORK, N.Y., DECEMBER 1967
CAVE GEOLOGY

LIMESTONE CAVES IN GLACIATED AREAS

Victor R. Baker
Department of Geology
University of Colorado
Boulder, Colorado

The effects of Pleistocene glaciation on cave development must be interpreted in terms of a dynamic, open-system model of karstic water movement. Progressive changes in the boundary conditions governing the equations for this movement result in progressive changes in the rate and/or location of solution. In the caves of Schoharie, New York; Pennine Mountains of England; and Dachstein, Austria, the Pleistocene glaciation represents the major dynamic influence for changing the boundary conditions governing cave formation. Important changes which result are divided into three categories, subdivided as follows:

I. Periglacial.
  A. Frost brecciation of limestone surface.
  B. Formation of glacieres ("ice caves").
  C. Formation of fissures (gulls) near limestone cliffs by slumping of wetted, underlying shales into adjacent valleys.
  D. Increased discharges and flow rates through cave conduits.
  E. Reduction in soil CO_2.
II. Glacial
  A. Ice Advance.
    1. Erosional changes in regional base levels.
    2. Blockage of recharge and resurgence areas with nearly impermeable till.
    3. Collapse of near-surface caves.
    4. Increase in surficial exposure of resistant limestones by stripping of overlying shales.
    5. Influx of considerable poorly sorted sediment into caves.
III. Post Glacial.
  A. Vertical expansion of thin-bedded limestones from unloading resulting in increased permeability.
  B. Deranged surface drainage and acidic swamps or peat bogs over till-mantled karst upland surfaces.

The largely vadose nature of glaciated limestone caves must be interpreted in terms of the above effects. Records of water wells penetrating sediment-filled, abandoned cave conduits are combined with hydrologic investigation of the present caves in Schoharie County, New York, to demonstrate changes in the caves wrought by glaciation. McFail's Cave, recently acquired by the N.S.S., is an outstanding example of processes discussed.

LIMITED INFLUENCE OF FRACTURES ON CAVE PASSAGES IN THE CENTRAL KENTUCKY KARST

George H. Deike, III
Department of Geology
Pennsylvania State University
University Park, Pennsylvania
and Cave Research Foundation

Joints in the Central Kentucky Karst are distributed in a planar northeast set, typically close-spaced in swarms but of limited extent, and a rough northwest set usually wider spaced, and of greater horizontal and vertical extent. The photo-geologic fracture traces in the region are most strongly developed parallel to the northwest joint set.

Cavern passages show straight segments on maps and/or field evidence of following fractures in only 40% of their length. This proportion of passages parallels the joint sets, with variations depending on dip direction and other factors.

The joint-influenced part of a passage has the same over-all trend that is shown by the entire passage, indicating that other directional factors select the joints which are utilized.

Disconnected joints, sometimes in en-echelon groups, direct parts of tubular passages along bedding planes, and permit changes of stratigraphic horizon as integrated passage systems develop horizontally close to base level in spite of dipping structures. Joint influence on later stream-eroded canyons cut from tubular passages is very limited.

Hydraulic factors are prominent in shaping the plans of non-fracture-influenced passage segments.

The mean amount of straight, fracture controlled cave passage for a variety of other karst regions is 75%. The limited control exhibited in the Central Kentucky Karst is ascribed to the short, disconnected nature of the joints present.

CORRELATION OF CAVE SURVEY DATA WITH LIMESTONE STRUCTURE

John M. Rutherford, Jr.
West Virginia Association for Cave Studies, Inc.
2804 Ranch Road
South Charleston, West Virginia 25303

The influence of limestone structure, particularly jointing, on development of passages in limestone caves is well known, and casual inspection of cave maps frequently reveals the presence of joints. We have found that sorting and accumulating survey data from large caves by one degree increments and applying statistical smoothing devices to improve the signal-to-noise ratio allows a comprehensive picture of the joint control to emerge. Although the technique needs further refinement, preliminary data on a few caves in Greenbrier County, West Virginia have shown that in addition to the dominant joint along the strike there are a multiplicity of minor joints exerting control over cavern development. For large caves the technique should simplify the task of speleologists by relieving them of the necessity of visiting extensive portions of cave to assess the role of jointing. Furthermore it provides a basis for quantifying not only the overall degree of joint control in a cave, but also on the relative influence of different sets of joints, and for drawing comparisons between different cave systems.

