BULLETIN TWELVE

NATIONAL SPELEOLOGICAL SOCIETY

NSS

Affiliated with the American Association for the Advancement of Science

IN THIS ISSUE . . .

Accurate and informative articles on caves including

CAVE LIFE OF THE OZARK PLATEAU

THE SURVEY OF SCHOOLHOUSE CAVE

FORMATION AND MINERALOGY OF STALACTITES AND STALAGMITES

SEX RATIOS IN HIBERNATING BATS

SPELUNKING IN A PYRAMID

CALCITE BUBBLES

CAVE MAPPING

ICE CAVES

AND OTHERS

NOVEMBER 1950

M. Houpt

BULLETIN TWELVE

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To stimulate interest in caves and to record the findings of explorers and scientists within and outside the Society

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EDITOR: Jerome M. Ludlow; EDITORIAL COMMITTEE: William E. Davies, James A. Fowler, William S. Hill, Philip A. Livingston, John D. Parker.

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THE NATIONAL SPELEOLOGICAL SOCIETY was organized in 1940. It now has members scattered throughout the United States, and also has many members in foreign countries.

THE SOCIETY is a non-profit organization of men and women interested in the study and exploration of caves and allied phenomena. It is chartered under the law of the District of Columbia. Its energies are devoted to the unlocking of the secrets of the netherworld.

THE SOCIETY serves as a central agency for the collection, preservation and publication of scientific, historical and legendary information relating to Speleology. It arouses interest in the discovery of new caves and encourages the preservation of the natural beauty of all caverns.

THE AFFAIRS of the Society are administered by a Board of Governors elected annually. The Board appoints the national officers. The Board also appoints committee chairmen—who are chosen not only for their proved ability in a particular field, but also for their activity in the work of the Society.

LOCAL SECTIONS of the Society are called Grottoes. They serve to stimulate and coordinate activity and increase the interest, enjoyment and productiveness of caving.

LIBRARY: An excellent speleological library is owned by the Society and is being constantly enlarged. Items on hand may be borrowed by NSS members. Extensive collections of cave maps, photographs and slides are being gathered and are available on a loan basis.

Membership helps to support the publications, special investigations, and the operation of the Society.

Associate	$ 3	Commercial or	
Regular	$ 5	Institutional	$10
Sustaining	$10	Life	$75

PUBLICATIONS include the BULLETIN published at least once a year, and the NEWS appearing monthly. All members receive the BULLETIN and the NEWS.

Preface to Bulletin Twelve

Since the publication of Bulletin Eleven, in November 1949, the scientific stature of speleology and of the National Speleological Society has measureably increased. The gradual change from a loosely organized group of sincere individuals interested in the promotion of speleological effort to a more mature scientific organization has been taking place for some years. Much credit is due the original personnel who conceived the organization of the Society on a national basis and who have stayed with it during its growth.

As a result of all this devotion to an ideal the professional scientist is now being attracted to us both because of our accomplishments and, more particularly, because of our objectives. Not the least important factor, by far, which reflects the higher regard with which we are held by the scientist, was our recent acceptance as an affiliate of the American Association for the Advancement of Science. The program at the annual meeting of that organization at Cleveland, Ohio, this year will include sessions on speleology for the first time.

Also, an intensified effort in the field of public relations has added to our prestige. The establishment of educational displays at both the New York and Philadelphia sportsmen's shows, the many columns of newspaper space, and the not infrequent magazine articles, have all played their part in our public recognition as a reliable source of information on the nation's netherworld.

Other factors contributing to our scientific standing have been our promotion of the International Speleological Congress at Monterrey, Mexico; the publication by the West Virginia Geological Survey and the Maryland Department of Geology, Mines and Water Resources of their volumes on caves in those states in which specific credit was given the NSS for valuable assistance; the visit to America of Dr. Robert de Joly, President of the Société Spéléologique de France (he also represented Swiss, Belgian, Italian, Greek and Portugese societies) and our own national convention where papers were presented on subjects ranging from sex ratios in hibernating bats to a talk on German underground installations.

Specific projects of our own, still in progress, should add additional knowledge to our scientific cave information. Among these are a project by a group in Trenton, N. J. to make a complete scientific study of Schofer's Cave near Kutztown, Pennsylvania, some geophysical prospecting undertaken last year by Rensselaer Grotto, a proposed archaeological survey of caves in the Valley Forge, Pennsylvania, area by the Philadelphia Grotto, and other projects undertaken by other grottoes.

All in all, these efforts point the way to still greater prestige in the future, and they impose upon each member not only a duty, but also a responsibility, to conduct the affairs of the Society and its related programs with sincerity, enthusiasm and dignity.

—J. M. L.

Trenton, N. J.

October 22, 1950

A. Perret, Pt-St-Esprit

Le Pomme de Pin, a unique stalagmite in l'Aven D'Orgnac, Ardeche, France. The size of the formation is shown in comparison with the figure of M. Robert de Joly, noted French speleologist, in the foreground. This cave was discovered and explored by M. de Joly in 1935 and acquired by the French government in 1938.

Ozark Cave Life

By CHARLES E. MOHR

Audubon Nature Center, Greenwich, Conn.

All photographs by the author

Little known to today's speleologists, two women made speleological history in the Ozark Mountains of Missouri more than 50 years ago. In the gay nineties a female caver was an eyebrow-raising event. The author tells some most interesting facts about these pioneers, as well as some dramatic experiences of his own in his more recent Ozark explorations.

More than 50 years ago two women made speleological history in the Ozark Mountains of Missouri. The writings of one and the scientific collections of the other focused attention on an area ripe for exploration.

Best known of the two, for her "Cave Regions of the Ozarks and Black Hills", was Luella Agnes Owen,[1] a member of the Missouri Geological Survey. Even before the appearance of her book in 1898, Miss Owen had been named an Honorary Member of the Speleological Society of France, and a Fellow of the American Geographical Society.

The second woman cave explorer we know only as Miss Ruth Hoppin. In the late eighties she sent hundreds of specimens of cave fauna to Curator Samuel Garman[2] at Harvard's Museum of Comparative Zoology. Miss Hoppin lived near Sarcoxie, Jasper County, Missouri, and explored caves and wells in that area, making collections and at Garman's request, detailed observations on cave life. Her lengthy letters provide the first comprehensive notes on Ozark cave life. Several of the subterranean creatures which she discovered were new to science.

While Ruth Hoppin would be considered a serious spelunker today, Luella Owen might well be classed a speleologist. For although she wrote that she visited the caves "for the gratification of private interest," she hastened to add that the exploration was "in the course of regular official duty on the Missouri Geological Survey."

During the summer of 1896, between mid-May and late September, Luella Owen made several expeditions into Stone and Oregon Counties in southern Missouri. Roads were poor, directions vague, and conveyances undependable. When the mail coach in which she was traveling to Gentry Cave, near Galena, broke down, Miss Owen continued on foot. Numerous reports of rattlesnakes, copperheads and water-moccasins seemed to alarm the geologist a bit, but fortunately no venomous reptile was encountered.

Even in the gay nineties caving was a surprising pursuit for a woman. Proper attire for female spelunkers had received little attention up to this time. For exploring the more difficult caves, overalls had been suggested. Miss Owen refused to wear such an "objectionable costume", selecting instead a short dress of special design.

"The unavoidable climbing," explained Miss Owen, "will soon prove the superior claims of a divided skirt. If it is properly made, only the wearer need be conscious of the divide." Rubber boots and waterproof cape and hat completed the costume.

In such an outfit our heroine penetrated the wet and muddy passages leading off from Marble Cave's huge Auditorium. In Sugar Tree Hollow Cave she crawled feet foremost through the two-foot high opening and wriggled downward for 15 feet over loose rocks.

The rubber boots gave some protection against the rocks, but their limitations were brought home with chilling suddenness in Greer Cave. While wading along the shallow edge of a subterranean lake, she stepped into deep water. Although she escaped complete immersion, she had the discomforting realization that "23 miles and a chilly night lay between us and dry clothing."

Miss Hoppin, on the contrary, spared only an occasional word to describe the difficulties encountered in her search for cave animals. In addition to the specimens of blind fish and numerous smaller forms of life which she shipped to Curator Garman, she sent specimens of the red mud or gumbo which covered the floors of some of the caves.

"Experiments proved its excessive fineness and stickiness," reported the scientist. It made some of the caves virtually inaccessible, wrote Miss Hoppin.

No one had ever entered Day's Cave before Ruth Hoppin and a young boy found a hole at the base of a cliff and enlarged it until the youngster could slip through. The blind fish they collected there proved to be a species new to science. When first examined by Garman in 1889, it was believed to be identical with *Typhlichthys subterraneus* of the Mammoth Cave region of Kentucky.

That blind cave fishes from areas separated by the Mississippi River might be identical caused excited speculation. But the resemblance between the two fishes was quickly proved a superficial one by ichthyologist Carl Eigenmann.[3]

"Judging from the degree of degeneration of the eye," he wrote, the Missouri fish "has lived in caves and done without the use of its eyes longer than any known vertebrate." He described it more fully in 1899 as *Troglichththys rosae*.

Miss Hoppin found numerous other specimens of blind fish in nearby caves and wells. One series of ten wells, from 11 to 30 feet deep, were situated from 5 to 80 rods apart. They had a common water level, and similar cave fauna. A large part of the collection came from these wells.

Examination of the eyeless fish gave some indication of their food habits. Their stomachs contained young crayfish and blind fish, crickets, and numerous isopods, the last evidently being the main food supply. Like most species of blind fish, these were small, none over two and a quarter inches long.

Today blind fish are rare in the Joplin area, and very few have been found elsewhere in the Ozarks. Byron C. Marshall of Imboden, Arkansas, told me that during his exploration of 150 Ozark caves he had seen blind fish only once.

The occasional reports of blind fish in the eastern Ozarks generally have been traced to a sculpin, *Cottus bairdii carolinae*. It has both pigmentation and eyes but is a cave-dweller to the extent of being "wholly capable of continued existence far within cave streams." [4]

On five caving visits to the Ozarks, I have spent many hours inquiring about and searching for blind fish. In June 1938, Kenneth N. Dearolf and I got our best lead. White fish had been seen recently at Moore's Cave, near Springfield, it was reliably reported.

We found the cave, situated in a pasture, its manhole-like entrance blocked with branches. Quickly clearing it we chimneyed downward to a ledge, then 15 feet farther. Here we encountered a small stream which immediately plunged into a fair-sized room, splashing on a rockpile 25 feet below. The only place a rope could be fastened was close beside the waterfall.

In this pre-NSS period our use of ropes was infrequent and amateurish. We had not expected to attempt any difficult descents, so carried a single 50-foot length of three-eighths inch rope. Odd as it seems today, the thought of using a safety rope never occurred to us.

Doubling the rope and fastening it in place, I started down hand over hand. The walls curved away and I began to spin on the rope. I had gone down half-way, when suddenly I swung beneath the falls. Chilled and blinded, I hung desperately to the rope. But in another instant the water filled my boots and knocked me onto the rocks.

Drenched and half-choked, I crawled away from the pounding water. Fortunately, my glasses were intact and my flashlight worked. Reassured to see me moving about, Dearolf lowered my collecting kit. Behind the falls was a low room, the water in it barely knee-deep.

Here were crayfish, milky white and streamlined. I caught one and then another. The second was a large female with white eggs attached to her abdomen. Carefully I transferred this prize to a jar, then looked for more. I was in the middle of the muddy pool when for an instant I saw a white fish appear and sink right out of sight again.

Squinting through water-fogged glasses, I scooped awkwardly for it but missed. For minutes I stood motionless, hoping vainly for another view of it.

Suddenly I became conscious of the roar of the falls. It seemed much louder now—and the ceiling of the small room seemed a little lower. *The water was rising!* Then I heard Dearolf shouting but couldn't make out what he was saying.

Unknown to me, it had begun to rain quite heavily. A lot of water was coming into the cave. Dearolf was pointing upward. Time to get out, he seemed to be saying. I headed for the rope. But the rope didn't quite reach the floor. The lowest loop came just to my shoulder, and weighted down with water-filled boots, I couldn't pull myself up. I took them off and sent them up, along with my equipment.

THIS OZARK CAVE CRAYFISH carries its eggs until the embryos are well developed. This cave species attains a length of three inches.

But even without the boots, I couldn't make it. Trying to overpower the watery bedlam, I shouted to Ken to go to the nearby farm for a heavier, longer rope.

As he disappeared from view, I ducked into the small room again. It wasn't so cold here, for there was less circulation of air. I turned out my light to save the batteries and swung my arms to keep warm.

The water kept inching upward. Finally, after what seemed an hour, I left the room just as a sturdy manila rope dropped into view. But the possibility of using the second rope as a safety still hadn't occurred to us.

I took a deep breath and started to climb. Wet as I was the sudden deluge was a shock. The force of the water jammed my headlight down over my ears. That was all that kept my glasses on. Halfway up the pounding began to slow my climb. A few more feet and I stopped. I clung to the rope, expecting that in another moment I would be dashed down again. But swinging back and forth, I kicked against a ledge. Kicking harder I swung in a wider arc until I was able to get a footing out of the water's reach, just beneath the brink.

Resting, I called to Dearolf to let him know what had become of me. Then taking a vise-like grip on the rope, I swung out into the cascade again. Climbing desperately, I quickly pulled up onto the overhanging ledge at the edge of the falls.

With Dearolf's help I was soon on the surface. He was as wet as I. The storm had been a veritable cloudburst. The trickle we had stepped across in the meadow had become a raging torrent and dozens of drowned chickens were floating past.

Three weeks later we returned to Moore's Cave. This time we hung our ropes from a beam anchored several feet farther from the falls. But we were drenched anyway. Eagerly, but slowly, I waded into the pool. There was the fish, in exactly the same place as before. This time it didn't get away.

It was a tiny, white, eyeless creature, scarcely two inches long. We sent it to Carl L. Hubbs and impatiently awaited his diagnosis. Had we discovered a new species? Eventually word came from Dr. Hubbs. It was *Troglichthys rosae*, the fish Ruth Hoppin had found nearly 50 years earlier.

Like Miss Hoppin, we noticed that the fish was sensitive to vibrations in the water, or even tapping on the rocky wall of the pool. Sounds, however, did not affect it. She wrote: [2]

"I tested their hearing by hallooing, clapping my hands, and striking my tin bucket when they were in easy reach and near the surface. In no case did they change their course or notice the sound."

The ability of the fish to detect even slight disturbances of the water evidently lies in the sensitive papillae, arranged in numerous rows over the top and sides of the head and jaws. The fish has a broad head with prominent eye-like structures. Actually these are round masses of fatty tissue in which the minute, fully atrophied eyes are buried.

The ease with which the fish locate and catch food is not believed to indicate a heightened sensitivity to taste. Rather, since they feed on living animals, it is the vibrations caused by the movement of their prey that enables the fish to find them.

Eigenmann visited the Jasper County caves in 1897 and again in 1898 in search of further material for his studies on the eyes of blind cave animals. He does not mention whether he met Miss Hoppin.

In 1930 Dr. Hubbs received a new species of Ozark blind fish. It was collected by Edwin P. Creaser in River Cave, Hahatonka, Camden County, Missouri. It has been tentatively named *Typhlichthys eigenmanni*[4] in honor of the great student of blind cave vertebrates. Publication of the description has been delayed for many years, however, in the hope that additional specimens would be found but the search so far has been fruitless.

Just as a scarcity of specimens hinders the study of Ozark fishes, so do the very limited collections of white crayfish delay investigations on these interesting crustaceans.

The egg-carrying specimen we found in Moore's Cave proved to be *Cambarus ayersii*, the same species I have seen on several occasions in Smallin's Cave. It was first found in 1897, in Fisher's Cave, and described by Mary Steele,[5] of the University of Cincinnati. All three caves are in the Springfield area.

The earliest Missouri white crayfish, however, was the one discovered by Miss Hoppin. It was named *Cambarus setosus* by Garman's colleague at Harvard, Walter Faxon.[6] It was found in Wilson's Cave, Jasper County, and has been seen only in that immediate locality. A third, undescribed variety, has been recently recognized by Horton H. Hobbs, Jr. The specimen was collected in Lewis Cave, 15 miles northwest of Doniphan, Ripley County, by Leslie Hubricht. A survey of the cave crayfish of North America by Dr. Hobbs is now underway, and additional specimens and data from the Ozarks are particularly desired.

If blind fishes feed on isopods—those flat, white, many-legged inhabitants of cave streams—what do the isopods and other tiny denizens of underground waters eat? My first clue came in Marvel Cave as the Marble Cave of Luella Owen's day is now called.

In a small, crystal clear pool within the White Throne, I found several bats' skulls. On them, perhaps feeding on a few remaining shreds of flesh, were several isopods. Bats, when they die, are quickly devoured by scavengers of all sizes. But the droppings of bats, the guano, is of far greater value in the food economy of the cave world than an occasional bat carcass.

Never have I seen more creatures nourished on guano than in a small Ozark cave 5 miles south of the town of Kansas, in northeastern Oklahoma. It is known locally as Bat Cave. The name is an appropriate one, as we discovered. For although the cave's mouth was screened by bushes, the unmistakable odor of bats led us unerringly to it.

We entered the cave by the lower of two entrances, coming, within 50 feet, to the beginning of a "guano bog", a deep guano deposit over which water was flowing. We managed to keep on fairly solid ground at the edge, and to cross the more treacherous areas on boards.

An isopod clings to a bat skull in a Marvel cave pool.

It was a veritable quagmire. Several times we tentatively stepped in with one foot. Each time we went knee-deep without touching anything solid. The stream was four to six feet wide, and out of it at the far side rose a guano slope 20 or more feet high.

Here was the bat roost. Hundreds of bats were flying about as we approached, disappearing into distant parts of the cave. Guano filled the stream for another 30 to 40 feet beyond the bat room.

It was the content of the shallow stream that fascinated us. Elsewhere in our cave visits we had occasionally seen a cave planarian, a white flatworm. Never had we found more than a dozen individuals in one cave. Here at our first glance we saw *hundreds* of flatworms. Several fair-sized concentrations were near enough shore to photograph. As we looked elsewhere in the soupy liquid and in the clear water, too, we saw them by the thousands. I believe that the total colony numbered in the tens of thousands—an almost incredible abundance. Along with them were hundreds, possibly thousands, of isopods. A number of isopods were clustered on a dead bat, evidently feeding.

The planarians chose smaller objects on which to concentrate: dead insects and disintegrating wood. Either directly or indirectly, however, they must have taken nourishment from the guano. They ranged in size from minute, thread-like creatures a few millimeters long to specimens nearly half an inch in length. They flowed along as they alternately lengthened and widened out. Related to the harmful liver flukes, internal parasites of larger animals, these cave forms are free-living and harmless.

The planarian in Bat Cave was discovered in 1936 by A. H. Blair. When studied by zoologist Libbie H. Hyman, it proved to be the first species of an Asiatic genus of flatworms to be found in the New World. It has been named *Sorocelsis americana*.[7] We collected it also in Watson Cave, near Prairie Grove, in northwestern Arkansas, and in a spring near the cave.

Another new cave flatworm, collected in eastern Missouri by Leslie Hubricht, has been named *Speophila hubrichti*[8] by Dr. Hyman.

The bats, the direct benefactors of the fantastic flatworm population, were identified as Gray Bats, *Myotis grisescens*. This was the species I had found in great numbers in Marvel Cave on my first trip to the Ozarks in 1935.

Ever since high school days when I began to collect salamanders, I had wanted to go to the Ozarks to see the strange blind salamander, *Typhlotriton spelaeus*. While still in college my interest was greatly excited by my occasional contacts with the American Museum's experimental biologist, G. Kingsley Noble. His handsomely illustrated article "Creatures of Perpetual Night",[9] published in NATURAL HISTORY,

A TREMENDOUS population of flatworms lives in Bat Cave, Oklahoma. About half an inch long, the planarians can swim at the surface (group at left) or move along the bottom.

fired me with a tremendous urge to visit the Ozark caves.

Finally, after years of dreaming, a hurried side trip from a mission to St. Louis at Christmas time, gave me the chance I needed. I sped to Marvel Cave through a powdery snow. The greeting of the Lynch sisters who owned the place was warm, but their report that no blind salamanders had been found for years in the accessible portions of the cave was disheartening news.

They led me down a wooden stairway through a hole in the dome of a vast unlit ballroom and then along descending tourist trails. At last we reached a dripstone canopy; circling behind it, they pointed to a small spring.

"We used to see the salamanders here."

MARVEL CAVE'S "Auditorium" is entered through a hole in the roof. A piano lowered through the roof once provided music for subterranean dancing.

My hopes bounded. As I turned my flashlight toward the shallow pool I saw half-inch long, white isopods, and then a larger white creature—a larval blind salamander. Feather-like gills protruding from its neck established its immaturity. But it wasn't blind; I could plainly see its eyes!

Elsewhere in this BULLETIN, M. B. Mittleman tells about the amazing transformation that takes place as these larvae mature.

Naturally I wanted to see a "real", adult blind salamander, and my guides, unwilling that my visit to Marvel Cave should not be completely successful, suggested:

"If you could reach Blondie's Throne, you might find blind salamanders along Mystic River. Young Charlie Davison crawled back there while he worked for us; you might get him to take you to Blondie's Throne—if he's at home."

Following their directions through Harold Bell Wright's "Shepherd of the Hills" country, I found Charlie chopping wood outside his small cabin. He was willing, so early the next morning we set out on our search for *Typhlotriton*.