Though of little value in small caves lacking statistically significant amounts of survey data, the technique is especially relevant to extensive caves, whose size complicates more casual analysis. Analysis of these caves can be simplified with the aid of a computer. Excluding size limitations the main drawback to this analysis is the inevitable scatter in some of the data, and care must be taken to avoid use of prejudicial smoothing techniques.

THE EFFECT OF FAULTING IN CASSELL CAVE, WEST VIRGINIA

G. E. Eddy and D. B. Williamson
West Virginia Geological Survey and
Department of Physics
West Virginia University
Morgantown, West Virginia

Cassell Cave, located in Pocahontas County, West Virginia consists of over five miles of passages separated vertically by resistant strata into three distinct levels. Waterfalls near the north (downstream) end of the cave provide connections between levels.

Although not in a region of known faulting, the section of the cave in the vicinity of the waterfalls is marked by a zone of reverse faults. Fault surfaces are observed to intersect the waterfall rooms and adjacent rooms and passages. Evidence for the existence of the faults includes visual observation of the fractures and fault surfaces, distortion of strata by drag on adjacent beds, stratigraphic discontinuities and vertical displacement of strata. Several irregular fault surfaces are observed in a zone about thirty feet thick. Measurements of dip range from twenty-six to thirty-eight degrees to the northwest. Measured strikes range from N 9° E to N 38° E. Observed displacements range up to twenty feet and are limited to relative movement along the dip.

The effect of the faulting has been to interrupt the continuity of the resistant beds on which streams are perched and to bring more soluble limestones up into contact with the streams. Solution of these less resistant limestones has produced the observed waterfalls permitting the streams to descend to lower levels without penetrating the resistant beds.

SINUOSITY IN LIMESTONE SOLUTION CHANNELS

George H. Deike III and William B. White
Department of Geology and Department of Geochemistry and Mineralogy
Pennsylvania State University
University Park, Pennsylvania 16802
and Cave Research Foundation

Many reaches of cave passages have a pronounced sinuosity. If cave passages are regarded as segments of drainage conduits which have served some role in the hydrologic drainage net for the basin in which they lie, one may further compare the relationships of the features of the cave passage with the corresponding features of surface streams.

Cave populations, with predominantly conduit-like geometry, were sampled from the Central Kentucky Karst, the Appalachian Plateaus, and the Missouri Ozarks. Caves were selected that exhibited parallel uniform walls which did not branch in the measured reach. Two types of sinuosity were found: an angulate form generated by water flow down a hydraulic gradient diagonal to a rectangular joint set and a curvelinear form with sweeping S-bands apparently related to meanders in surface streams. The curvelinear form was found in bedrock canyons, in tubular passages, and in canyons incised in the floors of tubular passages.

Average bend spacings and channel widths were measured. The average bend spacing ($\bar{l}$) and the channel width (w) are related by $\bar{l} = Kw^n$. The ratio K has the value 6.1 in Central Kentucky, 6.2 for various Appalachian caves, and 7.2 for the caves of Missouri. The exponent, n, is approximately 1.0 for all populations. This equation is very similar to Inglis' equation for surface streams, but has a smaller meander length/channel width ratio than does Leopold and Wolman's surface stream relation.

SYMPOSIUM: ECOLOGY OF CAVE ANIMALS

TYPHLOTRITON SPELAEUS, THE GROTTO SALAMANDER: INFLUENCE OF FOOD ON SEASONAL ABUNDANCE, REPRODUCTIVE ACTIVITY, AND RELATIVE GROWTH RATE

Ronald A. Brandon
Department of Zoology
Southern Illinois University
Carbondale, Illinois

Over a five-year period some 200 specimens of the troglobitic "grotto salamander" were collected, during every month except February, from a cave in Shannon County, Missouri. The peak of salamander abundance in the cave occurs in May, and the fewest have been found in December and January. Periods of salamander abundance are positively correlated with rainfall, food in stomachs, and reproductive activity as judged by the amount of body fat, presence of enlarged and yolked ovarian eggs, hypertrophy of the oviducts, and prominence of the mental hedonic gland.

The Shannon County cave is small with only a small summer colony of bats and no extensive guano deposits. The salamanders in this cave transform and mature at a strikingly smaller body size than in several larger Pulaski and Laclede County caves which contain larger colonies of bats and bigger guano deposits and/or a rich invertebrate fauna.

THE LIFE CYCLE OF THE TROGLOBITIC CATOPID BEETLE *PTOMAPHAGUS LOEDINGI*

Steward B. Peck,
The Biological Laboratories,
Harvard University

The troglobitic catopid beetle *Ptomaphagus loedingi* was cultured at 15°C, 100% relative humidity. Days required for development were: eggs, 13-17; three larval instars, 14-24; residence in mud case before pupation, 9-12; pupal stage, 18-29; residence in pupal chamber after emergence, 1-7; and adult longevity, 180+.

In caves the beetles are clumped within a few hundred feet of the cave entrance in the vicinity of animal dung or decaying debris and their microflora. Competition for this food may come from collembola, millipedes, and phorid flies.

Summer trapping and mark-recapture in an Alabama cave suggested the same seasonal pattern. Numerous adults appear in August followed by high numbers of larva in two weeks. This pattern suggests some control of emergence from pupae or hiding places.

ANNUAL CYCLES IN CAVE ORGANISMS, ESPECIALLY CRAYFISH

Thomas C. Jegla,
Department of Biology,
Kenyon College

Annual periods of reproduction have been reported in cave amphipods, crayfish, and fish but not in terrestrial beetles. In a population of cave crayfish annual periods of molting also occur. Although reproduction in the amphipods and molting in the crayfish occurs throughout the year, there are definite "seasonal" peaks. This suggests that the cycles of some of the individuals are out of phase with respect to the majority of the population. The majority may be synchronized by seasonal changes other than light or temperature. Individual beetles may have a seasonal cycle but they are not synchronized by a seasonal cycle.

Individual cave crayfish show molting and reproductive cycles of about a year in a "cue-less" laboratory environment of darkness and constant temperature. Some live for two years in this environment. Individuals had molting and/or reproductive periods ranging from about 330 to over 400 days in length.

STRUCTURE OF SOME WEST VIRGINIA CAVE STREAM COMMUNITIES

David C. Culver
Yale University and West Virginia Association for Cave Studies, Inc.

Survey samples from several cave streams in Greenbrier County, West Virginia were taken at various times during the year. The data are considered both in terms of presence or absence of species and in terms of abundance of the more common species (amphipods). Correlations of the data that showed significant departure from a Poisson distribution with environmental parameters are attempted. Predictions concerning niche breadth were possible because of the simplicity of the cave environment. These predictions were tested in the laboratory by simple experiments such as substrate preference and tendency to aggregate. Certain aspects of game theory proved to be a useful conceptual framework. The problems involved in using game theory in a more rigorous sense are discussed. Both the theoretical models and the laboratory experiments are applied to the field results in an attempt to explain some of the important parameters in the structure of the cave community.