A waterfall marks the spot in the cave where the tourist turns back. It was there that our trip began. A fifteen-foot, slippery clay bank stopped us, until we had dug toeholds. At the top we found ourselves in a series of pools of varying depths. That was Mystic River. The first plunge into 55° water left us breathless, but our exertions soon warmed us. For half an hour we alternately waded and crawled beneath the three-foot ceiling, alert for specimens along the way. At last we reached a large room. What a relief it was to stand up!

Blondie's Throne towered above us. Named for a fair-haired boy who found it long ago, it proved to be a huge stalagmite which virtually separated the room into two chambers. Beyond, a broad pool marked the continuation of Mystic River. We waded knee-deep along the shallow edge, looking more hopefully now for salamanders, but still without luck.

Pushing on, we searched more anxiously—down on our knees again as the roof abruptly lowered. The stream slowly dwindled and finally disappeared as the passage began to rise. Loose rock made crawling a clumsy process. I was breathing with difficulty. After another steep climb we found that the passage ended in a pocket. The dung of animals, probably raccoons, covered the floor. My breathing became even more labored. I was perspiring freely. Could this be one of the oxygen-deficient pockets said to occur in a few caves?

I didn't wait to make any further observations. The blood was pounding in my ears as I backed awkwardly down the narrow passage. I gasped the cooler air over the underground river. The impulse to hurry out of the cave was overpowering, but just then, directly ahead of me on a tiny island in the stream, I saw a blind salamander.

"It's looking right at us," I whispered excitedly to Charlie, but he objected, saying, "It's blind, isn't it?"

Blind it was, but perfectly aware of our presence, if its alert pose indicated anything. It showed little resemblance to the white larva I had seen. This salamander was definitely pink, not from pigment but from the dense network of blood vessels in its skin. It had no lungs—when it grew up the gills disappeared and oxygen, thereafter, was absorbed directly through the moist skin.

Undisturbed, the amphibian moved along like a sniffing dog, apparently in search of food. Collecting was easy; I pushed an open jar toward my victim, then touched its tail gently. It walked right in.

We found blind salamanders also in the terraced pools inside River Cave, at Hahatonka. Sometimes both larvae and adults were seen in the same bathtub-sized pool. Several of the gilled larvae were longer and heavier bodied than the adult *Typhlotriton speleus.* They were undoubtedly the neotenic, "permanent larva" later described by Sherman C. Bishop as *T. nereus.*[10]

The biggest salamander population we found in the Ozarks was at Watson Cave, Arkansas. There, in June 1938, we counted 44 slimy salamanders, *Plethodon glutinosus,* in the first hundred feet of the cave.

TWO SPECIES of blind salamanders occupy the same pool in River Cave, Missouri. At left is the large "permanent larva," TYPHLOTRITON NEREUS, about four inches long, and at right an adult T. SPELAEUS. Young of the latter species also have gills but never attain the size of T. NEREUS.

If it had been late summer we would have made a special search for eggs of *glutinosus*. It was on August 17, 1928, in Sheridan Cave, near Mountain Home, Arkansas, that Byron C. Marshall [11] found for the first time the eggs of this species. And on September 3, of the same year, a second set was discovered, in Indian Cave, near Belle Vista, Arkansas.

There were 18 eggs in the first bunch, 10 in the second. They were found in small crevices, three and four feet above the floors of the caves. One set was near the entrance, the other 100 feet inside. The eggs of this species have been found only one other time, by James A. Fowler in a West Virginia cave.

Caves, of course, offer the best opportunity for studies of salamander life histories. The eggs of several cave-frequenting species have never been found. That includes *Typhlotriton*, *Eurycea longicauda lucifuga*, and a number of species found in Eastern caves.

After we had captured *Typhlotriton* in Marvel Cave we explored another of the larger side passages. There we came upon several hundred square feet of wall covered by a great furry blanket. Examining it at closer range, we recognized it to be composed of thousands of hibernating bats. To my surprise they proved to be Gray Bats, *Myotis grisescens*, the first large colony to be found in the Ozarks. Calculating carefully, we concluded that there were 14,500 of the creatures. Our photograph of them later confirmed this estimate.

BAT TAPESTRY in Marvel Cave is composed of 14,500 hibernating Gray Bats. The colony has been much reduced in recent years.

During the following winter Mary J. Guthrie,[12] latest of Missouri's women speleologists, banded 583 bats, approximately 14% of the colony. Nine months later the University of Missouri zoologist found only three banded bats, although 3,100 bats were handled in the search. Another group of 148 individuals were banded in Rocheport Cave, Boone County, with no subsequent recoveries.

While the banding experiment proved to be disappointing, Dr. Guthrie and her students eventually carried out a series of significant investigations on the reproductive cycle in bats.

Six species of bats have been found in Ozark caves. This includes four species of the widespread genus *Myotis*, the small, solitary *Pipistrellus subflavus subflavus*, commonly known as the Pygmy Bat, and the largest cave species, the Big Brown Bat, *Eptesicus fuscus fuscus*.

Most widely distributed throughout the Ozarks is the Pigmy Bat, scattered individuals hibernating in virtually every cave. They are sometimes found also in summer. These little bats are light yellowish or reddish brown; when moisture-covered they may look silvery white.

The hardy Big Brown Bat is uncommon in the Ozarks. Small numbers have been found both in Arkansas and Missouri caves in winter; occasionally in spring.

Most numerous of the genus *Myotis* is the Gray Bat, *M. grisescens*, which we found in Marvel Cave. In that cave it appears to be a year-round resident but elsewhere in the Ozarks and farther east, in Alabama and Tennessee, the females, at least, occupy the caves principally in summer. There are still many gaps in our knowledge of the distribution and seasonal movements of this species.

The status of *M. sodalis*, the Cluster or Pink Bat, likewise is not too clear. In Denny Cave, in northwestern Arkansas, John D. Black [13] found 500 hibernating on December 21, 1934. They have been observed in Rocheport Cave, Missouri, where Dr. Guthrie suspected them of migrating during the winter following breaks in the cold weather. Scattered individuals have been reported in summer.

The common Little Brown Bat, *M. lucifugus lucifugus*, was a conspicuous, regular hibernator in the northern Ozarks, though not abundant, writes Dr. Guthrie. It hasn't been reported from the southern Ozarks, however.

The only record for the Little Long-eared Bat, *M. keenii septentrionalis*, is from Rocheport Cave where a few apparently migratory individuals were taken on February 6, 1932.

The great bat colony in Marvel Cave has dwindled considerably since 1935. It is doubtful whether bat banding and the moderate collecting for research studies at the University of Missouri seriously affected the colony. It is known, however, that a collector took 4,500 specimens for sale to a biological supply house. Such heavy collecting—approximately 30% of the colony—seems entirely unwarranted.

It must be recognized, too, that the need for specimens of blind fish, salamanders, and crayfish for legitimate scientific research poses a threat to the very existence of these rare creatures. It would indeed be unfortunate, if in our desire to better understand them, we brought about the extermination of any of these truly unique cave inhabitants.

Certainly every speleologist and spelunker should use restraint in collecting. It would be far better to *report* the presence of the larger cave animals—salamanders, crayfish, and fish—to the NSS Fauna Committee and to specialists studying these groups than to collect them. Members of the NSS have a special responsibility for preserving our irreplaceable cave fauna so that generations of speleologists and spelunkers still unborn may enjoy this remarkable feature of the Ozark underworld.

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Cavern-Dwelling Salamanders of the Ozark Plateau

By M. B. MITTLEMAN

The Ozark Plateau, by reason of its topographic relief, abundant drainage, plentiful cover, and relatively mild climate, has proved to be an ideal center of differentiation for plethodontid salamanders. Its caves not only provide the dim light or darkness preferred by these animals but also afford the only habitat with relatively constant conditions of moisture so necessary to most of them.

North and Middle America are well endowed with a great variety of amphibian species, and are especially characterized by a greater number and diversity of salamanders than is any other land mass. By far the most important American salamanders, numerically speaking, are the many genera and species which comprise the family Plethodontidae. These are salamanders which when adult are easily identified by their lack of lungs, by the presence of a nasolabial groove (a fine groove running from the lower edge of the nostril to the edge of the upper lip), and by the presence of teeth (parasphenoids), on the roof of the mouth between the eyesockets or between the inner nares.

Herpetologists agree generally that the focal point of origin and dispersal of the Plethodontidae in North America has been the southern Appalachian uplift. The progressive expansion of many plethodontid forms from their ancestral Appalachian home has been accompanied by successive changes in bodily form. Generally speaking, the greatest diversity of forms has occurred in those regions characterized by sufficient relief and topographic variation to provide a variety of ecological habitats capable of supporting without undue competition a dynamically developing salamandrine population. The Ozark Plateau, by reason of its topographic relief, abundant drainage, plentiful cover, and relatively mild climate, has proved to be an ideal center of differentiation for plethodontid salamanders.

Amongst the most important salamander habitats afforded by the Ozark Plateau—and by all odds the most interesting—are the many caves with which the Plateau is marked. In passing, it may be said that most plethodontid salamanders are negatively phototropic, or in simpler words, prefer to avoid light so far as possible. Hence it might be anticipated that the Ozark caves would constitute an ideal haven for various species of salamanders, and such is indeed the case. The caves not only provide the dim light or darkness preferred by these animals, but in many areas afford the only habitat with the relatively constant conditions of moisture so necessary to most salamanders.

The salamander fauna of the Ozark caves can be roughly divided into three types: *true cavernicolous species* showing radical structural modifications as a result of a cave existence, these being wholly restricted to caves at least when adult; *crepuscular*, or *twilight-zone species* which have adopted shallow caves and cave entrances as their preferred habitats, but which occur also in non-cavernous habitats; *visitant species*, which occur in non-cavernous habitats usually, but which take to the twilight zone of caves when the opportunity affords or when conditions demand (as for instance as a result of unusually hot and dry periods, when the relatively constant conditions of moisture and temperature in many caves provide a welcome refuge).

Only three genera of true cavernicolous salamanders are known in the western hemisphere (an additional genus occurs in Europe), these are the genera *Haideotriton*, *Typhlomolge*, and *Typhlotriton*. The first two genera occur in Georgia and Texas, respectively, while *Typhlotriton* occurs only in the Ozark Plateau. Two species of *Typhlotriton* are known, *T. spelaeus* Stejneger and *T. nereus* Bishop. In both species the larvae occur in open streams, are of a tannish color stippled over with a slightly darker pigment, and functional eyes are present. As the larva approaches imminent maturity, at least in *spelaeus*, it returns to its cave home, and there undergoes an almost complete degeneration of its optical apparatus, the eyes becoming atrophied and the eyelids becoming virtually fused. In addition, almost all color is lost, and the animal is then a ghostly white, or pinkish white. In *nereus,* which is believed to be a neotenic species (i.e., a permanent, larval-breeding species), the eye in the mature larva becomes somewhat reduced in size but is still functional. Specimens found in caves are considerably more pallid than those from open streams. Nothing is known of the breeding habits of these remarkable salamanders, nor have their eggs been described—here is a fertile field for the patient speleobiologist. *Typhlotriton* are known from Rockhouse Cave, Wilson's Cave, Downer's Cave, Marble (Marvel) Cave, Doris Cave, River Cave, and numerous springs and streams in Missouri, Arkansas, Oklahoma, and Kansas. Adult *Typhlotriton* have been taken from points 600 feet within Rockhouse Cave (Barry Co., Mo.), and from a point over half a mile inside of Marble (Marvel) Cave (Stone Co., Mo.).

ALTHOUGH it is the most widely distributed of the world's five species of blind salamanders, TYPHLOTRITON SPELAEUS is found only in the Ozark Mountains. It was discovered in Rock House Cave, Barrie County, Missouri, in 1891. Adults reach a length of four inches.

Closely related to the cavernicolous *Typhlotriton,* are the crepuscular or twilight species of the genus *Eurycea.* Three species of *Eurycea* occur in and around Ozark Plateau caves, these being *Eurycea longicauda melanopleura, Eurycea longicauda lucifuga,* and *Eurycea multiplicata.* The first two species, *melanopleura* and *lucifuga,* are large (approximating $4\frac{1}{2}$ to $6\frac{1}{2}$ inches in length), boldly-patterned salamanders, easily identified by their flecked or speckled appearance, and by their long and vertically compressed tails which constitute at least 60% of the total length in adult specimens. The third form, *multiplicata,* is considerably smaller, averaging about three inches or so in total length, and having a somewhat rounded tail which comprises barely 50% of the total length. The salamanders of the genus *Eurycea* undergo no changes of a degenerative nature, so far as their visual equipment is concerned. Rather, since they prefer the twilight zones of their cave habitat, their eyes are distinctly functional and are somewhat better developed (as to size) than are those of their

UPPER: EURYCEA LONGICAUDA MELANOPLEURA. **Rarely found outside the Ozarks. Length: 5 inches.**

LOWER: EURYCEA LONGICAUDA LUCIFUGA. **Frequents caves from Virginia to Oklahoma. Length: 6 inches.**

PLETHEDON GLUTINOSUS GLUTINOSUS. **Found from New York to eastern Texas. Length: 6 inches.**

kindred relatives living wholly outside caves. The three species of *Eurycea* listed here as being dwellers of the cave twilight zone are found also outside of caves, but generally prefer a cavern habitat whenever it is available. The breeding habits of *melanopleura* and *multiplicata* are very poorly known, and their eggs are undescribed. The larvae of *lucifuga* are fairly well known, but the eggs are undescribed. These species of *Eurycea* have been found in many of the caves listed for *Typhlotriton,* but detailed distributional and ecological data are much to be desired.

Two remaining species of salamanders often found in Ozark caves are in the category of visitant species. These are the terrestrial forms *Plethodon glutinosus glutinosus* and *Plethodon cinereus angusticlavius,* which normally occur outside of caves in the greater part of their ranges, but which often resort to caves, especially in hot and dry periods. Like the species of *Eurycea,* the *Plethodon* species largely prefer the twilight zone in caves. *Plethodon g. glutinosus,* the slimy salamander, attains a fairly large size, up to about 6½ inches in total length, and is a dark bluish-black above and below, with many white flecks dorsally, and especially along the sides of the head and body. Its common name, slimy salamander, is very apropos, for it secretes an extremely sticky slime when handled. The life history, and especially the breeding habits, are very imperfectly known, and further information is much to be desired. The Ozark red-backed salamander, *P. cinereus angusticlavius,* has been described only recently (1944), and practically nothing is known of it save for its distribution and structural variation. The type specimen was collected at Mud Cave, near Fairy Cave, Stone County, Missouri, and other specimens are known from various localities in southern Missouri and northern Arkansas. It is a small species, probably attaining a maximum total length of about four inches; the tail is round in cross-section, and the most striking feature of pattern is the very narrow vertebral stripe, which is reddish, and thus stands out fairly prominently against the grayish or blackish ground color of the back. A species very close to the Ozark red-backed salamander is the eastern red-backed salamander, *Plethodon cinereus*

cinereus, which occurs in extreme eastern Missouri, and which may be found in caves in that area. It is distinguished from the Ozark red-backed salamander by its much wider dorsal red stripe (see identification key).

It will be seen readily that study of the distributional, ecological, and breeding nature of the cave-dwelling salamanders of the Ozark Plateau provides an extremely fertile field for investigation. Virtually any information on these salamanders is much to be desired, and there is every likelihood that undescribed species will yet be found in some of the Ozark caves and their attendant drainage systems. The author will be pleased to correspond with interested students of the Ozark herpetofauna, and would be especially grateful for any specimens of salamanders from the Ozark caves.

Identification Key for Adult * Salamanders from Ozark Caves

1. Tongue round, free on all sides, on a central stalk and rather mushroom-like in appearance....2
   Tongue adhering to the floor of the mouth, free only on the sides and in the rear, no central stalk 4

2. Costal grooves between the limbs on the sides of the trunk 19-20; the fingers and toes of the fore- and hind-limbs separated by 8 to 10 costal grooves when appressed towards each other. Tail about 50% of the total length. MANY-RIBBED SALAMANDER. *Eurycea multiplicata*.

   Costal grooves 14; appressed toes overlapping, just meeting, or separated by not more than 1 or 2 costal grooves. Tail approximately 60% of the total length 3

3. Belly speckled, spotted, flecked, or mottled. Sides dark brownish, with many light dots. DARK-SIDED SALAMANDER. *Eurycea longicauda melanopleura*.
   Belly not speckled, mottled, or flecked, but immaculate. Sides and back orange or reddish, with many black dots or spots. LONG-TAILED CAVE SALAMANDER. *Eurycea longicauda lucifuga*.

4. Eyes degenerate, eyelids fused. Color whitish, or pinkish white, little or no dark pigment. OZARK BLIND SALAMANDER. *Typhlotriton spelaeus*.
   Eyes normally developed, body pigmented 5

5. Size large (up to 6½ inches); color blue-black above and below, with many white flecks and patches on back and sides of body and head, or on sides only. SLIMY SALAMANDER. *Plethodon glutinosus glutinosus*.

   Size smaller (4 inches or less), a distinct reddish or chestnut-colored band or stripe running the length of the back; belly salt-and-pepper mottled, not uniform blue-black 6

6. Width of the dorsal red stripe 13% to 33% (average 28%) of the width of the body. OZARK RED-BACKED SALAMANDER. *Plethodon cinereus angusticlavius*.

   Width of the dorsal red stripe 34% to 57% (average 45%) of the width of the body. EASTERN RED-BACKED SALAMANDER. *Plethodon cinereus cinereus*.

* As used here, the term "adult" refers to metamorphosed (non-larval) specimens.

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The Invertebrate Fauna of Ozark Caves

By LESLIE HUBRICHT

From the standpoint of the fauna there are two types of caves in the Ozarks. In the most common type the water they contain is derived from *seepage through rock* and all organic matter has been filtered out. In such caves bat guano is the primary food source. Since there is no way in which animals may be washed in they are all of the *voluntary* type, that is, they are living in the cave because they are adapted and "prefer" to live there.

The second type comprises the sink-hole and tunnel caves. These are found mostly east of the Crystal City Escarpment. In these caves the water is derived *directly from the surface*. Such caves have an abundance of organic matter in the form of dead leaves, sticks, and sometimes logs which have been washed in. Such caves are likely to have many *involuntary* residents which have been washed in after storms, such as frogs, sunfish, snails of the genus *Physa*, and many smaller organisms, some of which may adapt themselves to the total darkness and live and breed there.

The following list contains only species which appear to be able to live and breed in the total darkness of caves. Species found only about cave entrances and accidentals have not been listed.

Phylum PORIFERA (Sponges)

Spongilla sp. Freshwater sponges are sometimes found abundantly in cave streams which have direct surface connections, as in tunnel and sink-hole caves. Abundant in Jam-Up Cave, Shannon Co., Missouri.

Phylum COELENTERATA (Hydras)

Hydra sp. Hydras are sometimes found in tunnel and sink-hole caves, as in Cliff Cave, St. Louis Co., and Jam-Up Cave, Shannon Co., Missouri.

Phylum PLATYHELMINTHES (Flatworms)

Speophila hubrichti Hyman. Common in many caves in the eastern Ozarks.

Sorocelis americana Hyman. Found in caves in northeastern Oklahoma and northwestern Arkansas.

Geodesmus atrocyaneus (Walton). This land planarian has been found in Mecker Cave, Perry Co., and River Cave, Camden Co., Missouri.

Phylum BRYOZOA (Moss Animalcules)

Plumatella sp. Occasionally found in tunnel and sink-hole caves.

Phylum ANNELIDA (Segmented Worms)

A small, slender, white earthworm about an inch long, very much like those used to feed tropical fish, is occasionally found in drip-pools.

A reddish-brown, free-swimming leech, about two inches long when extended, is sometimes found in sink-hole and tunnel caves.

Phylum ARTHROPODA (Crustaceans, Insects, etc.)

Copepods

Copepods are occasionally seen in the drip-pools in caves, but whether they represent distinct cave species is not known.

Amphipods

The following species of *Amphipoda* are known from Ozark caves:

Gammarus troglophilus Hubricht & Mackin. Found in caves in the eastern Ozarks.

Gammarus limnaeus (Smith). Found in central Missouri in caves which have large colonies of bats, which provide them with an abundance of guano for food.

Gammarus acherondytes Hubricht & Mackin. Found in two caves in southern Illinois.

Allecrangonyx pelucidus (Mackin). Found in caves in the central Ozarks and in the Arbuckle Mountains, Oklahoma.

Crangonyx forbesi (Hubricht & Mackin). Found in caves throughout the Ozarks.

Crangonyx gracilis packardi (Smith). Found in southeastern Kansas.

Bactrurus mucronatus (Forbes). Known from caves in southern Illinois and Missouri.

Bactrurus brachycaudus Hubricht & Mackin. Found in caves in the eastern Ozarks.

Stygobromus heteropodus Hubricht. Known only from Ste. Genevieve Co., Missouri.

Stygobromus onondagaensis (Hubricht & Mackin). Found over most of the Ozark region.

Synpleonia clantoni Creaser. Found in the western Ozarks.

Synpleonia americana (Mackin). Found over most of the Ozark region.

Isopods

In addition to the species of *Asellus* listed below, there are a number of new species the descriptions of which have not as yet been published.

Asellus brevicaudus Forbes. Abundant in many caves in the northeastern Ozarks.

Asellus stygeus (Cope). Found in caves east of the Crystal City Escarpment.

Asellus nickajackensis (Packard). Found in caves east of the Crystal City Escarpment.

Asellus antricolus (Creaser). Found over most of the central Ozark region west of the Crystal City Escarpment.

Asellus tridentatus (Hungerford). Found along the northern fringes of the Ozarks.

Asellus dimorphus (Mackin & Hubricht). Found in the southeastern Ozark region.

Asellus macropropodus (Chase & Blair). Found in northeastern Oklahoma and northwestern Arkansas.

Crayfish

In addition to epigean species of crayfish which sometimes enter caves, there are two white, blind species described from caves in southwestern Missouri.

Cambarus ayersii Steele. Fisher's Cave, Smallin's Cave, and Moore's Cave, all near Springfield.

Cambarus setosus Faxon. Wilson's Cave, Jasper County.

Cambarus sp. A still undescribed species from Lewis Cave, Ripley County.

Arachnids

A pseudoscorpion, several species of blind, unpigmented mites, and pale blind spiders, all probably unnamed are found in many Ozark caves.

Millipedes

Millipedes are common in many Ozark caves. The following list is supplied by Richard L. Hoffman:

Conotyla specus Loomis. St. Louis and Franklin counties.

Scoterpes dendropus Loomis. Jefferson, Franklin, and Stone counties.

Tingupa pallida Loomis. Camden, Crawford, Maries, Wayne, Texas, Miller, and Pulaski counties.

Cambala minor (Bollman). Ste. Genevieve County (Cellar Cave at Zell).

Zosteractis interminata Loomis. St. Louis and Ste. Genevieve counties.

All of the foregoing except *C. minor* are truly troglodytic. Other, epigaean, species wander into caves from time to time. *Pseudopolydesmus hubrichti* (Chamberlin) has been found in caves in St. Louis and Pulaski counties. It is not a true cave form.

Of the above species, *Zosteractis interminata* is the only known form in its family. The other species of *Tingupa* occur in Utah and California.

Insects

Several species of blind, white springtails are found in Ozark caves. They are probably undescribed.

Camel crickets can be found in most Ozark caves. During a country-wide survey T. H. Hubbell visited many Missouri caves and reported the following species:

Ceuthophilus williamsoni Hubbell. First collected in Krapf Cave, near Waynesville, 1929, and Onondaga Cave, 1930. It was the only species *inside* these caves, but in Lesterville Cave it was outnumbered by *gracilipes*. Commonest species in the Ozark uplands.

Ceuthophilus gracilipes Haldeman. A wide-ranging species. In the Ozarks it has been found in caves in Reynolds, Iron, Carter, and McDonald counties.

Ceuthophilus seclusus Scudder. Collected in the western part of the Ozarks, particularly at Big Mouth Cave, near Grove, Oklahoma.

Ceuthophilus uhleri Scudder, and *C. silvestris* (Bruner). Have both been found outside Onondago Cave.

Several species of beetles are found in Ozark caves. The commonest species is *Ptomaphagus cavernicola* (Schwarz).

The following species of flies have been identified from Rice's Cave, Jefferson County, Missouri: *Megaselia cavernicola* (Brues), *Leptocera tenebrarum* Ald., *Sciara* sp.

Phylum MOLLUSCA (Mollusks)

Amnicola aldrichi antroecetes Hubricht, is found in cave streams in the eastern Ozarks from the Gasconade and Current River Drainages to the Mississippi.

Amnicola procerpina Hubricht, is found in cave streams only in the counties bordering on the Mississippi River.

Carychium exile (C. H. Lea), this land snail is found abundantly in River Cave, Camden County, Missouri.

Physa sp. This species occurs in several tunnel caves where they have been washed in and adapted themselves to the darkness, and have multiplied.

Ferrissia sp. Found abundantly in Hall's Cave, Boone County, Missouri.

Musculium sp. Very abundant in some of the sinkhole and tunnel caves east of the Crystal City Escarpment.

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Bones in the Brewery

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A Paleontologist's Rendezvous with History and Prehistory in St. Louis

In the heart of a great city, under the very feet of its unsuspecting citizens, an archaeological treasure is brought forth after thousands of years of burial. The exciting story is reprinted here from NATURAL HISTORY, June 1946, pp. 252-259, by special permission of its author and of Editor Edward M. Weyer.

Three currents of history meet at the corner of 13th and Cherokee Streets in St. Louis, Missouri. South of Cherokee, where 13th does not run through, there is now an immense shoe factory. On the northeast corner of the intersection, there is a large but apparently rather plain brick house. The northwest corner is a lot with only one small structure, which looks like a one-car garage. Each of these buildings is more than it seems to be because each has a historical significance. The shoe factory was formerly a brewery: it recalls a current of history that started in the Rhineland, more than a century ago. The house turns its plain side to the street but when viewed from the east, within its own spacious grounds, it is seen to be a stately mansion with a graceful, pillared portico: its history traces back through the De Menils and the Chouteaus to the pioneer days of the Mississippi. The apparent garage is really the entrance to a cave that rambles beneath the surrounding buildings: its history is the most ancient of all, and in it are buried animals that lived before man ever saw the site of St. Louis.

Our introduction to this convergence of history at 13th and Cherokee Streets began with a letter. Lee Hess, a pharmaceutical manufacturer in St. Louis, wrote to say that he had found some bones in the cellar of a brewery. Would the Museum be interested? Many such letters come to a curator's desk. Nine times out of ten, they do not lead to anything of value, but we always follow them up as far as possible because the tenth letter may be a clue to an important scientific discovery. We wrote to Mr. Hess asking him to send some of the bones so that we could determine their possible importance.

The bones sent to us had been considerably broken by the workmen who found them, but when we pieced them together in the laboratory we found that they included a skull of an extinct peccary, *Platygonus compressus* by name. Now, *Platygonus* is not a particularly rare fossil. Its remains had already been found in many places throughout the United States. For instance, 22 skulls (12 of them nearly complete) had been collected for the United States National Museum in a cave near Cumberland, Maryland, 5 partial skeletons had been found in a peat bog near Belding, Michigan, and 9 nearly complete skeletons had been discovered at Goodland, Kansas, in the clay-pit of a brickyard, and sent to the University of Kansas. One of the Kansas skeletons, obtained from the University by the American Museum of Natural History, was restored and mounted in a lifelike pose and has been exhibited here for years.

In spite of these and other previous discoveries, we became quite excited about the bones from St. Louis. *Platygonus* had never turned up in a beer cellar before, and extinct animals are rarely found in the heart of a great city. How they came to be there was a mystery worth solving, and we resolved to go to St. Louis and try to clear up the mystery with a little geological detective work. I wrote to Mr. Hess asking whether more bones remained in place and whether we could come out and investigate the find. His reply assured us that many bones remained to be excavated and cordially invited us to study the occurrence. In a few days George O.

Whitaker, of our fossil vertebrate laboratory, and I were off for what turned out to be an unexpectedly fascinating rendezvous with history, ancient and recent.

Mr. Hess met us in St. Louis and drove us immediately to the De Menil mansion, the historic home at 3352 South 13th Street. This house, unoccupied but restored by Mr. Hess with sufficient modernization for comfort, was our camp throughout our stay: a camp such as a bone-digger has seldom enjoyed in his wildest dreams of luxury. Before we were through, it was also our bone laundry, shellackery, and packery. Here we dropped at once into an atmosphere of old St. Louis of the pioneer days before the Civil War. The house was originally built in the 1840's by Henri Chatillon, a western guide and hunter of that period. In 1854 it was purchased by Dr. Nicholas N. De Menil, and in 1863 he enlarged it by adding several spacious rooms and the magnificent portico on the east side, overlooking his large garden and the slope of Arsenal Hill down to the Mississippi.

Nicholas De Menil, who had come to America on a visit (which proved to be life-long) in 1833, was a physician who established the first successful chain of drugstores in St. Louis and became one of the aristocrats of that growing center. He married Emily Sophia Chouteau, linking his family with the real pioneers of the region, for she was the great-granddaughter of Marie Therese Chouteau, the first white woman to settle in St. Louis and still revered as the mother of that city.

Alexander De Menil, son of Nicholas, lived in the house throughout his long life. By the time he died, Arsenal Hill was no longer a swanky residential district but had been overgrown with smoky factories and surrounded by slums. His heirs chose not to live there, and the property finally passed out of the family when they sold it to Mr. Hess, almost a century after the family acquired it. Like his father, Alexander was a physician, but he was also interested in literature and became a poet of local renown. Among his voluminous productions is a rather quaint but forceful defense of his great-great-grandmother, the famous Madame Chouteau. (She left her husband in New Orleans because of his cruelty to her and formed an irregular union with Laclede, who became the founder of St. Louis; her solution of a marital problem when divorce was impossible was approved by her contemporaries, but became a worry to some of her descendants.)

We often thought of these vanished occupants as we roamed through the house or rested on its spacious balconies and watched spring come to the garden. If, however, the ghosts of the Chouteaus and the De Menils roamed through the house at night, we never knew it, for we slept soundly after our hours of bone-digging. Ghosts still more exotic might conceivably have troubled our slumbers. The fascinating hodge-podge accumulated by Mr. Hess with a view to future exhibition included a reconstruction of a Damascus palace with its furnishings. After display at the St. Louis fair in 1904, these oriental trappings had been crated and stored until recently when our host acquired them and piled them into the De Menil house. Thus it happened that our library included an Arabic Bible, along with Hedin's *My Life as an Explorer,* the Catholic Directory, Boccaccio's *Decameron,* and *How to Develop a Winning Personality.* Pending the availability of more space and the sorting of all these treasures, our quarters were furnished in a medley of styles in charming confusion. Tubular metal modernistic

In the "field laboratory" in the DeMenil house: George Whitaker and Lee Hess examine the skull of an animal that lived at least 20,000 years ago, during or shortly after the Ice Age. Mr. Hess discovered the bones on his property and invited the American Museum to excavate them.

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chairs jostled a mid-nineteenth century *chaise longue*, over which was thrown a vivid Mexican serape and beside which was an old Turkish tabouret of ebony inlaid with mother-of-pearl. The introduction of our prehistoric peccaries struck no jarring note but seemed only to complete this remarkable mixture.

History and Pre-History

It was, after all, the prehistoric peccaries that had called us here and that claimed most of our attention, but even these brought us into contact with history as well as with pre-history. Unrest in the Rhineland well over a century ago was one of the influences that led to our journey to St. Louis last March and to the exhuming of these ancient remains. It was in the 1820's that one Gottfried Duden came to the Mississippi Valley to spy out the land for his German neighbors. Here in St. Louis he found several caves in the limestone underlying the city and he reported that the site was propitious for breweries. Before the coming of artificial refrigeration, successful brewing on a large scale required natural repositories where the temperature was constant and low throughout the year. These caves, which retain a temperature near 55° regardless of the weather outside, were ideal for the purpose. Rhineland brewers migrated to St. Louis and converted the caves into storerooms for their lager. It was one of these immigrants, Adam Lemp, who cleared out the cave at 13th and Cherokee and built his brewery above it.

Toward the end of the nineteenth century, air-conditioned storehouses made the caves unnecessary, and they were abandoned by the brewers. One or two were converted into underground beer parlors and places of amusement: Uhrig's Cave was such an establishment in the gay 90's and is nostalgically remembered by St. Louisians. But the cool, dark dampness of the caves, so suitable for beer before it is drunk, seemed to depress the customers after they drank the beer. "Uhrig's Cave" became an open air theater above the actual cave. The cave itself enjoyed only one more brief flair of fame when a large distillery was discovered in it during prohibition. The other caves were closed, their entrances walled up or blocked with debris, and eventually they became vague memories. The Lemp Brewery went out of business during prohibition, its buildings were sold to the International Shoe Company, and its cave, the Cherokee Cave, was forgotten until Lee Hess recently conceived the idea of reopening it as a site of historical and geological interest.

When we arrived, we took only a quick glance at the noble De Menil mansion ("our pup tent," George called it), and then hurried down into the cave. A circular, brick-lined shaft about 35 feet deep had been reopened and a spiral iron staircase installed. At the foot it opens into a long series of storage rooms, once full of lager beer but now dismally empty. The rooms were formed simply by clearing out a natural cave, a former underground river channel within the solid limestone, and by dividing it by masonry walls. The first room at the bottom of the shaft still bears traces of its use for private theatricals and parties by a gay blade of the Lemp family who took it over when the beer was moved out. Across one end he constructed artificial scenery made of wire screen and plaster. The scenery represents a fair imitation of the wall of a cave; this hiding of a real cave wall behind an artificial cave wall is one of the touches that made us feel at times as if we had stepped into Alice's Wonderland. There are still remains of the crude but serviceable floodlights used to illumine this scene.

The cave extends in an easterly direction for some 200 feet beyond this "theater." There it is joined by another channel, coming from under the former brewery to the south, also cleared and converted into storage rooms. At the intersection is a concrete-lined pool, presumably used as a reservoir in the old brewing days and reputedly used as a swimming pool in the later (but now also old) days of theatricals and parties, although we thought that a party would have to be very stimulating, indeed, to tempt us to plunge into those Stygian waters!

Where No Man Has Been

This was the end of the cave so far as the brewery was concerned. It terminated here with a masonry wall. To see where it went beyond, Mr. Hess had the wall broken down with a hydraulic jack and was disconcerted to find that although the cave does, indeed, continue, it was almost completely filled by a deposit of stiff, wet clay. This made it impassable for anything much larger than a rat. He had workmen dig a narrow passage in the clay, following the ancient channel of the cave. Within 20 feet from the wall it turned to the left, northward, and had, at the time of our visit, been followed in that direction for some 200 feet farther, with no sign of ending, or of coming out to the surface, or of joining another, adjacent old brewery cave (the Minnehaha Cave) with which Hess hopes eventually to make a connection. The point where the cave turns is almost under the porch of the De Menil house, where we used to relax at lunch or in the evening, 40 or 50 feet straight above our diggings.

A more talented and imaginative writer might contrast these superposed scenes in a sort of allegory. In the upper world it is spring. The air is warm and balmy, and the sun is shining. The grass is green and sprinkled with violets. Bushes and trees are in bloom, and innumerable birds are setting about their seasonal loves and labors. The caretaker's pretty baby girl toddles about, learning to walk. The world of life is developing its future in a scene just old enough to be leisurely and pleasantly mellowed.

In the lower world there are no seasons. The motionless air is always cool but never cold. The humidity is always near 100% and nothing is ever quite dry. The white limestone ceiling is dewey as if perspiring quietly, and water drips slowly from the tips of the scattered stalactites. The water is limpid but it carries in solution minute quantities of lime, the slow, imperceptible precipitation of which through the ages has formed the stalactites, stalagmites, and cave onyx, all forms of what has appropriately been called dripstone. Yellow lights illumine a scene that has never known the sun and make temporary islands of light in a sea of absolute darkness that has been lightless for hundreds of thousands of years. Smeared from head to foot with yellow mud, workmen slide along the narrow passage, digging out the sticky clay, penetrating still farther into the mysterious entrails of the earth where man has never been before. In spite of this rash intrusion, the strange scene seems as ancient and timeless as a tomb. And it is a tomb, a place of mass burial, sealed away as a monument of the dead past, before the first Indian ever hunted a deer along the top of the hill inside which it lies.

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The author, assisted by George O Whitaker, also of the American Museum, digging for prehistoric animal bones in the cave. For many years the cave was used for the storage of beer and as an entertainment center, without anyone suspecting that it contained remarkable scientific treasures.

A Nice Find

That filling of clay is an exasperating and expensive nuisance to the men who want to reopen the old cave channel, but it is a delight to the bone-digger. It was in this clay that the workmen found the bones that brought us to St. Louis, and we began finding more bones as soon as we dug into it for ourselves. In the week that we were there, we found too many bones to count, but we guess that we excavated between 2,000 and 3,000 of them, some almost too small to see while others were large, complete skulls.

As we dug bones, we began our detective work. What the bones are is perhaps the least part of the mystery, and their identification had to be done back in New York, anyway, where we could study and compare the bones at our leisure. Here the problem was how the bones came to be here, in the core of Arsenal Hill under the De Menil house. Some clues are still missing and a more fortunate detective than I may prove someday that I am wrong, but we did soon find enough clues for a tentative solution of the mystery.

As Clue No. 1, there is the cave itself. By that I mean the long, branched, channel-like cavity in the limestone, regardless of the fact that it is or has been nearly filled up with clay. It averages 20 to 25 feet wide, with solid limestone walls and ceiling. We do not know how long it is, where it comes from, or where it goes to: important missing clues. We do not even know how deep it is or what the floor is like; because as deep as anyone has yet dug (12 to 15 feet in places), the bottom of the clay has not been reached.

Clue No. 2 is the clay, or rather, this is a series of clues, because the clay proves on investigation to be complex and to include several distinctive superposed layers. The lowest layer visible, as far as it has been excavated, is massive, yellowish gray, and somewhat gritty. We found no traces of bone in this. At its top in some places but not in all is a layer of dripstone (cave or "Mexican" onyx) from which rise stalagmites, buried by the overlaying layers of clay. The next higher clay layer, sometimes absent but in other places two feet or more thick, is very smooth and fine, without grit, and is deposited in thin, horizontal layers. There are no bones here, either, except occasionally right at the top where they probably sank in from above when the clay was less compact. The top of this is sharply distinguished from the overlying bed but it has no layers of dripstone so far as we saw. Next higher is a bed of clay quite variable in thickness but averaging 18 to 20 inches, also fine and plastic, but without layers and containing many scattered chunks of limestone and of dripstone. Almost all the bones are in this bed of clay, which we called "the peccary layer." Above it there is occasionally, but not usually, a thin layer of dripstone. At the very top is a bed, usually less than a foot thick, of relatively loose, granular, earthy clay. In places it fills holes extending down into the lower layers. A few very small bones were found in this bed. In some places where there is a small unfilled space above this top layer there are small stalagmites on it, and where these occur they are usually set on small plaques of dripstone.

Our major clues are the bones themselves, not only because of what they are but also because of how they occur. As I have said, almost all the bones are in the "peccary layer." You cannot dig long in any part of that particular stratum without finding bones, but they do usually tend to be more common toward the bottom of the layer. Even when several are found together, they are just piled up at random. No two bones of the same animal are found together. Most of the long bones are buried in a more or less horizontal position, but some are oriented without regard for the natural bedding of the deposit and they may even be vertical. Small, solid individual bones are usually whole, but the longer and more fragile bones are usually broken. We did not find a single complete rib. A few of the bones have tooth marks and had been gnawed before being buried here. Bones of the extinct peccary are by far the most common, but there are also a few bones and teeth of other extinct animals and of some living species in this layer; I will give the list later.

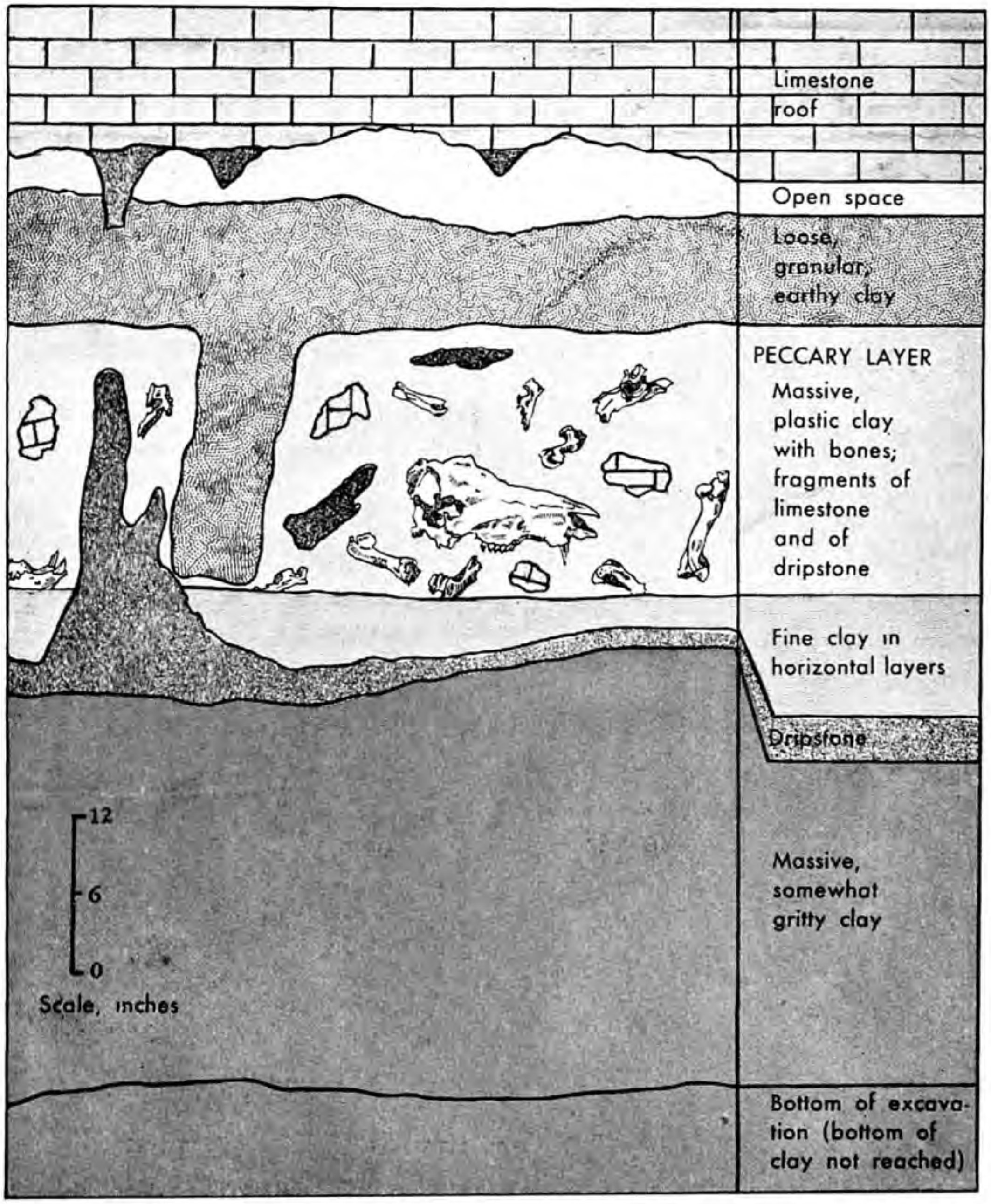
The rare bones in the highest layer tend to occur in a few pockets, scattered but sometimes with the remains of one individual near each other. Except for one or two bones apparently washed out of the peccary layer, there are no extinct animals in this bed and most of the bones belong to small, burrowing rodents.