A COMPARISON OF TEMPERATE AND TROPICAL CAVE COMMUNITIES

Robert W. Mitchell
Texas Technological College

Striking difference exist between temperate and tropical cave communities. More troglobites (obligate cave-dwellers) are found in temperate caves, but the most drastic difference lies in the paucity of terrestrial troglobites in the tropics. Most tropical troglobites are aquatics. Three hypotheses are offered to explain these disparities. First, there are fewer troglobites in tropical caves since the higher energy input into these caves lessens the positive selective pressures for the "regressed" phenotype and slows evolutionary rates. Second, the scarcity of terrestrial troglobites in tropical caves is further promoted by the tropical climate which presents few barriers to gene flow between surface and cave populations of the same species. Third, most tropical troglobites are aquatic since the aquatic species are readily isolated geographically from the surface fauna by being trapped in subterranean waters.

DIVERSITY IN AQUATIC AND TERRESTRIAL CAVE COMMUNITIES OF FLINT RIDGE, MAMMOTH CAVE NATIONAL PARK

Thomas L. Poulson and David C. Culver,
Yale University and The Cave Research Foundation,

Within-habitat diversities were calculated using species-abundance criteria. Stream data are from complete censuses of fish and crayfish and samples of plankton, isopods, and flatworms. In terrestrial habitats both timed search per area and trapping contributed to calculations of diversity.

Diversities were rank-correlated with productivity, spatial heterogeneity, stability and predictability of primary production, predation, competition, and rigor of microclimate.

Several hypotheses might explain diversity differences within each habitat. Climate is stable within caves and, due to local geology, ecological and evolutionary time were constant throughout the cave system. Predictability of primary productivity and rigor of microclimate showed positive correlations with diversity. Spatial heterogeneity, predation, competition, productivity, and stability of primary productivity showed generally poor correlations with diversity although spatial and temporal distribution of microhabitat and food provide a possible explanation of differences in patterns of diversity between the terrestrial and aquatic communities.

(supported by USPHS Grant GM-12231)

CAVE GEOGRAPHY AND EXPLORATION

THE CAVES, KARST, AND SUBTERRANEAN DRAINAGE OF RYE COVE, SCOTT COUNTY, VIRGINIA

John R. Holsinger
Department of Biology
East Tennessee State University
Johnson City, Tennessee 37601

Rye Cove is a strongly karsted limestone plateau located in west central Scott Co., Virginia. Nearly this entire area of approximately 15 square miles is floored with low-dipping, Middle Ordovician limestones and drainage is almost exclusively subterranean. Presently, 35 caves have been recorded and all but a few have been explored. Five of these caves are of significant size, and two of them include about one mile of surveyed passage each.

Karst is well developed throughout the Cove and two of the largest sinkholes in the Appalachians occur here – the largest of the two being three miles long and up to 300 feet deep. Karren, lapies, and sinking streams are also outstanding surface features of the area.

The major caves of Rye Cove appear to be developed either in the Rye Cove limestone or along contacts between this limestone and its underlying and overlying formations. A large, five-mile trunk channel, composed in part by three intimately related cave segments, is developed from west to east along the southern flank of the Rye Cove Syncline. Flannery Cave forms the western-most part of the system, and McDavids and Jackson Caves form the middle part; traversable passage has not yet been discovered along the eastern part of the system. This continuous underground stream has been traced with flourescein dye from Flannery Cave eastward to a point where it resurges through a series of springs along the northwestern side of Mill Creek. The combined flow of these springs was calculated to be between 10 and 11 gallons per day during May 1967 and accounts for 75 to 80 percent of the drainage from Rye Cove. The remainder of the Cove is drained to the northwest to Cove Creek through a series of small caves.