The Story of the Cave

Those are the main clues. This is my proposed solution, so far as it has yet been carried:

The very first thing that left traces here happened so long ago that it is only indirectly involved in our problem of the bones. This was the deposition of the limestone, which occurred in a sea that covered this site about 300,000,000 years ago. Much later, perhaps only a million years or so ago (the event has not been very exactly dated, and it took a long time), the cave was formed. The sea had withdrawn long since and the region had been uplifted gently. Water began to percolate along the cracks and seams of the limestone and as it went, it slowly but steadily dissolved the rock. Eventually it formed a large underground channel which was, and is, the cave. At this stage the cave was free of any extensive deposits of clay, and it probably had a subterranean stream or river at the bottom. This probably reached the surface some distance away and eventually flowed into the Mississippi.

Somehow the exit from the cave became clogged and the clay and silt brought in by streams from the surface, instead of being washed on through the cave and out again, began to pile up in the cave. These sediments eventually filled the cave up to within a few feet of its ceiling. Then for a long time there was no particular activity except the slow dripping of lime-filled water within the cave, developing dripstone deposits here and there on the top of the silt which now formed the floor of the cave. This floor was not even but contained shallow depressions. The next recorded event, which probably occurred during a particular rainy



The geological story of the cave before and after the animals lived in the region was deciphered from the cross section of the deposits that had partly filled it, as described in the article.

period of the Ice Age, was the filling of these depressions with water, forming within the cave a lake, or a series of small lakes. Tiny, insoluble clay particles were slowly washed into this standing water and they accumulated at the bottom, forming the bed of horizontally banded clay that we found below the peccary layer.

Now came what is for us the great event: the deposition of the bones in the cave. The evidence shows clearly that these animals did not live or die in the cave and it strongly suggests that this was not the first place in which they were buried. The animals probably fell into a sinkhole or fissure somewhere near the cave, perhaps a hole that had been an entrance to the cave but had been sealed off from it by the older accumulation of clay or by a fall of rock. The exact spot has not been found and search for it would not be very hopeful now that the whole region has been built up as part of a great city. The bones of many animals, hundreds certainly and perhaps thousands, piled up in this sinkhole or fissure and were buried there in mud and clay that washed in over their bones. Then the accumulation—clay, bones and all—was somehow washed into the cave. There are several ways in which this could have occurred. Perhaps the most likely is that the sinkhole or fissure filled up with water above the clay and bones, that this water found an outlet into the cave, and that it suddenly flushed the whole deposit into the cave and spread it out over the older clay deposits of the cave. The nature of the peccary layer in the cave suggests that it came there rapidly, perhaps in an hour or two—one dramatically rapid event in a sequence where most changes can only be measured in terms of thousands or hundreds of thousands of years.

After this sudden change, things quieted down again. A little more clay was washed in from time to time. Rodents occasionally wandered into the cave, rooted around a bit in the top clay, and died there. These later events did not matter much so far as our interests go, until the final event of the reopening of the cave by man. It is surprising that the discovery of prehistoric animals here was delayed until 1946. When the brewery cleared part of the cave, many tons of clay were removed and in this there must have been thousands of bones. So far as is known, no one paid any attention to them. Presumably they were carted off with the clay, dumped somewhere, and buried again: their third burial.

The bones that have now been recovered and saved for scientific study include all anatomical parts of numerous individuals of the extinct peccary, *Platygonus compressus*. Both sexes and all ages are represented, from tiny jaws of peccaries newborn, or perhaps actually not yet born when they died, to skulls of big, tough boars. North America was peccary headquarters for millions of years. Numerous extinct kinds have been discovered, and there are two kinds still living in South and Central America one of which, the collared peccary *(Tayassu angulatus)*, ranges as far north as southern Texas, New Mexico, and Arizona. Peccaries are sometimes called "wild pigs" and they do look much like pigs, but the real relationship is not very close. They do not belong to the pig family (Suidae) but to a distinct family of their own (Tayassuidae). True pigs have never been native to the Western Hemisphere.

The living peccaries are rather small animals, seldom over 20 inches high at the shoulder. They usually run in bands and are inoffensive vegetarians, although their sharp, curved tusks give them a somewhat fierce appearance. Some travelers have told horrendous tales of being attacked by large bands of peccaries, but more reliable observers report that they will not attack except as a last resort when they are molested. The normal use of the tusks is to pull up and cut roots for food. Our extinct peccaries from Cherokee Cave had the same habit, because several of the tusks that we found have grooves worn in the sides from rubbing against gritty roots. In fact, these ancient peccaries must have looked and acted very much like their surviving cousins, except that they were about twice as large.

Other Animals

We had hoped to find remains of other animals that lived at the same time as the peccaries, and in this we were successful, but only one of our additional discoveries was particularly striking. Apparently the trap in which these animals were originally buried, the sinkhole or fissure from which their remains were flushed into the cave, was specially adapted for catching peccaries. Few other animals fell into it, but we did find scanty remains of a black bear, a raccoon, and a porcupine, all much like those still living in the region when white men arrived there. The unexpected discovery was an extinct armadillo, related to the recent Texas armadillo but larger. This is an important new record, because St. Louis is much farther north than any other known occurrence of an armadillo, living or extinct. Recent armadillos range no farther northward than Texas, and the only comparable previous finds of extinct armadillos were in Florida.

Both the armadillo and the peccary, also a warmth-loving animal, suggest that when these animals lived there the climate of the region was milder than at present. They may have lived just before or just after the last glacial stage of the Ice Age, for these were times of relative warmth. Aside from this inference, it is impossible to give a very close answer to the question as to how old the bones are. The difficulty is increased by the fact that the bones were not originally buried where they are now found. They may have lain for a long time in their original tomb before being washed into the cave. They are pretty surely more than 20,000 years old, and it is not likely that they are more than 500,000 years old—the interval gives a good deal of leeway. In any case, they are very ancient in terms of human history but are quite young as fossils go.

Bones Almost Like New

Hermetically sealed in continuously damp clay since shortly after the animals died, the bones have been unusually well preserved. The marrow and other soft animal matter have decayed and disappeared, but the hard bone substance has not changed at all. The bones were roughly jolted when they were flushed into the cave and many of them were broken then, but even the fragments are strong and fresh and some of the unbroken bones look almost as if they were the remains of last night's pork roast. This beautiful preservation made the bone-digger's job much simpler and quicker than it usually is. It was not necessary for us to apply preservatives to the bones immediately on exposure or to encase them in reinforced plaster before moving them—procedures usually necessary with fossil bones. After carefully exposing them on one side, they could immediately be pried out of the clay without damage. The problem of cleaning them was also unusually simple. No slow grinding, scraping, and chiseling to remove the rock in which most fossil bones are buried. We simply soaked them in a wash basin for an hour or two and then scrubbed off the clay with a stiff brush.

With the help of Mr. Hess and the gang of workmen he provided, we developed a mass-production system in our bone-digging. The bones were piled up in boxes as we dug them out, and the full boxes were then taken up to the De Menil house, where we had what we called our bone laundry. Here, in the old kitchen, they were set to soak, and when the clay had softened sufficiently, they were thoroughly scrubbed. The clean, wet bones were then spread out to dry on tables in the dining room. Like fresh bones, they do tend to crack when dry; the fact that they had not been dry for thousands of years is a reason for their exceptional preservation. So the next step in the production line was to paint them thoroughly with thin white shellac and then to dry them again. The shellac soaks in sufficiently to seal all the incipient cracks and forms a transparent protective coating that will preserve them practically forever. Then they were ready for the last step and were moved on along the line into the parlor, where they were carefully wrapped and packed in boxes and barrels for shipment to New York. Between the cave and the mansion, our bone mine, laundry, shellackery, and packery hummed all day and sometimes far into the night. In only one week we had what would ordinarily be a good bag for a whole collecting season. Not only that, but nine-tenths of the bones were all ready for study or exhibition when we shipped them, requiring none of the usually tedious additional preparation in the New York laboratory.

So the mystery of the bones in the brewery was solved and a goodly sample of the bones moved on to the Museum by way of the De Menil house. De Menils and Chouteaus; peccary knuckles and beer; caves and palaces—these were some of the ingredients in a unique adventure in bone-digging. It was a curious mixture, so strange that at times we were hardly sure whether we were awake or dreaming. But as I write these last lines a peccary skull looks at me blankly, reassuring me that the fascinating medley of history and prehistory was real.

SEX RATIOS IN HIBERNATING BATS*

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An apparent preponderance of males in hibernating bat populations of eastern Ontario, Quebec, New England, New York, Pennsylvania and New Jersey poses a problem of interest to scientists. This unbalanced sex ratio gives rise to the need for further study. The author gives a number of possible explanations and urges cooperation from speleologists in solving the mystery of the "missing" females. For the time being, at least, the rallying cry of the chiropterist may well be "cherchez la femme!"

To the ordinary spelunker, "a bat's a bat, for all of that"—just a part of the cave picture. The more scientific-minded speleologist may interest himself to the extent of learning the identity of the various species of cave bats. The chiropterist (not chiropodist or chiropractor, if you please), and by that I merely mean batman, is concerned not only with the identity of the bats but also with many other aspects of their lives. Since caves are the common meeting place of spelunkers, speleologists and batmen, it seems appropriate for me as a batman to report to this annual meeting of the National Speleological Society certain findings regarding the ways of bats and to point out how cavemen may help the batmen in their investigations into the ways of the original troglodytes—the bats.

Since 1939 I have been studying hibernating bats in caves and abandoned mines in Ontario and Quebec. Living some 400 miles from these caves, I have visited them infrequently—usually but once a winter. Obviously much more could be learned by a more continuous observation. I have banded most of the bats found in order to get data regarding their movements and longevity. In banding bats it is necessary to record the sex as well as the species of each individual. The necessity of keeping banding records first made me aware of the fact that during hibernation the males greatly outnumber the females, as shown in Table 1 below.

Table 1. Population of Hibernating Bats, by Sex

Species	Ontario and Quebec				Penna.
	Total	Males	Females	% Males	% Males
Eptesicus f. fuscus	1048	805	243	76.8	64.9
Myotis keenii septentrionalis	279	214	65	76.7	——
M. l. lucifugus	1814	1389	425	76.6	62.3
M. subulatus leibii	528	291	237	55.1	57.1
Pipistrellus subflavus obscurus	152	138	14	90.8	74.7

Although these figures represent totals of many populations at several different locations, the ratios for individual populations show in general but little deviation from those of the entire group. Percentages for four species studied in Pennsylvania by Charles E. Mohr, Vice-president of this society, have been included for comparison.

I shall treat in detail only one of the species, the common little brown bat, *Myotis l. lucifugus*, but before doing so let us glance at the others. In Table 1 you have already noted that in all

* A talk by Harold B. Hitchcock, Associate Professor of Biology at Middlebury College, Middlebury, Vermont, at the seventh annual convention of the National Speleological Society, Washington, D. C., March 31-April 2, 1950.

five species males outnumber females. Although the highest percentage is shown by the pipistrelle, the figure may not be too significant, since tne ratio is for a total of only 152 bats. The case for *M. keenii septentrionalis* is similar, in that the ratio is based on a total population of only 279. In each of the other species at least 500 bats were concerned, making the ratios more significant. *Myotis subulatus leibii* shows the least predominance of males—55.1%. The largest population I encountered of this species, at Fourth Chute, Ontario, February 26, 1944, was equally divided—71 males and 71 females. It is interesting to note that Mr. Mohr, who wrote a paper on sex ratios of hibernating bats in 1945, found in a 14 year study of this species in Pennsylvania that 57.1% were males—a difference of 2% from my figures in Canada. *Eptesicus f. fuscus*, the big brown bat, shows a clear predominance of males, but in December, 1949, I encountered in an Ontario mine a population of 15 consisting of one male and 14 females. Interestingly enough, Mohr also found one instance where females outnumbered males in the big brown bat, though his overall percentage of males was 64.9.

Mohr, as I have already indicated, found a scarcity of hibernating females in Pennsylvania. Others have found the same situation in New England and eastern New York, notably Donald Griffin. In Europe the same situation has been reported for *Myotis myotis* by Eisentraut, who found that in a total of 4,890 hibernating bats 58% were males. Two recent converts to bat banding in England, Mr. and Mrs. John Hooper, have written me that they, too, are finding a preponderance of males. The phenomenon, therefore, seems not to be restricted to the eastern United States and Canada.

In comparing my ratios for the little brown bat with those of Mohr and others I noted that the preponderance of males was greater in Canada than to the south. The idea came to me that the difference might be a clue to the solution of this problem. Might it not be that the females are more inclined to migrate to a warmer region, leaving the males behind? There the shorter winter would give them more time in which to raise their young. Migration by one sex only might seem to be unlikely because, you say, the males should be with the females to insure a new generation. That's right. But these bats are known to mate in the fall, the females retaining the male sex cells until the eggs are liberated from the ovary at the end of hibernation (Wimsatt '44 and '45). That being the case there would seem to be no biological necessity for the males to travel with the females. What's more, in this species, the males don't seem to like the females, or *vice versa*, for during the summer the females retire to large maternity roosts which males for the most part avoid.

To check on this idea I visited bat caves and mines during the winter of 1947-48 as far south as Mammoth Cave, Kentucky, looking for the "missing" females. I am indebted to Mr. Mohr for helping me select the best ones and to the American Academy of Arts and Sciences for financial assistance. My first stop was in the Helderbergs with Ted Judd of the Schenectady Grotto as guide. At Knox Cave 76.0% were males—the same percentage I had found in Canada. At Durham, Pennsylvania, where I was assisted by a large group from the Philadelphia Grotto, the old iron mine yielded 1,280 little browns, 63.4% of which were males. The next location in a somewhat warmer area, though not so far south as Durham, was at Hibernia, New Jersey. Here Dr. William Stull of Ohio Wesleyan and I worked a full day, scarcely making a dent on the tremendous population of little brown bats there. Of the 947 little brown bats handled, the percentage of males was 56.3. Perhaps the theory was right—at any rate the percentage of males was dropping. Dixon Cave, Kentucky, part of the Mammoth Cave system, was as far south as I went. Although there were plenty of bats there, most of them were of a closely related species, *M. sodalis*. I did find 110 little browns, however, and of these, 65.5% were males. My theory no longer seemed so good. Here, where winter is shorter than in New Jersey, there were more, instead of fewer, males. Moreover, both Mohr and Wimsatt had reported males comprising 54-56% of the population at Aitkin Cave, in the mountains of central Pennsylvania. This location I had had to omit for lack of time, and at several other places, such as Roxbury, Connecticut, where LeRoy Foote and assistants from the New England Grotto had helped me, there were too few little brown bats to be significant.

Perhaps the phenomenon of sexual unbalance can best be explained by assuming that the females have a higher mortality rate than the males. This explanation has been advanced by both Griffin and Eisentraut. Do shorter summers and the longer, colder winters of Ontario and Quebec account for a greater mortality there than in New Jersey? One might well conclude that such would be the case. But there may be another explanation, as the following will suggest.

During the summer of 1939 I banded 154 adult females at a summer roost near London, Ontario. In 1940 and 1941 the roost was visited many times and 75 of these bats, or 48.7% were recaptured. The average percentage of recaptured females at the Canadian caves studied most intensively is 10.1. At Durham, Pennsylvania, Mohr recaptured 39.1% of the females banded there. Thus, it would appear that the London bats survive even better than those hibernating in Pennsylvania, if one assumes that bats regularly return to the same place for hibernation, and that collections for each location were reasonably complete.

Where do the females go? That is the question you can help answer as you poke your way into the caverns all over the land. Some migration seems inevitable, for the caves in eastern Canada, New England and New York do not begin to hold the number of these bats that are resident locally in the summer months. Look for banded bats, and if you find one, record its number carefully and report it to the Fish and Wildlife Service, Washington, D. C. This government office will not only tell you who banded the bat, and when and where, but will also notify the bander so that he will know where the bat was picked up. Do not remove bands unless you find the bat already dead. Release the bat unharmed; maybe you'll find the same one there again another year. If you can identify bat species, and find a large population of little browns *(M. l. lucifugus)*, determine the sex of a hundred or so to see how the ratio stands. Perhaps you can discover the winter home of what at present must be called the missing females.

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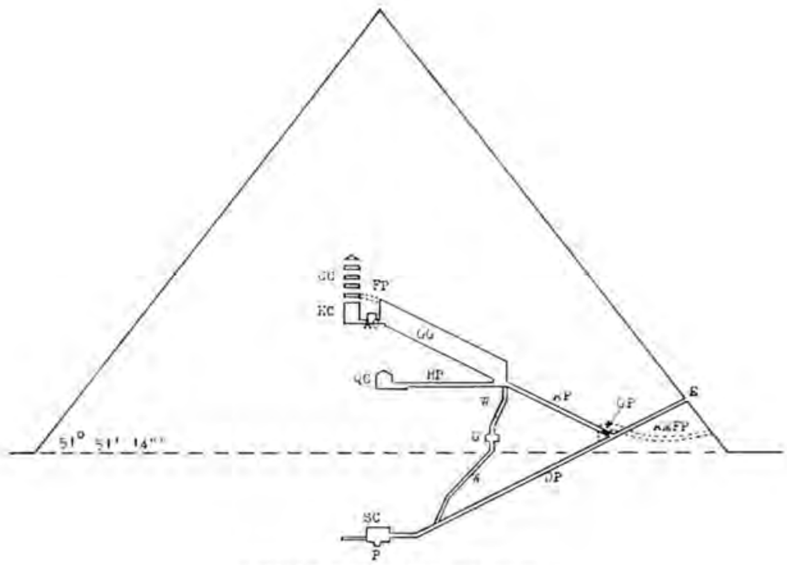
SPELUNKING IN A PYRAMID

By ALEXANDER D. THERRIEN



GREAT PYRAMID OF GIZA
Cross-section
Looking West

AC	Ante Chamber	GG	Grand Gallery
AMFP	Al Malmoun Forced Passage	GP	Granite Plug
AP	Ascending Passage	HP	Horizontal Passage
CC	Chambers of Construction	KC	King's Chamber
DP	Descending Passage	P	Pit
E	Entrance	QC	Queen's Chamber
FP	Forced Passage	SC	Subterranean Chamber
G	Grotto	W	Well

Scale: 1 inch equals 100 feet

Any spelunker who happens to visit Egypt should plan his trip so as to have a day or two to do a little cave crawling in the man-made passages in the Great Pyramid of Giza, near Cairo.

There are many passages to explore and most of them are so small that it is necessary to stoop or crawl. Two of the passages slope at an angle of 26 degrees which does not add to the ease of progressing along them. One almost vertical passage requires some expert rope work.

The passages herein described are in the largest of all the pyramids in Egypt, of which there are more than seventy. This pyramid was built about 2700 BC perhaps, as some think, as a tomb for Pharaoh Khufu or Cheops. Due to the religious beliefs of those times rich treasures were buried with the Pharaohs. This, of course, resulted in many of the tombs being plundered. In an attempt to circumvent this plundering elaborate systems of secret passages and hidden rooms were built.

The Great Pyramid originally had smooth sides which were covered with high quality casing stones. These have almost all been removed and used in the construction of buildings in and around Cairo. However, a few of the original casing stones of the lowest layer are still in place along the north side of the pyramid.

Around the year 900 AD Caliph Al Malmoun attempted to plunder this pyramid and forced a passage into its north side. This would indicate that the regular entrance was not known at that time. However, Al Malmoun after forcing a passage into the pyramid for a distance of about 100 feet, did discover the passages that are known today. This discovery was quite accidental as his passage was in the center of the north face of the pyramid, whereas the original passages are somewhat east of center. The accident which caused him to discover the original passages was the falling of the ceiling stone at the intersection of the descending and ascending passages. His workmen heard this stone fall and they forced their way to the east into the original passage system. The falling of this stone also led to the discovery of the Granite Plug and upper passages.

The entrance to the system of passages is on the north face of the pyramid about 70 feet above the base and a little south of center. Upon entering the pyramid one finds himself in a low passage which descends at an angle of 26 degrees for a distance of about 335 feet. It descends into bed rock below the pyramid where it joins a short horizontal passage leading to the Subterranean Chamber which has a very unfinished appearance due to its irregular floor, in which there is a small pit or well.

Back up about 80 feet from the entrance, by using a part of Al Malmoun's forced passage one can climb around the Granite Plug and into the Ascending Passage. The Granite Plug and ceiling stone which fell in Al Malmoun's day were probably originally installed in an attempt to keep plunderers out of the upper passages and chambers.

After crawling about 128 feet up the Ascending Passage one reaches what is perhaps the most breath taking scene in the pyramid. At this point one enters the Grand Gallery with its high ceiling, peculiar side ramps and overlapping wall sections. From this point one has the choice of going in any one of three directions; up the sloping floor of the Grand Gallery to the King's Chamber, along the Horizontal Passage to the Queen's Chamber, or down the Well.

Getting started up the Grand Gallery is quite a little problem. The end of the sloping portion of the Grand Gallery floor is about three feet above one's head. This is due to the entrance of the Horizontal Passage being at this location. After negotiating the sloping floor of the Grand Gallery for about 150 feet one arrives at upper end where there is another step. This step although only 36 inches high is not easy to climb as one is standing on a floor sloping at 26 degrees.

Having reached the top of this step one is on a horizontal floor. From this point to the King's Chamber is through a low passage where one has to stoop, through a small ante-chamber and finally through another low passage. This whole distance is about 27 feet.

The King's Chamber is a large rectangular room with granite walls and ceiling. It is about 17 feet by 34 feet by 19 feet high. The ceiling is horizontal.

The King's Chamber has two ventilating ducts, the entrances being on the north and south walls.

The only original object within the King's Chamber is a stone Coffer about 38 by 90 inches by 41 inches high.

One interesting feature of the King's Chamber is the large granite beams which form the ceiling. Because they wondered how stone beams could possibly support the tons of rock above the chamber, egyptologists forced a passage from the Grand Gallery to a point above these beams. This lead to the discovery of the five Chambers of Construction above the King's Chamber. A climb into these chambers would be a delight to a spelunker who likes to crawl into places where he shouldn't!

If one returns to the lower end of the Grand Gallery it is comparatively easy to proceed along the Horizontal Passage to the Queen's Chamber. However, the ceiling is only about four feet above the ffoor as far as the step, which adds about 21 inches to the height of the south portion of the passage.

The Queen's Chamber is an empty room about 17 by 19 feet and has a gable like ceiling the peak being about 20 feet above the floor. A peculiar niche in one wall of the chamber is of interest. Originally the Queen's Chamber was without ventilation. However, in 1872 it was discovered that ventilating ducts had been built in, but purposely had not been connected to the Queen's Chamber. By breaking away a few inches of stone these ducts were opened which greatly improved the air in this chamber.

Returning to the north end of the Horizontal Passage one may descend into the well. This is the most difficult passage to negotiate and requires the use of ropes. It is a very irregular passage with some vertical and some nearly vertical portions. About half way down this Well there is a small room called the Grotto. Its chief interest to spelunkers might be its use as a place to rest.

There are many interesting features about this pyramid which are quite removed from speleology and will therefore be mentioned briefly.

There are many interesting mathematical features. For example, many investigators claim that the sides of the pyramid slope at the exact angle necessary to make the ratio of the original height to the distance around the base the same as the ratio of the radius of a circle to its circumference.

The Descending Passage should be of interest to persons interested in Astronomy. Due to the slope of this passage and the latitude of the pyramid, this passage is almost parallel to the axis of the earth. Some calculations indicate that this passage may have pointed to what was the North Star at the time the pyramid was built, at the autumnal equinox.

Cavern Hymn of the Earth Planet

1. Mine eyes have seen the glory of wild caverns none display;
They have witnessed matchless beauty ne'er within the light of day;
They have viewed Creation's splendor by a feeble man-made ray;
Our caves form, fill, allure.

Cho.: Gleaming, serried, 'lactites pendent;
Sparkling, crusted, 'mites resplendent;
Twisted, fluted, shapes transcendent;
Earth's caves form, fill, allure.

2. In the darkness everlasting, life, tho blindly, still holds sway;
Greater fauna rounds its cycle, animalculae its prey;
Crystal growth profusely rampant, flora merely held at bay;
Where caves form, fill, allure.

3. Toward man's effort to recapture, iridescent charm portray,
Light intense he's learned to master as he photographs his way.
Thus to myriads in absentia, caverns' secrets share their say;
As caves form, fill, allure.

4. With the dawning age atomic: What transpireth? Who will pay?
Will our caves aid our salvation? Will a neutral part they play?
Let us humbly, sanely ponder! May we ever watch and pray;
While caves form, flll, allure.

March 1, 1950

JAY ESSPEE.

ICE CAVES*

By PATRICIA MERRIAM

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Ice caves are permanent caves in which ice forms and remains far into the summer or throughout the year. Several suggestions as to their origin are presented. The factors necessary for their formation are probably a rock formation with many crevices, cold winters, a good circulatory system and adequate shading in the summer. A list of ice caves in the United States is presented.

Introduction

Ice caves may be present wherever freezing weather prevails several months each year and the condition of the rocks is such as to permit very low temperatures in the cavities and crevices. An adequate shading by forest cover or a northern exposure also favors ice cave development.

The term *ice cave* does not include caves actually in ice such as occur in many glaciers. The term is used instead to designate permanent caves in rock formations, in which ice forms and remains far into the summer or throughout the year. Ice found in mines and talus piles should also be considered in connection with ice caves.

The earliest recorded notice of an ice cave occurs in a letter dated 1584 concerning the Glacièrè de Champ-les-Passanant (Balch, 1900). Since that time, there have been innumerable reports of ice cave occurrences in various parts of the world. The most complete work on the subject is by Balch (1900) who lists about 300 ice caves throughout the world. Henderson (1932) presents an extensive bibliography on the subject and provides much general information. Articles on ice caves of the United States are numerous and only those considered by the author as outstanding are included.

Formation of Ice Caves

It has often been suggested that cave ice is a remnant of glacial ice left from the Glacial Epoch. Though some cave ice at high altitudes or high latitudes may date back to the Pleistocene, in most caves all the ice melts before the end of the summer or is greatly reduced during this period.

A popular fallacy concerning cave ice is that the ice melts in winter and freezes in summer. This is probably based on observations by tourists, in certain well known caves, of water on the cave floor in the early spring and solid ice in the same area in late summer. Another fallacious concept suggests the freezing action being due to ammonia in some form, an idea derived from the prevalence of ammonia gas in ice plants and not from actual presence of it in any cave that has been studied.

Stearns (1928), who examined occurrences of ice in the Craters of the Moon district in Idaho, dismisses the question with the statement that "water is frozen by cold circulating air". This statement, though undoubtedly true does not explain why there should not be an equal circulation of warm air in the summer which would melt the ice. Also, several other caves exist in the same region but no ice remains through the summer in any of them (Harrington, 1934).

Andrews (1913) in his visit to the Sweden Valley Ice Mine in Pennsylvania, attempted to account for the peculiar conditions. The mine is located in a shaft in limestone, 12 feet deep, at the base of a steep hill. In winter, it is dry and free from ice, the temperature outside being the same as that inside. In spring, the snow on the hill melts and water trickles down the sides of the shaft where it is frozen as small icicles. Freezing continues until by July, the sides of the pit are completely covered with a coating of ice a foot or more in thickness. In early fall, the process stops and the ice gradually melts.

* Additions to the author's list of ice caves and to the bibliography have been made by the National Speleological Society.

According to Andrews, the explanation for this lies in the presence of cold currents of air issuing from the crevices in the rocks along the sides of the shaft (see Figure 1). The air must gain access to these fissures at some other point, which must be at a higher altitude than that of the pit. This being true, in the winter time, the column of air directly over the pit is cooler and consequently heavier than that in the rock

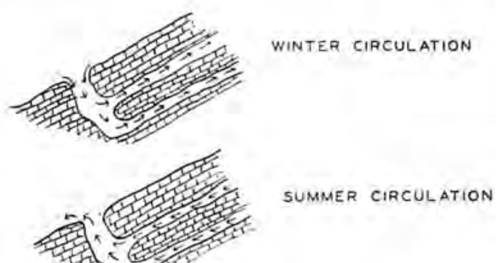

Fig. 1. Circulation in Sweden Valley Ice Mine (after Andrews).

passages. Therefore, it forces its way down into the pit and up through the limestone, chilling the rocks to a great depth and storing up a vast quantity of "cold".

As the warm weather comes on, the column of air over the pit becomes heated and is displaced by the cold, heavy air flowing down out of the passages. This cold current of air freezes any surface water which flows over the edges of the pit and maintains a freezing temperature as long as the supply of "cold" in the hill lasts, after which the circulation of air ceases and the ice formation melts.

Miller (1913) suggests that Andrews' diagram should be inverted:

"Every 'freezing cave' that has been represented in vertical section shows the more remote recesses of the cave lower than the mouth, and the more nearly vertical the circulation of the air is in consequence of this, the better the conditions for ice accumulation. Into these passages, the cold air tends to descend in winter and from them to rise in summer, due to changes in relative density conditions of the internal and external atmosphere."

Many ice caves occur in the numerous basalt flows of the western United States. Harrington (1934) offered an explanation for conditions at one of the Shoshone Ice Caves after a number of tests were made with smoke to determine the air circulation at different times of the year (see Figure 2). The theory is as follows:

"The letter A indicates a small air passage. . . . Letter B represents the basin, about 50 feet deep, through which entrance is made to the cave. This basin faces south, and the winter sun strikes a large part of it. Its sheltered position gives it a temperature in winter a number of degrees warmer than exposed points like A. . . . In such a case, an air circulation would be set up from A, through the cave, and out at B. . . . If water froze in the cave, the heat liberated would help warm the air passing out through the entrance D. Such a circulation would freeze ice in winter and would actually draw the cave full of very cold air. That this circulation actually does exist during the winter was determined by the writer who made a number of tests with smoke.

" . . . The summer sun is more nearly vertical and part of the basin B is sheltered from the direct rays by the overhanging cliff. On the other hand, vent A is exposed to the direct rays of the sun for a longer part of the day. On such a day, the temperatures at B and A would probably be nearly the same, with A possibly the warmer resulting in no or a reversed circulation. . . . Some of the ice near the entrance melts in summer, but this melting stops near the middle of the cave and the ice wall is always intact in summer or winter."

Swartzlow (1935) has described the ice caves in and near Lava Beds National Monument in

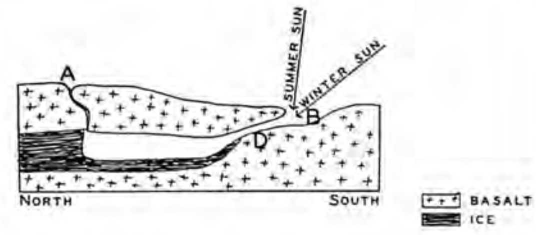

Fig. 2. Circulation in Shoshone Ice Cave (after Harrington).

northern California. Water has collected in about one-third of the 300 caves in the region by percolating downward through the pervious basalt. Swartzlow agrees with Harrington (1934) that the water is converted into ice by an active circulation in winter and little in summer:

"During the cold months the surface air increases in density and naturally migrates to lower levels. In doing so, it displaces warmer air that may be present. This process repeats itself until the temperature at the bottom of the cave reaches or passes the freezing point of water. During the summer months the warm surface air expands and rises, but the cold air adjacent to the ice is not displaced; thus the summer is a season of minor circulation. The dead air spaces in the vesicular basalt act as an efficient insulator."

A more spectacular instance of ice being preserved due to the poor heat-conducting qualities of an overlying rock was found at Mt. Etna. A glacier was covered by volcanic sand, then by a stream of hot lava without being destroyed. The ice was preserved for many centuries and in 1828 was quarried out for use during the summer in the nearby towns. Instances of alternating layers of ice and lava have also been reported (Lyell, 1850).

Adiabatic cooling has been suggested as another possible cause of ice formation (Macdonald, 1948). The air upon entering the cave through a small orifice would be compressed. The sudden expansion when reaching the wider cave beyond would cause it to become cooler than it was before entering the opening. While this may well be a subsidiary cause, it is doubtful that enough pressure could be developed to reduce the temperature more than a very few degrees.

Ice Caves of the United States

Arizona. In 1901 ice was being hauled to Flagstaff from the Winona ice caves in lava 9 miles to the southeast (19) * (Knox, 1935). Another in the White Mountains (20) was said to be held sacred by the Zuni Indians (Henderson, 1932). The ice caves at Sunset Crater National Monument (18), 17 miles northeast of Flagstaff are well known (Park, 1929).

* Numbers refer to figure 3.

California. The ice caves in and near Lava Beds National Monument (7) in northern California have been described on a preceding page.

Colorado. There is a report of an ice cave on Cow Mountain, Pike's Peak District (17) (Henderson, 1932). Berthoud (1876) found well-defined veins of solid ice parallel with the bedding of the rock and filling all its cracks in several mines on Mt. McClellan at Georgetown (16). The ice began a few feet below the surface and extended the full length of the excavations.

Connecticut. At two locations between Hartford and New Haven (32), ice was found as late as July in talus, protected from the sun by a heavy forest (Silliman, 1822). Chasms of considerable extent occur near Salisbury (31) "forming natural ice-houses where the ice and snow remain most of the year". (Lee, 1824).

Idaho. There are 15 reported ice caves and ice-water pools in the lava of Craters of the Moon National Monument (9) (Stearns, 1928). The Shoshone Ice Cave and a smaller nearby cave are located 30 miles north of Shoshone (8) (Harrington, 1934).

Iowa. In the Decorah ice cave (24) ice begins to appear in mid-winter and lasts until early autumn. (Henderson, 1932). An ice cave is reported at Bixby (25).

Kentucky. Miller (1913) mentioned a "freezing cave" near Gap Creek, Wayne County (26).

Massachusetts. Kimball (1901) described a cave in the Northfield Mountains (33) containing ice in August.

Montana. Freeman (1919) describes three ice caves located near Lewistown, in the Bitter Root Range and other mountains (10) (11) (12).

Nevada: S. M. Wheeler reports an ice cave in the Baker Creek region (NSS files).

New Hampshire: Ice was noted by Henry Herpers, Geologist N. J. Geological Survey, in a talus pile caused by a landslide at Carter Notch in the White Mountains, in September, 1940.

New Mexico. 50 miles southeast of Gallup (21) there is a cave in lava where a perpendicular wall of ice extends across the cave a distance of 50 feet and rises 14 feet above the floor (Lee, 1926). Harrington (1934) visited an ice cave in lava at Grants (22) and found conditions prevailing similar to those at Shoshone Ice Cave. Other ice caves are known at Johnson Mesa and Sierra Negras (23).

New York. Ice was found as late as August in a cave near Caldwell, Warren County (36) (Kimball, 1901).

Oregon. Arnold Ice Cave, southeast of Bend (5), Edison Ice Cave, southeast of Bend (4) are among several in lava (Henderson, 1932). Stalagmites of ice in Malheur Cave (6) have been reported (Dake, 1936).

Pennsylvania. There are two natural ice-manufacturing plants in rock crevices near Coudersport, Potter County (30). One of these, "Snow Hole", in a rock crevice near Pownal (34) where snow remained throughout the year protected by a forest cover. On a later visit he found that destruction of the forest caused the snow to be melted by the first of August. A nearby chasm, more fully protected, had an abundance of ice and snow throughout the year.

Washington. Ice found in lava, 35 miles from the mouth of White River (3) was used by Portland during the early sixties (Condon, 1896). The Mt. Adams Ice Caves (2) also have

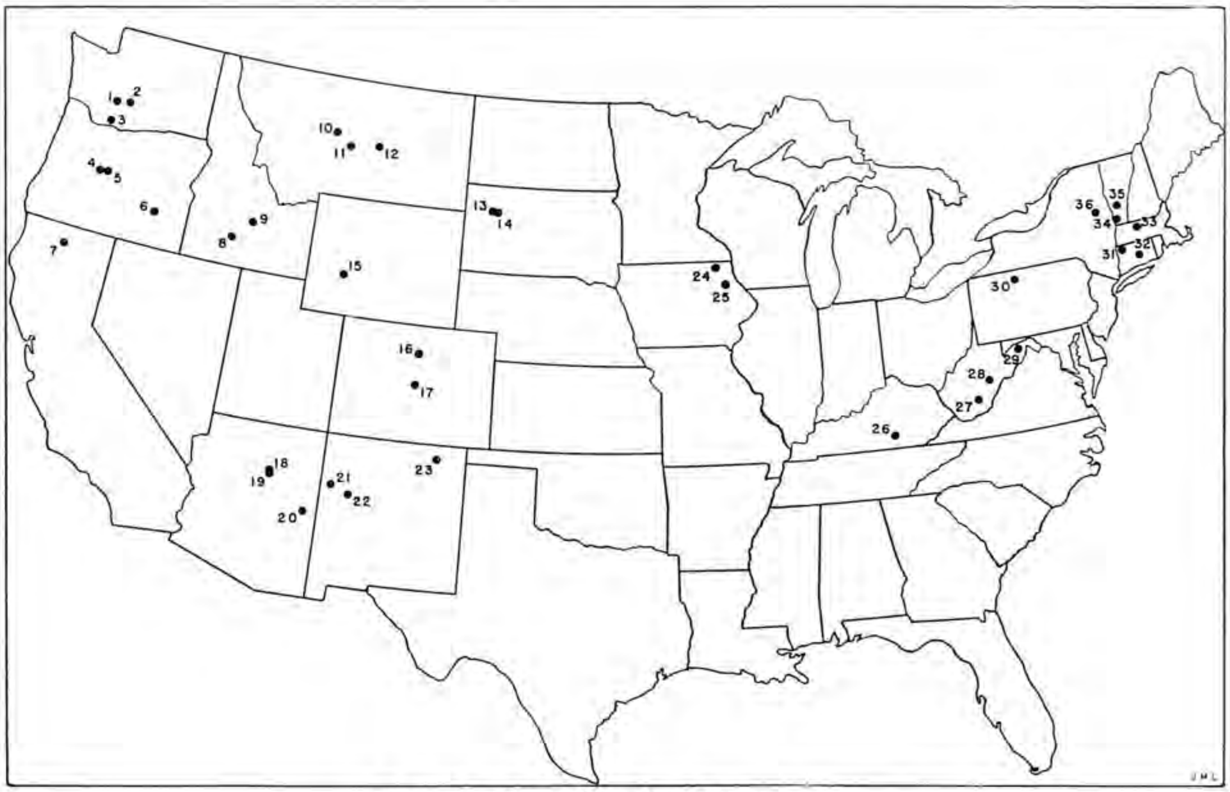

Fig. 3. Ice Caves of the United States

the Sweden Valley Ice Mine has been described on a preceding page.

South Dakota. An ice cave "is reported" at Galena (14) (Henderson, 1932), and another near Spearfish (13) (Pahasapa Quarterly, April, 1915).

Utah. An ice cave southwest of Panquick is said to be "well known".

Vermont. Ice occurs, or did occur in a ravine filled with talus at Wallingford, Rutland County (35). It was present in sufficient quantity at one time to supply inhabitants of adjacent town (Lathrop, 1844). Dewey (1818) described a been reported by Condon (1896), and ice caves on Mt. St. Helens (1) are mentioned (Anon., 1903). The NSS files contain notes on ice caves near Chelan and at the northeast corner of Five-mile Prairie, near Spokane.

West Virginia. Ice was found in the talus on the northwest slope of Ice Mountain in Hampshire County (29) (Hayden, 1843). Ice has been found in talus and shelter cave at Ice Cave, Droop Mountain, Pocahontas County (28); and at Crowder Cave, Monroe County (27).

Wyoming. A horizontal sheet of ice, as much as a foot thick and about 18 inches beneath the turf, was reported in the Rocky Mountains, 40 miles from South Pass (15) (Gibbs, 1853). Due to the high altitude, the phenomenon is probably similar to the "permafrost" of the Arctic region.

Conclusion

Rocks containing numerous crevices or honeycombed by small, connected passages, which permit free circulation of air during the early part of the winter, and presenting a large amount of surface to the cooling effects of the atmosphere, are favorable to the production of ice caves. Thus, they are usually found in limestone formations or in lava. In general, the cold air in winter, slowly circulating through the various openings, thoroughly chills the rocks to considerable depths and freezes any water contained in the cavities. As snow melts in late winter and spring, the water runs down the crevices and freezes in the chilled caves. The freezing process in the cave may continue long after warm temperatures prevail above ground. It is interesting to note that there is always a lag at both ends of the season, freezing not beginning in the cave until some time after it begins at the surface, and melting not beginning below ground until some time after it begins above. The length of time the ice remains in the cave and also its thickness depend, of course on the prevailing temperature and amount of precipitation during the winter.

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List of Grottoes

Wherever sufficient interest in speleological research or other activity exists members of the National Speleological Society are encouraged to form Grottoes. These localized units generally select their own officers, organize field trips, carry on self-inspired research projects in a particular cave or series of caves, and otherwise implement the efforts of the parent body. Following is a list of such local units, with the names and addresses of persons to contact for information:

1. *Atlanta*
   J. Roy Chapman,
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    R. D. No. 3,
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12. *New England*
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    Thomaston Savings Bank,
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14. *Philadelphia*
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Calcite Bubbles - A New Cave Formation?*

By GORDON T. WARWICK

Chairman of the Cave Research Group of Great Britain and lecturer in Geomorphology, University of Birmingham

Calcite deposited around air bubbles was found in rimstone pools in one of the limestone mines of Dudley Castle Hill, Worcestershire, England. A brief description is given of these mines together with a full description of the calcite bubbles and a report on the conditions under which they were found. To date no calcite bubbles have been reported from true caves, but it appears possible that the postulated conditions for their formation should be found in natural caverns.

Rising from beneath the Coal Measures of the Black Country, in the heart of the English Midlands, are three inliers of Silurian rocks. They form the hills of Sedgley Beacon, the Wren's Nest and Dudley Castle Hill and consist of strongly folded and faulted Wenlock limestones and shales and Ludlow shales. The three hills run en-echelon from northwest to southeast, though the general direction of their individual axes is roughly north-south. The most southerly of these hills, the Wren's Nest and Dudley Castle Hill are composed of sharply folded, elongated domes, with dips varying from 37-75°. The limestones occur in two main bands, separated by shale, and they were much sought after by the local iron-masters who obtained their fuel and iron-ore from the overlying coal-measures which outcrop around the inliers. Today the major part of these mineral resources has been exhausted.