GILLEY CAVE, LEE COUNTY, VIRGINIA

Roger Baroody
152 Stribling Avenue
Charlottesville, Virginia 22903

Located in Pennington Gap, Virginia, Gilley Cave has been known since 1870. In 1962 the University of Virginia Grotto began surveying and exploration of the cave. Five years of work have yielded four miles of passage, mystery in hydrology, and confusion in geology. Gilley Cave, in the Copper Ridge Dolomite, lies within an overturned anticline divided by three major active faults. In the past three years the activity of these faults has caused one large section of wall to separate and expose a stream channel. During this same period another passage became 300 feet longer; mostly through breakdown. Two drainage systems have been observed within the cave. One system drains the upper levels and discharges into the North Fork of the Powell River three-quarters of a mile distant. The lower level drainage has been traced to Echo Lake, 450 feet below the entrance and 90 feet below the North Fork of the Powell River. Although the stream feeding Echo Lake often floods, the lake itself changes very little in depth, with maximum change of three inches being noted during our exploration. A few of the features displayed in the cave are faults with up to thirteen inches of slippage, a complex of folds with passages lying along their axes, and peculiar hoop-like formations whose origin is as yet unknown.

INITIAL EXPLORATION OF FLOWER POT CAVE, WEST VIRGINIA

Douglas Medville
Department of Operations Research
University of Pennsylvania
Philadelphia, Pennsylvania

Flower Pot is a cave located in eastern Randolph County, West Virginia, two miles northeast of the town of Whitmer and 0.25 miles west of the Randolph-Pendelton county line. The structure of the cave is similar to that of English potholes. As of July, 1967 two miles of passage had been mapped and a depth of 331 feet below the entrance reached. The cave is in limetsones of the Greenbrier Series, specifically in the lower (Fredonia) member of the Union Limestone. Structurally the area is on the east limb of the Job Syncline, where the dip is about 10° to the northwest. The axis of the syncline parallels Dry Fork River, located two miles west and 500 feet below the cave entrance. Most of the cave passages are along two sets of joints, with one set following the dip and carrying the cave streams while the other set parallels the strike (N 20° W) and contains relatively dry passages. Exploration has been impeded by two factors: 1) a single pit entrance located at the upstream end of the cave, resulting in trips to the downstream sections averaging 15 hours; and 2) two waterfalls, 14 and 16 feet high, located over a mile from the entrance and both requiring the use of vertical equipment. Several questions regarding the cave remain to be answered, the primary one being the location of a resurgence which has not yet been found. Stratigraphically the Fredonia is 80-100 feet below the level of Dry Fork River, and it is possible that a resurgence as such does not exist. Exploration and mapping are currently in progress, and dye tracing of the cave stream reamin to be done. This report is thus of a very preliminary nature.

A STATUS REPORT ON "THE HOLE", GREENBRIER COUNTY, WEST VIRGINIA

John M. Rutherford, Jr.
West Virginia Association for Cave Studies
2804 Ranch Road
South Charleston, West Virginia 25303

"The Hole" is the first major cave found by WVACS in their Great Savannah Project, a continuing project devoted to the intensive exploration and study of the limestone terrain between Spring Creek and Fort Spring in Greenbrier County, West Virginia. The Hole, discovered in 1960, is located east of Frankford at the northeast corner of the Great Savannah. Exploration has been conducted intermittently since that time and is continuing. As of September 10, 1967 The Hole has three entrances and over ten miles of surveyed passage. The passages are developed mainly in the Hillsdale Limestone (Greenbrier Formation), although parts probably reach upward into the Sinks Grove Limestone. Significant portions of the cave are also found in beds of reworked Maccrady material along the unconformable contact between the Hillsdale and the underlying Maccrady Shale. Passages in the reworked Maccrady gravels are predominantly vadose and carry drainage from the surface contact down dip (N 60° W) to the originally phreatic passages in the Hillsdale. These then carry the streams northward along the strike (N 30° E) for ultimate delivery to Spring Creek. Dye traces have been conducted from the southern regions of the cave to Shale River in the northern section and thence to two resurgences on Spring Creek about 0.4 miles apart. Biological collecting has revealed mites, collembola, spiders, bristletails, amphipods, isopods, planaria, beetles, crickets, pseudoscorpions, and a variety of salamanders. Fish have been observed while crayfish are notably lacking. Abundant fossils are present which are frequently silicified and sometimes transformed into banded agates, especially *Lithostrontion.*

A PRELIMINARY REPORT ON THE BONE-NORMAN CAVE SYSTEM, GREENBRIER COUNTY, WEST VIRGINIA

John O. Davis and Charles W. Maus
West Virginia Association for Cave Studies
21 Norwood Road
Charleston, West Virginia

The Bone-Norman cave system, located in northern Greenbrier County, West Virginia, is a multi-level system in the Greenbrier limestone series. The upper levels are dry and contain what is believed to be ancient silt deposits and phreatic development. The lower level carries a major active stream of the area. The system contains several areas exhibiting a wide variety of calcite and gypsum speleothems.