At first, the outermost limestones were quarried from the flanks of these hills, but the inner (and geologically older) limestones were won by mining which commenced during the closing years of the eighteenth century, before the development of rail transport. In the case of Dudley Castle Hill a tunnel was driven through the hill for one of the local canals. Use was made of this in winning the limestone, a branch canal being constructed along the direction of the strike, in the limestone itself. At intervals, steeply sloping 'roads' were driven upwards from the level of the canal into the up-dip part of the rock to permit further exploitation of the stone. The limestone obtained from these operations was carried away by boat directly to the blast furnaces. Two galleries, parallel to the canal were also constructed at higher levels, leaving the roof supported by pillars of rock. These openings are 20 to 30 feet high. Many of the roads or headings were carried to the surface, where they can now be seen at the bottom of shallow quarries.

Active mining has not been carried on for over thirty years, and Dudley Castle grounds, which includes the hill has been taken over by

P. B. Binns

Fig. 1. View inside Dudley Castle mine showing the old canal and the roof pillars. The rock here dips at about 45°.

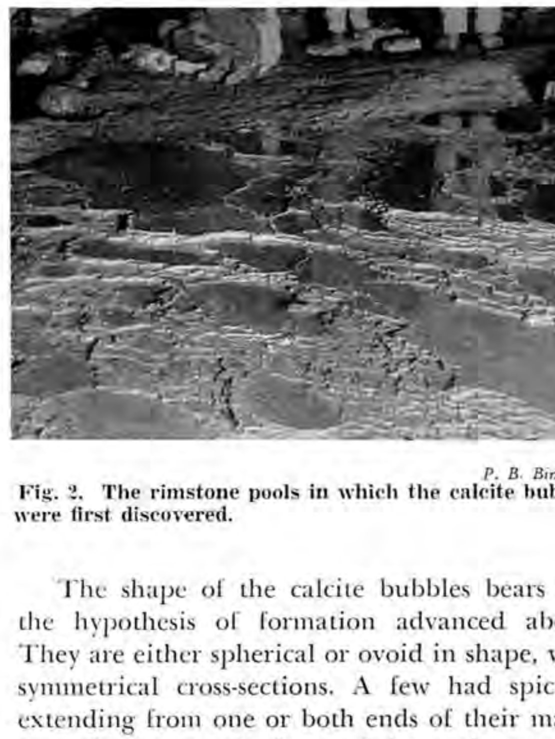
* A paper presented *in absentia* at the seventh annual convention of the National Speleological Society, Washington, D. C., March 31-April 2, 1950.

the Dudley Zoological Society for its zoo. It was through the good offices of the zoo manager, Mr. Donald Bowles, that the author and his friends Marjorie and Lewis Railton were able to explore these interesting old workings.

During this visit, carried out during the fall of 1948, the author was inspecting some shallow rimstone pools which had formed on the upper gallery, when he noticed several small, white bodies floating under the surface of the water. Similar objects were to be seen resting on the floors of the pools. Closer inspection revealed that they were hollow. Later some were dissolved in dilute hydrochloric acid with marked effervescence, and excess ammonium carbonate solution was added, which caused a white precipitate to be formed. It appeared from this superficial examination that the walls of these concretions were made of calcium carbonate—and probably in the form of calcite. To the best of our knowledge, this phenomenon has not been previously described, so it was decided to call these objects *calcite bubbles*.[1] They may be defined as hollow concretions of calcite deposited on the surface of a gas bubble, some of which are capable of flotation.

Judging by the interest shown in calcite bubbles when they were exhibited and described by Lewis Railton at the International Speleological Meeting at Valence-sur Rhône, 1949, it was thought that American speleologists might be interested in them and be encouraged to search for them in American caves. While it is true that these British examples were found in a man-made cavern, they appear to have been formed by natural processes which should be duplicated in natural caverns.

The rimstone pools, in which the calcite bubbles were found, were very shallow, being only about one inch deep, with occasional 'deeps' of two inches of water. The source of supply of the water was an opened fissure in the side of the wall, some forty to fifty feet below the surface. A thin film of dust and loosely connected calcite flakes was present on the surface of most of the pools. This film had drifted to the lower edge of the pools on our visit, probably due to the gentle flow across them following a period of rain which preceded our excursion. The calcite bubbles were imprisoned beneath this film which appears to play an important part in their origin. In addition to the calcite bubbles, ordinary ones were also present beneath the skin. It did not prove possible to have the contents of these bubbles analysed, but it would appear likely that they are air bubbles formed by drops of water falling into the pool. This process was observed by Lewis Railton on a second visit,[2] and some of the resulting bubbles broke immediately whilst others were imprisoned under the surface scum. When such bubbles are imprisoned in this way they would serve as nuclei for deposition in a saturated solution of calcium carbonate. Some of the ordinary looking bubbles were collected from under the surface and they showed remarkable resistance to pricking with a paint brush presumably indicating the presence of a thin protective coating of calcite.



P. B. Binns

Fig. 2. The rimstone pools in which the calcite bubbles were first discovered.

The shape of the calcite bubbles bears out the hypothesis of formation advanced above. They are either spherical or ovoid in shape, with symmetrical cross-sections. A few had spicules extending from one or both ends of their major axes. Resting on the floors of the pools were the remains of several half-formed calcite bubbles, with relatively large openings in the crystalline surface, all of which were found pointing upwards. These latter were of the order of 2-3mm across their major axis. The floating calcite bubbles varied in size from a fraction of a millimetre up to about three millimetres in diameter. A very noticeable feature was the fact that these floating bubbles in general did not protrude above the surface. A few bubbles however were exceptions to this rule. These were generally much larger, up to 2 cm diameter, and often short-lived. Some of them were seen to collapse, leaving a few extra plates of calcite on the surface. These larger bubbles were more common in a pool formed in the now-abandoned branch canal which was dammed by roof fall debris. The scum on the surface of this pool contained a much greater proportion of dust than on the surface of the smaller pools. This is largely due to their relationship to the entrance to the workings. This lies immediately above the canal pool, whilst the rimstone pools are about 200 feet away.

On a subsequent visit,[2] Peter Binns, another English NSS member took some of the photographs which illustrate this article. Also readings were taken with a whirling psychrometer. This revealed that the temperatures and humidities were slightly less inside the mine than in the open, and that the relative humidity at the pools (84%) was less than at the entrance and at the canal pool (91% and 88% respectively). On the day in question the external relative humidity was 92% at a temperature of 46°F. However, it has not been possible to make further observations of this character. The free air circulation within the mines, and the connection to the surface by at least one major opening, does permit drier conditions than are to be found in many caves.

Lewis Railton arranged for photomicrographs to be taken of some of the bubbles and some of these are published with this article. It can be seen that the inner surface of the calcite bubbles is smooth and the outer side a jagged mass of dog-tooth crystals—a further proof of their being calcite. The broken bubble was 2.4mm long and the walls vary in thickness from 0.06mm to 0.2mm.

So much for the facts,—what of the mode of formation? As already indicated, it appears that gas or air bubbles act as nuclei for calcite precipitated as a result of water and carbon dioxide losses from a calcium carbonate solution. Probably the latter is the most important factor. In percolating through the organic rubbish at the bottom of the quarries, the water will pick up extra carbon dioxide from the soil-air, but some of this will be lost when the solution again has atmospheric air above it. The scum on the surface appears to be connected with the nuclei offered by the dust particles, though such features are not unknown in dust-free caves on still pools. The imprisonment of the gas bubbles seems to be a pre-requisite to calcite bubble formation. After this, the process of precipitation on the surface of the bubble commences, but its development must depend on various factors. Presumably deposition commences at one point, probably at the top of the bubble where the solution is more saturated during stagnant conditions. From this and other similar nuclei crystal growth spreads over the surface of the bubble and also extends out from the surface as crystal faces develop.

R. A. W. Whittaker

Fig. 3. Calcite bubbles floating in a test tube. Magnification 4 x.

This development is most probably uneven, and the bubble gradually becomes top heavy, causing slow rotation. This probably permits deposition to take place on the under surface. It is suggested that this rolling movement causes the symmetrical development of the calcite skin, and prevents adhesion to the surface.

The half completed bubbles on the floors of the pools appear to have become too heavily coated for the buoyancy of the bubble and to have sunk, allowing the bubble to escape. Perhaps they may have become trapped, and rotation inhibited for they are just as thick as the other calcite bubbles, if not thicker, but have never completed their skin. Thus it would appear that the bubbles must not be too big, and the scum not too thin, to permit of the film being bulged upwards by the bubbles. Once the bubbles have sunk to the floor of the pool some of them become cemented to the floor, and no doubt accretion still continues. There were complete bubbles of all sizes also on the floor of the pools, indicating that the floating stage is only a temporary feature, being finished when the weight of the calcite bubble equals the weight of an equivalent volume of water.

Recently water collected from the rimstone pools was accidentally exposed to direct sunlight, and small bubbles (probably of carbon dioxide) were seen to rise to the surface where they broke and minute flakes, presumably of calcite, floated down to the bottom of the bottle where a similar deposit has accumulated. This gas may have been released owing to the heating effect of the sun, or it may have been produced by bacterial action. The source of the water is near to the surface, and there must be some organic matter taken into solution by water percolating through decaying vegetation. Associated with this will be bacteria, but this has not been tested as yet. It seems highly likely that bacteria

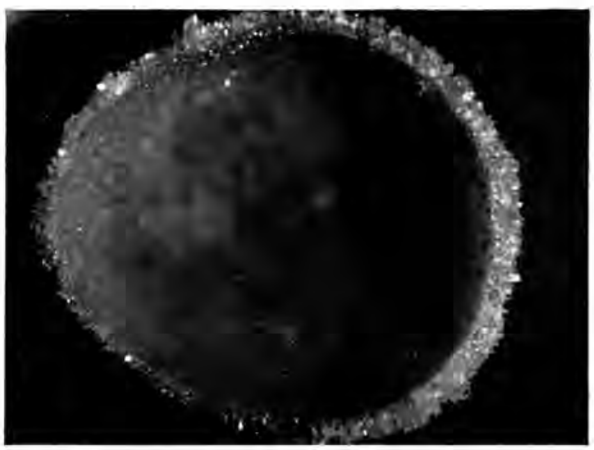


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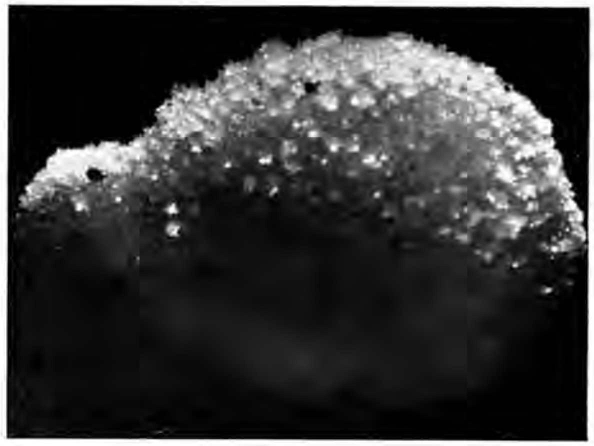
Fig. 4. The interior of a calcite bubble. Note the smooth internal surface in contrast to the irregular exterior. Magnification 26 x.

might help in the precipitation of calcium carbonate, but it is difficult to assess this factor. Perhaps speleo-bacteriologists may be attracted by this question.

Two observations of similar phenomena occuring under laboratory conditions have been discovered. G. H. Drew,[3] working on the action



R. A. W. Whittaker
Fig. 5. The exterior of a calcite bubble showing the dog-tooth crystals. The black spots are holes in the skin. This compound bubble was probably deposited around two coalescing bubbles. Magnification 26 x.

of denitrifying bacteria in the tropical sea-water of the Tortugas developed his bacterial cultures in a medium containing a high concentration of organic salts of calcium, and amongst some of his older cultures he obtained deposits of calcium carbonate around gas bubbles. T. W. Vaughan,[4] who spent many years studying the calcareous muds off the coast of Florida also noticed the formation of similar deposits around gas bubbles in samples of this mud after they had been removed from the sea-bed and put in storage for some length of time. He considered that they would serve as one of several types of nuclei for oolite formation. In this last case the bubbles were confined in the mud.

It has also been suggested [5] that some of the mysterious hollow spheres found in the English chalk and in the so-called Orbulina or Georgetown Limestone of Texas may have originated in this fashion. In this connection H. D. Thomas [6] refers to the development of crystals into the interior of the gas bubbles—this is not borne out in our examples. However Dr. Thomas regards the gas-bubble theory of the formation of these spheres as not fully proven.

In conclusion it appears that the optimum conditions for the formation of calcite bubbles are reasonably still water, with active deposition of calcite, and the presence of air or gas bubbles imprisoned beneath a surface film of dust or calcite, or a combination of both. These conditions should be fulfilled in natural caves and it is hoped that this paper will encourage others to look for them in such places. The author would welcome comment from speleologists and other interested persons, especially those interested in the processes of calcite crystallisation and the origin of the 'spheres' alluded to above.

I should like to pay tribute to Lewis Railton and his wife for their active help in the preparation of this paper, and to Peter Binns and Mrs. R. A. W. Whittaker for allowing me to use their photographs. Last but not least I should like to thank William J. Foster for the encouragement which he has given me, for arranging the original reading of this paper and for seeing it through the press.

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GORDON L. CURRY, 1872-1950

Dr. Gordon L. Curry, Dean Emeritus of the Louisville College of Pharmacy of the University of Kentucky, died on January 21, 1950. He was 78 years of age.

His enthusiasm for cave exploration was reflected in his varied speleological interests,—geology, flora, fauna, mapping and photography all receiving attention. From 1904 until 1930 he spent many of his vacations exploring the caves of Kentucky and southern Indiana, especially Wyandotte Cave, in every accessible part of which he had been at some time.

Dr. Curry possessed a wonderful collection of stereoscopic photographs mostly taken with flash powder and an Eastman stereo box camera in the days when stereo photography was not nearly as easy as it is now. He took many of his students from the Louisville College of Pharmacy with him on his trips and impressed all with the necessity of safety. No one was ever hurt or in the sightest danger throughout his years of exploration. He also impressed upon his many friends how hard God worked to create our caverns and how long it took to make this underground beauty for our enjoyment, admonishing his fellow-spelunkers on their duty and obligation to preserve it unspoiled for future explorers.

Up to about the middle 1920's practically all Dr. Curry's explorations were made using candles for light and red flares for illuminating any large rooms.

Dr. Curry was a member of the American Pharmaceutical Association, Kentucky Pharmaceutical Association, Kentucky Academy of Science, National Speleological Society, Fellow American Association for the Advancement of Science, charter member of Veterans Drug Club of Louisville and John Stark Chapter, Sons of American Revolution.

The Survey of Schoolhouse Cave

with a series of drawings and a Sketch Map by Tom Culverwell

By H. F. STIMSON[1]

Physicist, National Bureau of Standards

Editor's Note:

This article is reprinted by permission of H. F. Stimson and the Potomac Appalachian Trail Club which first published it in 1945. Because of its general interest to speleologists it was deemed advisable to present it to our readers also. For five dramatic photographs of some of the difficulties confronting Schoolhouse explorers see Bulletin Eleven of the NSS, Nov. 1949, pp 47-50.

Schoolhouse Cave, located in Pendleton County, W. Va., was described by Tom Culverwell in the January 1941 *Bulletin* of the Potomac Appalachian Trail Club in an article entitled "Mountaineering Under West Virginia." When he wrote this article, the expansion bolts had not been set for the traverse up along the Angel Roost to the Judgment Seat, so all the hopes, horrors, and headaches of the cave beyond the Big Room were unknown.[2]

[1]Dr. Stimson in writing his account of the survey of Schoolhouse Cave has presented the achievement in a manner so casual that the reader may be completely deceived concerning the arduousness of the labor which he had undertaken. A hint of the author's character and a better understanding of the task which he has performed may be gathered from the knowledge that this cave had remained unexplored beyond the Jumping-Off Place prior to 1939, although known for generations and even mined for nitrates during the Civil War. Furthermore, in November 1939 an expedition by the National Speleological Society, equipped expressly for the purpose of exploring this cave, had succeeded in getting but one person, Don Bloch, onto the sloping approach to the Cascade Pit, an advance beyond previous parties of approximately 50 feet forward and 100 feet down. It was over this forbidding route and the even more impossible regions beyond that Stimmie has taken his surveying equipment.

The remote stretches of this cave had spent the past in total darkness, but, to a man like Stimmie "there is no darkness but ignorance." This darkness and the mystery of Schoolhouse Cave he has forever dispelled with the light of definite knowledge furnished by tape and transit.—Donald Hubbard.

[2]See "Subterranean Rock Climbing," by Tom Culverwell," *Appalachia*, June 1943; "On Underground Trails," by Tom Culverwell, Potomac Appalachian Trail Club *Bulletin*, October 1943; and "About as Far as We Can Go," by Tom Culverwell, Potomac Appalachian Trail Club *Bulletin*, October 1944.

Three months later our climbers had gone on nearly twice as far and discovered the Great Gallery, which was blocked off at the far end by sediments containing stream-eroded stones. Since these stones must have come down from the surface, they gave us hope that the surface was near. We visioned the possibility of opening a secret back door to the Great Gallery, as a woodchuck does to his burrow, and thereby making that part of the cave accessible without all the rope-work and struggle it now takes.

Since we knew the length and direction of the cave to the end of the Big Room from Tom's string and compass measurements, we had an approximate idea of where the end of the Great Gallery might be with respect to features on the surface. An examination in that region disclosed a large sink with three holes which drained or vented down. The first hole was found to have a fluctuating current of air through it. This fact intrigued us with the hope that the blocked end of the cave was near this hole and also that the third hole was near the other side of the obstruction where we might enter the continuation of the Great Gallery. It seems certain that there are more galleries beyond this point because Schoolhouse Cave, Hell Hole, and the commercialized Seneca Caverns all lie along the Wills Mountain Anticline a little over a mile apart and probably all drain down into Judy Spring at the bottom of the valley near the Potomac River.

In order to find out how near the end of the cave was to this large sink, or to some other feature on the surface, a good survey was required. It was then up to Stimmie to add a vertical graduated circle to his 65-year old engineering transit so that a three-dimensional traverse could be made from the sink over the surface to the entrance of the cave and then inside the cave to the end of the Great Gallery. The circle had been installed so that the survey could be started on Memorial Day, 1941. Various people helped on four different week-end trips and by the end of the summer a preliminary survey had been run to the end of the cave. It proved to be incomplete and lacked the precision that inspires confidence. This effort should not be considered as lost, however, because during this period some simple devices were made for increasing the precision of measurement, and furthermore, some simple practices were adopted to prevent mistakes and omissions in a future survey.

As Easter was approaching in 1942, David Appel expressed his desire to spend his vacation helping to make a complete new survey in one long session. Good Friday afternoon found him and his high-school classmate, Bob Ludwig, on the way to the cave with Old Man Stimmic, ready to tackle the job. The work these young fellows did made the trip a success. Their interest and enthusiasm kept us going in the cave for 12 hours every day between our morning and evening meals, and there was no loafing.

The data collected in the following week not only satisfied our curiosity about the location of the end of the Great Gallery but also furnished the skeleton of Tom Culverwell's sketch map, which is reproduced here. Tom gave body to the skeleton and, if this body lives up to his earlier productions, new chambers will be found back of some of the shadows he has so faithfully reproduced. Some other fine examples of his sketches of the cave may be found in the June 1943 number of *Appalachia*, and still others in the October 1943 *Bulletin* of the Potomac Appalachian Trail Club.

Since the day following our arrival was warm and fair, it was the ideal time to do the surface surveying. We ran a line overland in ten easy jumps from the sink to the zero stake at the mouth of the cave. We had put this zero stake under the entrance arch of the cave in a place which is sheltered from rain, yet from which a sight could be made on the pole star, Polaris. This sight, although really unnecessary for our purpose, was made so we could refer our survey to the true or geographic north. The resulting map, then, is referred to the same north as the larger geologic maps of this region.

That afternoon, after we had finished the surface survey with the instrument over the zero stake, there were a couple of hours to spare before it would be dark enough to get a sight on the star. This time was spent, therefore, in teaching Bob a few of the first principles of rock climbing with a safety rope and, following these, the necessary technique of roping down. After supper we made the observations on Polaris, recorded them and the times they were made, and turned in for another night's sleep on the shelf under the entrance arch. The next morning we packed our transit and accessories in an Adirondack Pack Basket and started in with all our equipment for the survey over the course of stations which we had located on the preliminary surveys.

In cave surveying we run a continuous series of straight lines from the entrance through to the end. Our problem is to locate the intersections of these lines at places where the instrument can be placed to measure the angles. The data for these measurements are obtained by first pointing the telescope to a light at the previous place, i.e., a backsight, then making a foresight to a light at the new place. The azimuth and elevation of each sight are read on the horizontal and vertical graduated circles of the instrument for each setting, and the angles are derived from them by taking the differences of the readings. Steel tapes measure the lengths of the lines of sight.

The places where the instrument is located are marked by "stations," which are shallow drill holes in the rock either directly below the intersections or vertically above them in the ceiling. Each station on the main line through the cave was identified with a number marked on the rock. The lights for the foresights and backsights were from tiny electric flash-light bulbs. These bulbs were held in place on single flash-light cells with simple, bent-wire holders. The lights were located with a plumb bob, either directly above or below the stations, and in order to be seen from the instrument they usually had to be set on a camera tripod which was adjustable for height. Candles were used for the lights on the first two trips of the preliminary survey; but they were discarded on later trips in favor of the flash-light bulbs because the candle flames were too large and their positions changed as burning proceeded.

The height of the light up or down from its station and, similarly, the height of the axes of the instrument from its station, were determined

Swinging across one of the wells after rappel

The high line across the Entrance Room

Climb out of the Grotto

The Nick of Time

Traverse: Groan Box to Angel's Roost

for each sight. The distance of each sight, taken from the axes of the instrument to the light, was measured with steel tape. For some sights it was necessary to tie two tapes together to reach across from the instrument to the light. A simple spring device was used to put the same tension on the tapes during each measurement so that correct allowances could be made for the sag in the tapes.

The height at which the instrument had to be set to sight to the lights at the foresights and backsights varied from extra high in a few places to extra low in the lowest passages. For this we provided three sets of tripod legs to be used at different stations; one set had extendable, long legs giving a height of from four to seven feet; another set had extendable, short legs giving a height of from two to four feet; and another tripod had stubby legs about six inches long.

In many instances the straight lines from one station to the next seemed very simple in comparison with the indirect routes necessary to get there on foot. The lines of sight often went many feet above the depths to which we had to descend to get across. In about half of the cases moving the instrument across from one station to the next required taking it off the tripod and stowing it in the pack basket to tote. In about half of these instances we hauled the basket up cliffs with a rope because this was simpler than struggling up with the loaded basket. In a few places we had to hitch the basket along separately because there wasn't room for both the basket and a man at the same time. To get the tape across the sights over deep places we often tossed a cord across successive chasms and led it along till it reached the other station and the tape could be hauled in.

The sight to station 1 was no exception. It went near the ceiling of the entrance room to a shelf on the east side, avoiding the descent and steep crooked climb to the upper passage. In this case the end of one tape was dropped down from the shelf to the bottom of the entrance room and then carried up the slope till it could be tied to the end of the second tape. The shelf was so near the ceiling that it was rather cramped, and the transit had to be set on the stubby tripod.

Stations like this one, which were difficult to occupy, were well worth the effort because each such station usually saved us the trouble of setting up several others to get to the same end. It is axiomatic that the errors of measurement increase with the number of stations and, conversely, the number of stations saved means final precision gained.

Station 2 was well into the long upper passage where the instrument could be set up on its regular tripod. From here on to the Big Room the stations were relativly near together because the passage was both narrow and winding. As the line approached the Big Room where the floor was near the ceiling, the short tripod legs were used instead of the regular ones. Station 11 was at the Jumping-Off Place looking into the deep, damp darkness of the Big Room. As we left this station we were again reminded of Leo Scott's inscription on the wall, "All Hope Abandon Ye Who Enter Here." Station 12[1] was down the next slope very near the east wall at a place where we could sight for half the length of the Big Room to Station 14 on top of the Big Bite.

A station 13 was chosen during the preliminary survey but we abandoned it for this survey because station 14 had proved to be both superior and sufficient. This station 14 was a lucky find for us, because it was halfway between the ceiling and the depths of the Big Room at the one place where sights could be made all the way to stations near the ceiling at the ends of the room.

The Big Bite is an enormous chock stone, which is wedged across from the east to the west wall about midway between the Gargoyle Pit on the south and the deep Thunder Pit on the north. It gets its name from a part of a horizontal cylindrical surface on the east side, which looks like a bite out of a slice of cake magnified to seven feet broad.

It is evident that this bite was once vertical and part of the wall of one of the tall wells near the ceiling of the room. The stone slopes steeply

[1] Near this point a relatively inexperienced young spelunker (not a member of the NSS) fell 85 feet to his death on July 18, 1950. Apparently the rope which he used snapped as he climbed back up the slope, hand over hand, between Stations 12 and 11 *without an additional safety line.* His body landed on a ledge adjacent to the Nick of Time. This unfortunate occurrence points to the need for extreme caution on the part of even experienced speleologists when exploring caverns of this nature. It should serve to warn all who contemplate entering any dangerous cave to obtain detailed information in advance from the National Speleological Society or other competent source.

up on the north, south, and west sides, but the top is large enough and near enough level so the instrument could be set up on its short legs and manned by a person sitting on the rock. The top is only about as big as a dining table and, had we stood up to the instrument on its long legs, we would have had the feeling of plunging off into the depths of the wells beside it with every step around. To get up there we made a handhold traverse down across the south side over the Gargoyle Pit to the Gargoyle Bridge. From here we made a steep rock climb up the west side to the top, then hauled up the apparatus on the east side past the bite.

From this station the foresight went over the Guillotine, which is another large chock stone, and over the Judgment Seat to station 15 in a niche at the end of the room not far from the ceiling on the east side.

During the preliminary survey instrument locations for stations 16 and 17 had been made to order for us by Fitzhugh Clark and Leo Scott, who hewed many yards of clay out of the walls with trenching picks. The line made a switchback across from 15 in the east wall niche to 16 in their hewed-out alcove at the top of a high bank on the west. This alcove was in a vertical clay bank which was only a veneer on the cave wall and looked as if it were ready to peel off at any minute. As a consequence, all the operations were made in this alcove with both the operator and his instrument roped to the ring in an expansion bolt on the rock face beside the entrance to the Hodag Room passage. The passage is the one that Paul Bradt and others had reasoned should exist and had labored for five trips to reach. The ring used while observing at station 16 is the one that Fitzhugh first put there when he and Paul finally discovered the passage. Station 17 was on top of the clay headwall in line with this passage.

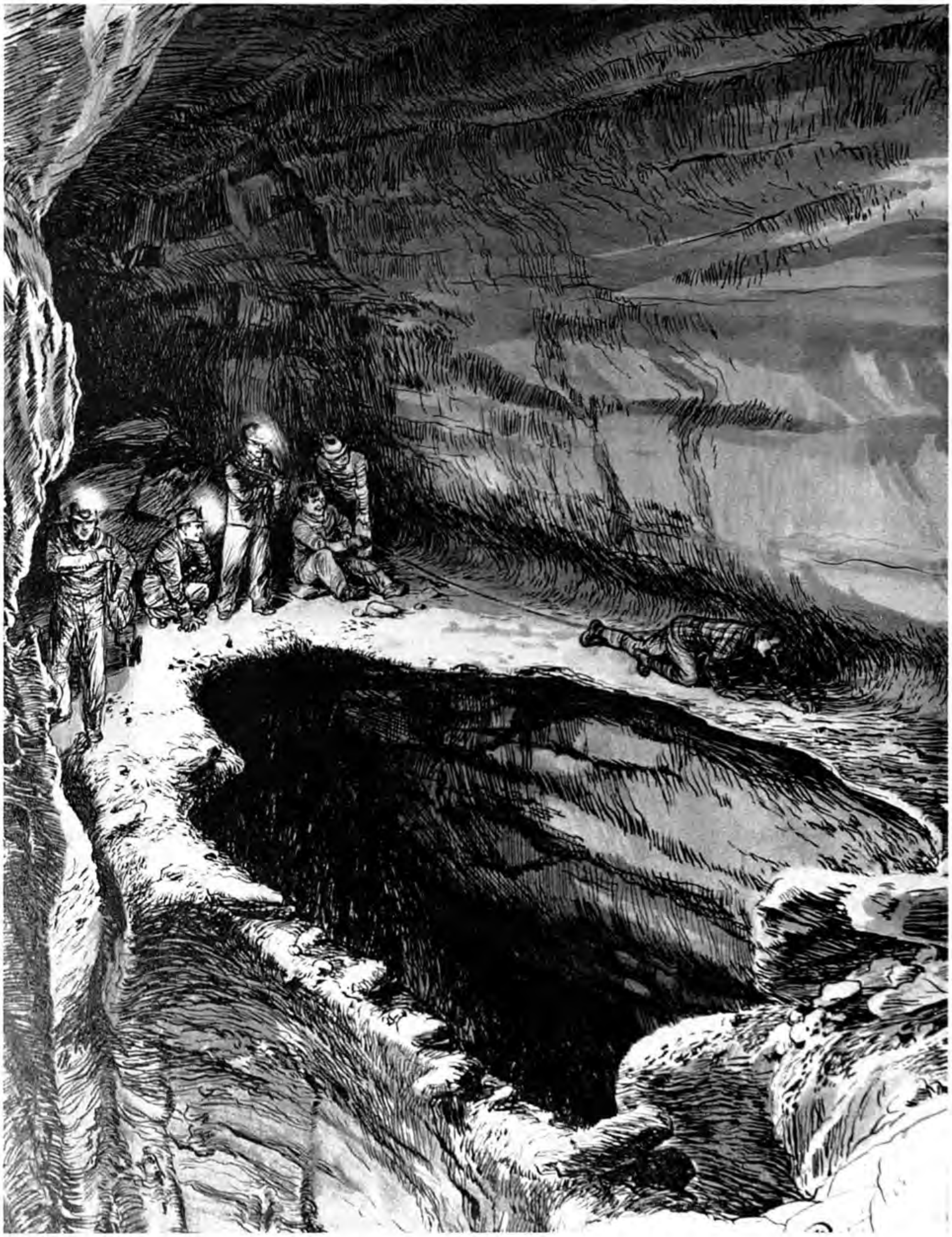
The sight on to 18 was long in spite of its going through the smallest two passages on the entire route. This sight was made possible by moving a lot of material out of the way, and even then there were only a few inches leeway. The first of these passages was so low that the pack basket with the instrument had to be dragged along on its face instead of upright. The sight then passed the full length of the Hodag Room and halfway through the second smallest passage. The traverse of the Hodag Room is made on the west wall near the ceiling, by means of fingerholds which are much like a picture moulding.

There are no footholds for about 30 feet of the traverse, and the slope is so steep that friction doesn't help much. Toting the basket of instruments across here had the Old Man puffing like a locomotive going upgrade, even though a safety rope held from each end added considerable moral support.

At station 18 a hole had to be dug in the clay floor to accommodate the legs of the stubby tripod, even when spread out flat. The ceiling was about 18 inches from the floor at this station, and all the observations had to be made with the observer sprawled out on his stomach. During the preliminary survey, after the instrument had been laboriously leveled, it was found to be a fraction of an inch too high to see all the way back to 17, so it had to be set lower and releveled. When the light still couldn't be found, Fitzhugh had suggested it would be better if the cap were taken off the telescope. After we had crawled on our hands and knees several times back and forth through these low passages, it was a relief to get out to station 19 at the head of the Parapet, where there was room to stand up once in a while.

Getting the line across the Thunderbolt Room to station 20 was even more laborious than across the Big Room. Fortunately a position could be made to order by building up a platform with rocks at the brink of the First Balcony. A stone was cemented in place with clay on this platform to mark the station. To make some of the readings here, the observer had to lean out over the brink while holding on to a rope tied to a big rock on the Balcony.

In order to measure the distance across this room three people had to maneuver the tape to a position where it would swing free when the tension was applied. Getting across the room, from station 20 to 19, involved going back on the Balcony to the loose rocks, where there is a passage to the underside of the Balcony; going forward to the front; roping down from here to the end of the big pit; climbing up the side of the pit and over to the Pendulum Pit; climbing a wire ladder to a sharp edge leading back through a keyhole into the bottom of the Avalanche Pit;



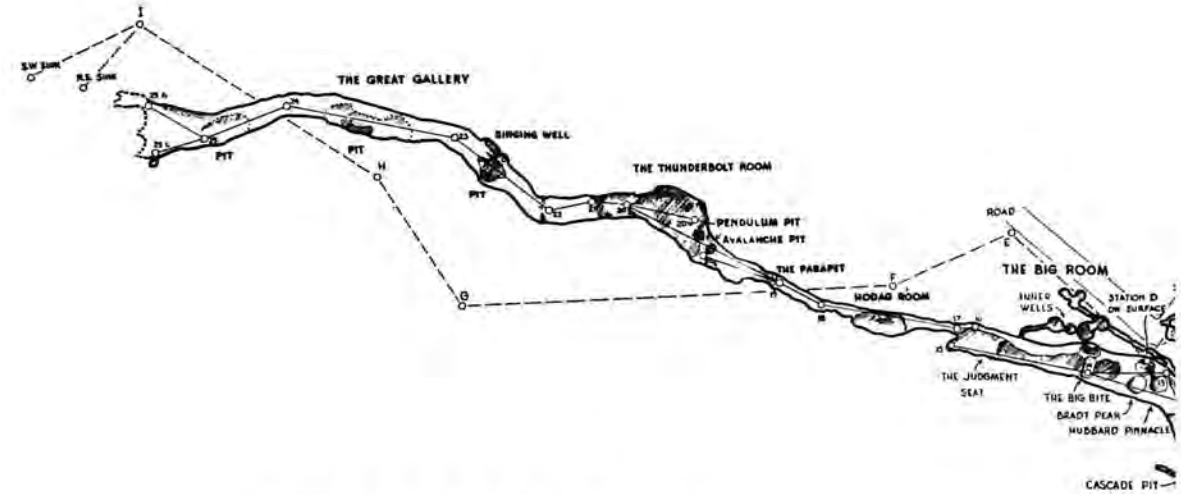
The Great Gallery traverse

Traverse across the Guillotine Stone

Climbing up to the Judgment Seat

The west wall Main Room

Traverse across the Hodag Room

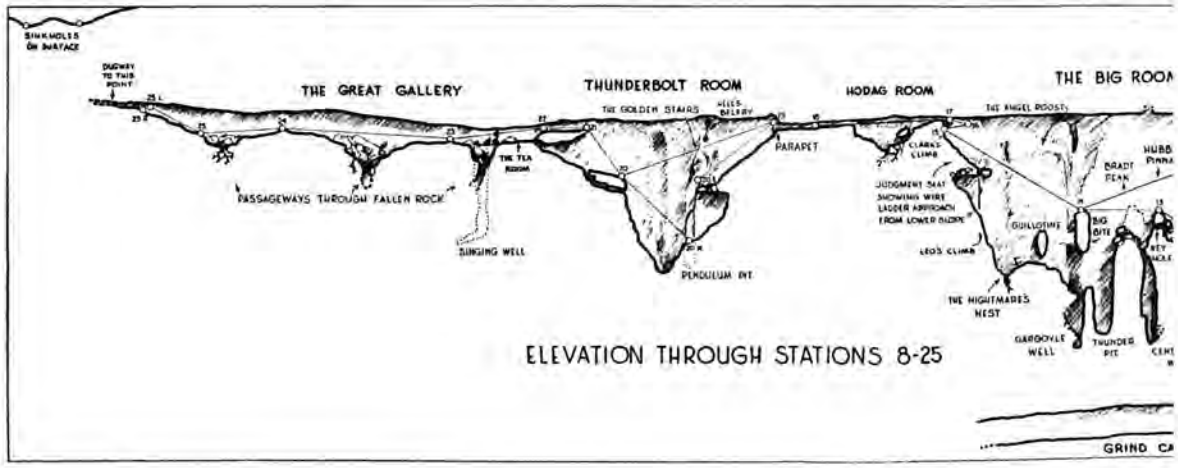


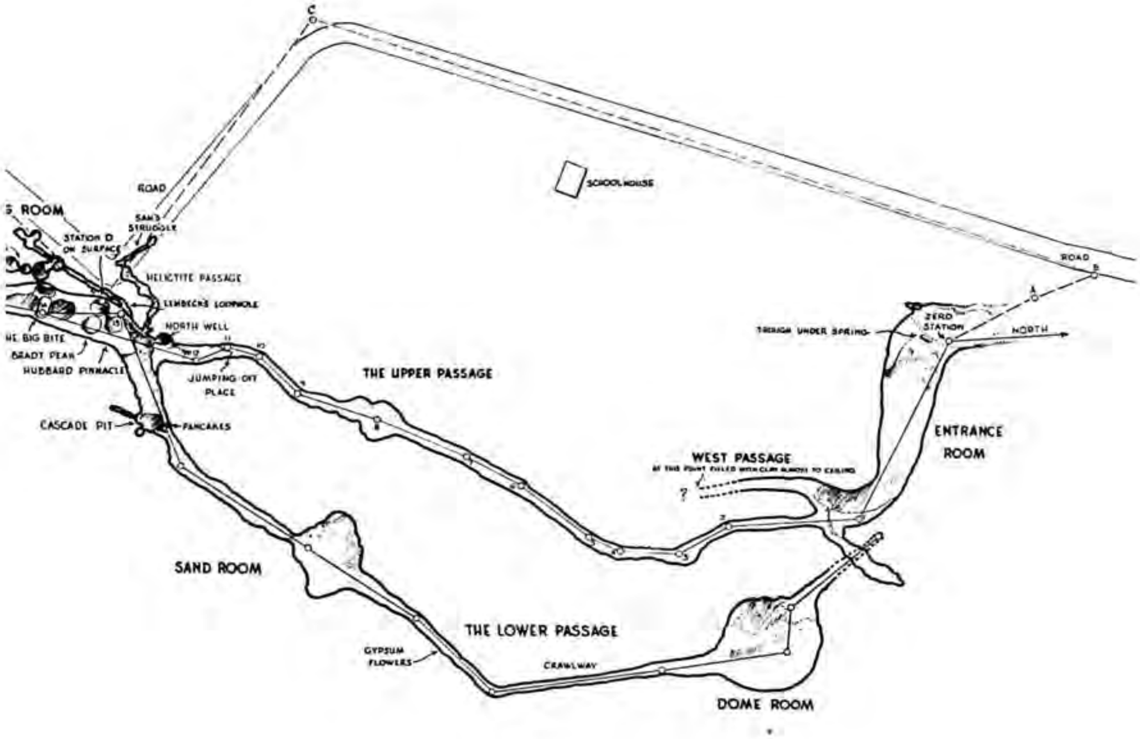
SCHOOLHOUSE CAVE

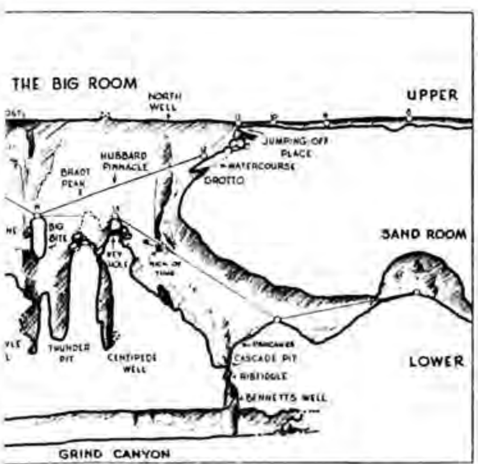
PENDLETON COUNTY - WEST VIRGINIA.

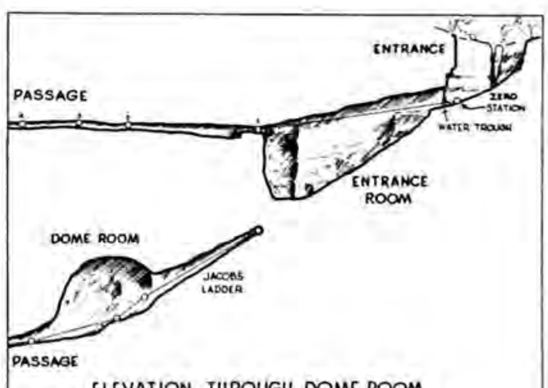
THE SMALL CIRCLES INDICATE STATIONS ON THE SURVEY AND ARE IDENTIFIED by NUMBER IN THE ACCOMPANYING ARTICLE. IN THE SCALE OF THE MAP THESE CIRCLES ARE SIX FEET in DIAMETER. BEING APPROXIMATELY THE HEIGHT OF A MAN, THEY WILL GIVE SOME IDEA OF THE PROPORTIONS OF SCHOOLHOUSE CAVE.

SCALE IN FEET









ELEVATION THROUGH DOME ROOM AND ENTRANCE ROOM.

climbing a rope for 18 feet to get out of this well to the Bridge; toiling up the steep rolling clay slide to the vertical clay wall of the Parapet; and finally crawling up this wall to the level of station 19. When the tape had been led to the stations at each end, it still had to be held aside with a string in the region of the Bridge by a third person while the tension was being applied, so that it would not be caught under protruding ledges.

Station 20 is apparently located at the only place where the instrument could have been placed to run the survey line through to the end of the cave. Certainly the job could not have been done without several more stations that would have been nearly as awkward. Even here the telescope had to be pointed up at an angle of 56° from the horizontal to sight to the next station, and the eyepiece of the telescope was so near the plate that a reflecting prism had to be used to make the sight. As Donald Hubbard remarked, "This station nearly had Stimmie stymied." While the instrument was at station 20 we made two other secondary stations, 20W and 20E to determine the dimensions and depth of the Thunderbolt Room.

The site of station 21 was at the edge of the Second Balcony, as far back from 20 as possible. It was on the dry dirt where the Balcony was thin and, although some of the edge had been broken off to sight further back, Paul still did not consider the remaining support any too substantial. He had insisted, therefore, that in using this station both the observer and the instrument be roped for safety.

From the brink of the Second Balcony the line was run through the Great Gallery by leaps and bounds. The sights were about 100 feet long, and convenient locations could be found for the stations where the observer could stand up to the instrument.

The last station was number 25. From this, however, two more sights were made on as far as we could see, one to the left side and the other to the right side of the gallery up where the fill was close to the ceiling. Beyond the right sight it was possible for a small person to crawl about 30 feet more, over sticky mud, to a small upright chamber large enough for two to sit in. This chamber was the enlargement of a fault in the ceiling, the top of which was wedged tightly with rounded cobbles. These cobbles indicated that the fault was one of the channels through which the sink had emptied its contents into the cave. From the lower part of this chamber there were holes extending out under the ceiling, but these were too small for even a "little old man" to get through.