The two known entrances (including approximately ½-mile of passage), of the system have been known since the late 20's or early 30's. A reconnaissance trip in 1961 led to the discovery of a connection of the two entrances. The main route through the cave is a stream passage which has been traced approximately 2½ miles, to a point where it pools and resurges at several points on the Greenbrier River.

Exploration and surveying of the system continues as one of the West Virginia Association for Cave Studies' projects. The known system now totals greater than five miles and more discoveries are expected.

Memoriam to Burton S. Faust

Burton S. Faust, N.S.S. member 237, for 35 years an ardent speleologist, died suddenly of a heart attack July 31, 1967 at his home, 2178 Harbor View Drive, Dunedin, Florida.

Mr. Faust retired in 1966 from the position he had held for 25 years as a patent examiner for the U.S. Patent Office in Washington, D.C., but had continued his research and writing on the early saltpetre caves of the eastern U.S., which played an important role in early American history.

Born August 5, 1898 in Belle Plain, Iowa, he held a B.S. degree from Iowa State Teachers College and an M.S. in science from the University of Chicago. After World War I service in the Marine Corps, he went to Florida where he was an engineer for the Florida Power and Light Company, and later taught high school in Miami. He went to Washington to join the Patent Office in 1941.

He explored and photographed many of the limestone cavern systems in the eastern U.S. and became a recognized authority on colonial saltpetre mining and refining. The saltpetre deposits in caves played a major role in the manufacture of gunpower for clearing land and for fighting all wars from the French and Indian conflicts to the Civil War. He was author of the monograph *Saltpetre Caves and the History of Virginia,* embodied in the bound volume "Caves of Virginia," edited by Henry Douglas.

Mr. Faust was director of the N.S.S. national conventions of 1948 and 1949 and with Pedro Wood of Monterrey, Mexico he organized the first international convention in 1952 in Monterrey. He organized the first International Salon of Speleological Photographic Art, and conducted judgings of Salon entries during each annual convention. He recently published several papers on saltpetre mining and nitre refining in Mammoth Cave, Kentucky. He presented a paper at the 1966 Convention of the American Chemical Society in Atlantic City entitled *Ancient Greek and European Refining and Utilization of the Chemical Saltpetre.*

He is survived by his wife, Dr. Wilda Freeborn Faust, who retired in 1966 from her post as executive director of the Future Teachers of America program of the National Education Association. She is continuing the family home in Dunedin and is completing work on several of Burton's manuscripts that were in process of preparation at the time of his death.

Benton T. Hickock

NATIONAL SPELEOLOGICAL SOCIETY

THE NATIONAL SPELEOLOGICAL SOCIETY is a non-profit organization devoted to the study of caves, karst and allied phenomena. It was founded in 1940 and is chartered under the law of the District of Columbia. The Society is associated with the American Association for the Advancement of Science.

THE SOCIETY serves as a central agency for the collection, preservation, and publication of information relating to speleology. It also seeks the preservation of the fauna, minerals, and natural beauty of caverns through proper conservation practices.

THE AFFAIRS of the Society are controlled by an elected Board of Governors. The Board appoints National Officers. Technical affairs of the Society are administered by a Research Committee of specialists in the fields that relate to speleology.

PUBLICATIONS of the Society include the BULLETIN published quarterly, the NEWS appearing monthly, and the OCCASIONAL PAPERS. All members receive the BULLETIN and NEWS.

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