The sights from station 25 completed the primary survey line all the way on the outside, from the sink to the entrance of the cave, and thence on the inside, from the entrance of the cave to the fill at the end of the Great Gallery. We next wanted to know about the position of the Lower Passage, which had been explored on the first trip into the Big Room in February 1940. As our time was getting short we decided to spend only one afternoon on this survey. To expedite matters we decided not to haul the transit down there through the downpour which rains into the Cascade Pit, but rather to survey the passage with an army compass, a hand level, a carpenter's rule, and the tape.

From the Big Bite station 14 we located a new station numbered 13 high above the Keyhole beside Hubbard Pinnacle, where we could set the transit. Here was another station where the observer had to hold a rope and lean out over the brink to peek through the telescope. From 13 we could sight steeply down, over the bottom of the Cascade Pit and over the Pancakes with their continual rain of water, to a dry station 161 feet away near the east wall. This one measurement was so long and through so much water that we preferred not to use and muddy the steel tapes. Inasmuch as it was of secondary importance we chose rather to get this distance with a cord whose length we compared with the tapes further on in one of the straight sections of the Lower Passage. Seven more sights took us all the way through to the end of the Lower Passage at the top of Jacob's Ladder.

This line ended the surveying we did in April 1942. Tom, on the other hand, had spent many hours before and after this session making measurements of the rooms and the positions of things with respect to the primary survey. From his copious notes of these measurements he put the flesh on the skeleton of the line survey. This work, however, will have to be left for him to describe at some other time.

One part of the cave which we would have liked to have put on the map more completely is the Grind Canyon. This Canyon can be entered by wiggling down from the bottom of the Cascade Pit through Lowell's Rib Fiddle along with the water which drains out of the north end of the Big Room on its way to join the stream in the canyon. The canyon is 25 feet deep for a long way; it averages 2 feet wide and meanders so much that few places afford a straight line sight for as much as 30 feet. The sides are covered with myriads of helictite nodules, which are so sharp they make one's bare hands sore; from these the canyon gets its name of "Grind." A few crude string and compass measurements were made about New Year's Day, 1941, going downstream 500 feet and upstream 100 feet. These showed that the stream flowed in a southerly direction if we disregarded the meanders and that it was not directly under any of the other passages of the cave except at its entrance. The ceiling for the last 100 feet slopes down to the stream level and shuts off any further advance in this direction unless one chooses to swim under water.

We were now eager to learn the results of our week's survey and find out whether the vision of a secret back door running down from the bottom of the sink could be made a reality.

The first step was to derive the azimuth of the true north from our observations on Polaris, using the tables in the Nautical Almanac for that particular day of the year and those times of day at which the observations were made. From then on, the azimuth of each successive sight was found by the change of azimuth derived from horizontal circle readings at each station.

The next step was to derive both the horizontal and vertical distances between successive stations. The horizontal distances were computed from the tape distances along the lines of sight by using tables of the trigonometric functions of the elevation angles, which had been measured with the vertical circle. The vertical distances along the lines of sight were computed in a similar manner, but to get the differences in elevation between stations an account had to be taken both for the height of the instrument and the height of the lights from the stations on the rocks.

The next step was to compute the three coordinates of each successive station, using the zero stake as the arbitrary origin of coordinates. Since the cave is all south of the entrance, the three rectangular coordinates were taken as positive to the south, the west, and up. The south and west coordinates were derived from the horizontal distance and azimuth of the foresight, by use of trigonometry, and summed together successively for each station. The vertical heights were obtained by adding the successive differences in height between stations.

Following all the way back to the end of the cave on the inside, and over the surface to the sink on the outside, we found how far the bottom of the sink was from a point directly over the end of the cave and also how far it was above the cave. The survey shows that the last point sighted on at the right side of the Great Gallery beyond station 25 lacks only a little over 50 feet from being directly under the first hole of the sink. Since the small chamber beyond this last sight is another 30 feet in the direction of the hole, this chamber must be only about 20 feet from a point directly under it. On the other hand, the holes are 70 feet above the small chamber, a distance too far to burrow down easily for a back entrance.

It is possible that a water passage is inclined down to the small chamber along a joint in the rock at this slope of 20 feet in 70. If this is the case, then perhaps the far hole of the sink may drain into the continuation of the Great Gallery on the far side of the shut-off, and an equal distance on from the small chamber. If this is true, it would require tunneling a distance of only 38 feet to get through. It is even possible that the middle vent goes to the far side, so tunneling in this direction is intriguing. Paul is willing to try and has already enlarged the thin crawl passage for more than half its length, so that mud and stones can be dragged out as the tunnel advances.

One fact that shows up very clearly from the survey is that the ceiling of the cave is essentially level over its entire length. Taking this into consideration, the ceiling is more than 70 feet above station 13. This ceiling, on the other hand, is only 75 feet below station D on the surface where the bend in the road crosses the stream gully. A little upstream from the road the gully is approximately over the Cascade Pit and probably accounts for the continual spatter of water down onto the Pancakes and the Cascade Pit.

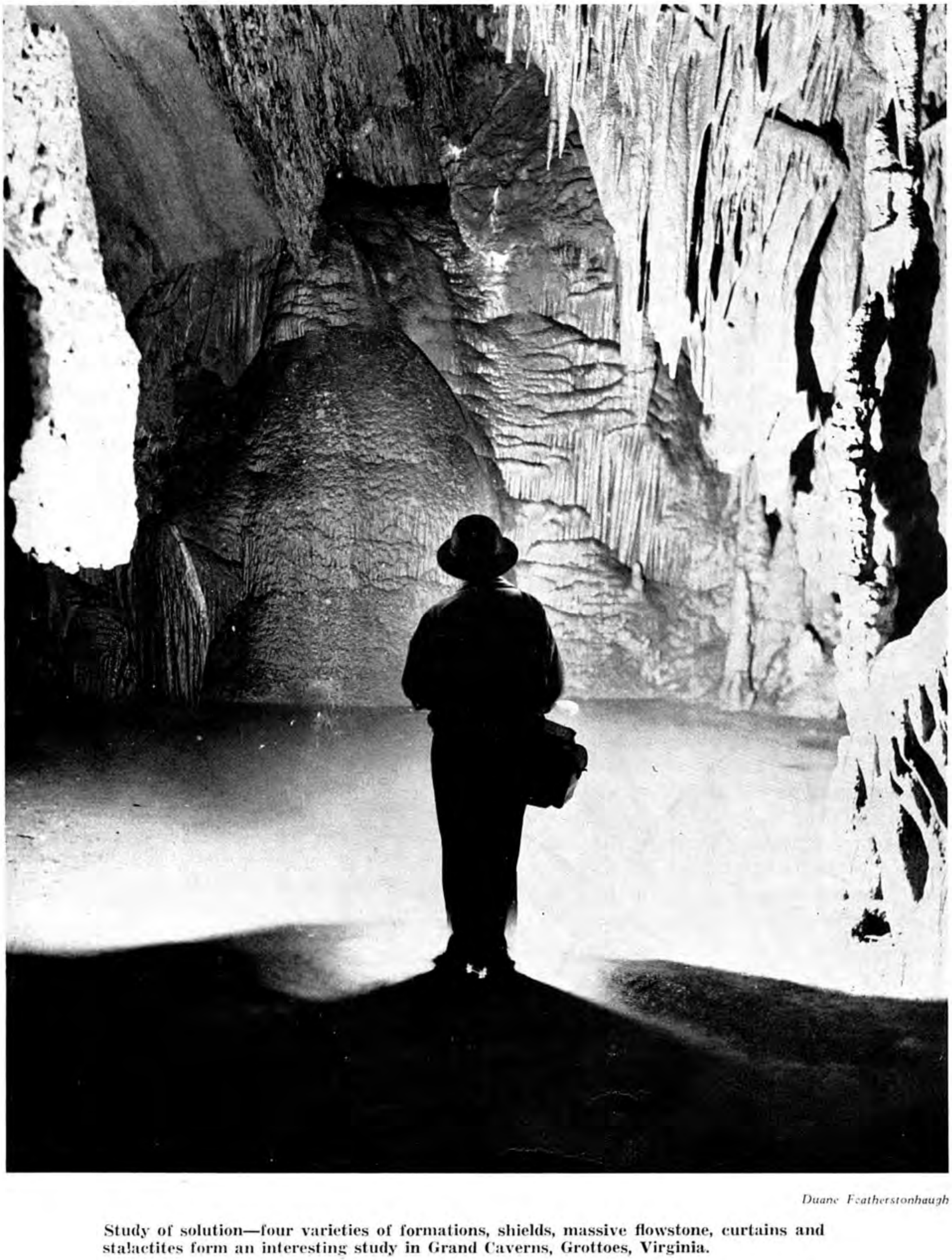
It appears that the cave was first formed by underground water dissolving the softer limestone along a fault under the crest of the long anticline of harder rock. The cave was subsequently filled almost to the ceiling with silt. Remains of this silt level still show along the West Passage, into which one can crawl for 100 feet to a point where the silt is too near the ceiling for even a thin person to proceed further. Remains of this silt level also exist the entire length of the Upper Passage from the Entrance Room to the Jumping-Off Place; then again in the small passage from the south end of the Big Room to the Hodag Room; again in the longer passage from the Hodag Room to the Parapet at the north end of the Thunderbolt Room; and finally on the Second Balcony between the Thunderbolt Room and the Great Gallery.

At a still later time the water coming in from the surface found its way down to streams at a much lower level, such as the Grind Canyon stream, and washed out the silt to form rooms. As the surface streams changed their locations, the rooms became larger. This process has taken a very long time, as is shown by the fact that some of the present mud slopes are covered with flow-stone "icings" that have taken thousands of years to build up to their present thickness.

The crude survey of the Lower Passage showed that it is far from being directly under the upper one, although the Sand Room in the Lower Passage corresponds to the widening of the Upper and doubtless is due to a softer rock in that plane. Another thing the survey of the Lower Passage indicates is that the deep Entrance Room was formed by material dropping down from it into the north end of the Dome Room. The present distance from the bottom of the Entrance Room to the top of Jacobs Ladder at the end of the Dome Room is about 25 feet.

To summarize the whole survey, it has been shown that the shut-off at the end of the Great Gallery was caused by the emptying of the sink, but that the distance down from the surface is too great for any amateur excavators to dig an enrance either to the known part of the cave or to the continuation that probably lies beyond it. How long a part of the cave is filled by this intrusion is merely a matter of speculation—guesses vary from a few feet up to a hundred. In a similar manner it is possible that a continuation of the Lower Passage may have been sealed at the far end of the Dome Room by the material which came down when the big Entrance Room was formed.

The ceiling of the cave was found to be at essentially the same level over its entire length, and the chambers of different sizes vary vertically only in the depth to which they have been cut below the ceiling by water erosion. The Cascade Pit is not only the deepest, but has the most water falling into it, and furthermore it was found to lie under the water course now on the surface. Following along the direction of the anticline beyond the sink for a few hundred feet, there is another larger watercourse under which we may expect another big room. This and other features await the explorer when some way can be found, or made, for him to get to them.



Duane Featherstonhaugh

Study of solution—four varieties of formations, shields, massive flowstone, curtains and stalactites form an interesting study in Grand Caverns, Grottoes, Virginia.

CAVE MAPPING*

By A. C. SWINNERTON
Professor of Geology, Antioch College

One of the most important contributions which can be made to speleological science is the construction of accurate maps of existing caverns. The author, a recognized authority on karst topography and limestone terranes, presents herein some valuable suggestions to the cave enthusiast which will enable him to perform this necessary cartographic function with a minimum of equipment and knowledge.

One of the important ways in which spelunkers can assist with the solution of some of the scientific problems relating to caves is by providing sketch maps. Professional scientists can visit only a limited number of caves, but when more cave maps, including those made by exploration hobbyists, become available the professional can visit the mapped caves by proxy.

Mapping a cave for science is not the only reason a caver should learn to map. A sketch map, drawn carefully and to scale, records the fact that a cave has been explored thoroughly, not just clambered into, and shows vividly and in correct dimensions all the noteworthy features. A simple outline plan is usually not enough; accuracy in dimensions and elevation are required and this can not be achieved by guess. Although mapping need not be difficult, it does require time. Mapping can be fun and meeting the challenge of careful accurarcy and patience brings a tremendous sense of accomplishment.

The map of a cave has for its purpose the representation of the cave on a piece of paper with its various parts having the same measureable relationship to each other as in nature. A cave is a more difficult mapping problem than a terrain because the cave is entirely enclosed: a cave map must show the dimensions and form of the inside of a complete hollow. The difference between a *map* and a *sketch map* is that the latter does not pretend to the same accuracy as the former. A map made with engineering instruments should give distances to a fraction of an inch. The methods described in this article will not make a cartographer out of the average person but they should enable him to draw an outline that is accurate to a few feet. So these techniques are really map sketching rather than mapping, but if carefully practiced give results that are very useful.

I.

The first step in any kind of map sketching is to survey the whole cavern in order to get a comprehensive idea of size and general shape. You will then know what scale to select. Scale is very important for it expresses the dimensional relations between the map and the cave. The scale should be chosen with practical considerations in mind. The larger the scale the more accurate the map; but you do not want a scale so large that the map is bigger than your piece of paper. For example, if your paper is 10 x 12 inches, if the cave is a long narrow cavern 2,000 feet long, and if you chose a scale which represents 100 feet of cave distance by 1 inch on the map, then the map of the cave would be 20 inches long and would "run off" the paper. On the other hand if you select 1 inch equal to 1,000 feet, the cave map will be only 2 inches long and will be too small. So something in between, like 1 inch equals 250 feet, making the cave map 8 inches long, will give good proportion and allow for a marginal border and labeling. Of course, you can take advantage of a large scale by mapping the cave in sections and put the sections together when completed.

* Editors note: For another article on this subject see Cave Maps and Mapping, by William E. Davies, *Bulletin Nine, N.S.S.*, Sept. 1947, pp. 1-7.

As part of the reconnaissance you should select at least a few stations where later you are going to make your observations. Doing this will establish a plan, or at least an approximate route to follow. After a little experience the choosing of stations and route will become almost intuitive and will enable you to map efficiently.

One simple way of delineating a cave is to survey a line along the center of the bottom of the cave and then impose on this framework an outline and a series of cross sections and a longitudinal section. Such a representation, if carefully made, can serve many purposes, especially if the center line and sections give the changes in elevation.

A somewhat more complete sketch map can be drawn if the contour principle is applied. Most speleologists have used the topographic maps of the United States Geological Survey or other government agencies and are familiar with the brown contour lines which are used to show the elevation above sea level, as well as the shape of hills and valleys. Representing caverns by contours is just as simple as representing a landscape, but reading a contour map of a cave is not as easy as reading the contours of a valley. For the cave is like a valley covered by a roof. And the reader is apt to get the valley contours mixed with the roof contours. Once the principle is mastered and some experience has been gained in cavern-contour reading, the contour map is ideal for inducing a mental image of the cave.

Since the outline-section method is simpler than contouring the former will be discussed first. Contouring depends basically on the principles used in the outline-section technique so that method should be learned first. The equipment is the same for either method and a few words will be devoted to what has to be done in map sketching and what instruments are needed to make observations both easy and accurate.

The elements of mapping are fourfold: level, direction, distance and slope. You have to be able to tell when an object or a line is level; you have to orient yourself and determine the direction of a line of sight; you have to measure distances accurately even to inaccessible points; and you have to be able to measure a vertical angle above or below the horizontal. There are other things which supplement those four requisites but the four are sufficient to produce a satisfactory sketch map.

Simple instruments are available for all of these determinations; some can be homemade. For telling when an object is at the same level as your eye there is the hand level; it can also be used to level your work table. The direction of an object can be told by a compass, preferably one with square sides and a sighting device; if the compass does not have sights a triangular ruler can be used for direction sighting. Distances can be measured directly by a steel tape; but inaccessible objects can be located by triangulation or their distances can be measured by using a small range finder like those used with cameras, but preferably measuring up to 500 or 1,000 feet. The angle of a sloping line can be measured by a clinometer—some compasses are equipped with them. If you can't buy one cheaply, make one. A six inch square board, a protractor, a thumb tack, a short piece of string and a small weight like a fishing line sinker are all that are required. In addition you will need pencils, eraser, a couple of pins, a protractor, Scotch tape or thumb tacks.

Mapping consists of applying the four separate factors of level, direction, distance and slope, relating them and recording them on a piece of paper. The easiest way to do the recording is to draw the map as you make it. A flat board like a bread board to which you have fixed a socket so it can be attached to a sturdy camera tripod is a convenient work table. In mapping the board and tripod combination is known as a plane table. Fasten the paper to the board with Scotch tape or thumb tacks and you are ready to start.

II.

Having made a quick survey, keeping in mind a tentative selection of principal stations and route, and having decided on an appropriate scale, you can begin actual mapping. The first step is to set up the plane table. The table top should be level; this can be checked and adjusted by using the bubble of the hand level or by the clinometer. Check the level in various directions.

Orient the table by placing the compass parallel to one edge of the board and turning the table until the edge is north and south. Mark this direction with a line and indicate clearly which end of the line is north. *This is very important* since working underground is not like surface mapping and it is easy to lose track of your orientation. No map is so hopeless as one in which the directions are reversed. If you are in a region in which magnetic north (i.e. north by the compass needle) is different from true north you can do either one of two things: adjust the compass (if it is adjustable) so as to give true north readings, or make your map on magnetic orientation and when it is finished indicate by appropriate arrows the magnetic and true bearings. The latter plan is the simpler and is just as accurate. In fact it may be more accurate for an inexperienced person, as even those who ought to know better, are apt to adjust the compass in the wrong direction.

Orienting one edge of the table north-south is not absolutely necessary. If the proposed map will fit better if the north-south line is at an angle, then draw a north-south line and place an edge of the compass on that for orientation. But, let me repeat, *be sure to mark the north end of the line.* Actually maps can be drawn without using a compass, by orienting along the sight lines between stations, a proceeding called "backsighting". But this requires skill and experience and since a compass is part of the caver's usual equipment it might as well be used in mapping.

After leveling and orienting the board, select a point on the paper to represent the spot in the cave where the tripod is located. Put a fine pencil dot on the paper; this is "Station 1" and should be so marked. Next put a common pin firmly through the dot and place your sighting device against the pin and sight toward some object which is to be represented on the map. Take time to sight accurately and to check to be sure the edge of the sighting device is against the pin. When the sight direction is accurate, draw a fine line from the pin *in the direction* of the object. Then take the range finder and determine the distance to the object. If good accuracy is desired, take at least three readings of the distance and average them. By reference to the selected scale, mark off the distance on the pencil line. If your scale is 1 inch equals 250 feet, and if the range finder readings show the object is 375 feet away, then your mark should be $1\frac{1}{2}$ inches from the pin and on the penciled sight-line. The object has then been located and should be labeled "A" and either listed on the map margin or directly beside the object.

If the object is not on the same level as the plane table and you wish to determine the difference in level, take the compass, if it has a clinometer, or your slope board, sight the object and determine the angle of the sight line above (or below) the horizontal. If the angle is 5°, reference to trigonometric tables (sines) will tell you that you multiply the 375 foot distance by .087 and that the difference in elevation is therefore 35.225, or approximately 35 feet. For reasonable accuracy you must add the height of the table or whatever your sighting position was. See Figure 1.

You should also remember that your first sight line is not horizontal and the range finder distance should be corrected by a small amount. The correction factor is found in the table of cosines, and turns out to be .996. The true, horizontal distance is therefore 375 x .996 or 373.5 feet instead of 375. See Figure 1. If the angle is larger the amount of correction becomes more important.

If your mapping program is likely to involve these calculations it will be useful to compile a small table of factors for both vertical and horizontal distance such as the following:

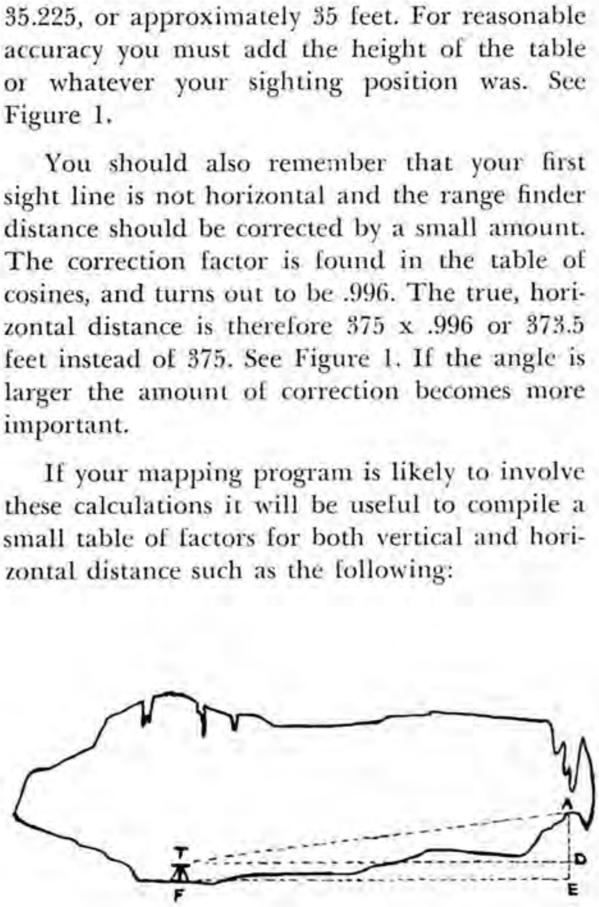


Fig. 1. Sketch to illustrate the principle of determining elevation. The line TA is the line of sight from the plane table T to the top of large stalagmite A. The angle ATD is measured by the slope board. The difference in elevation between the point of observation and A is AD; the height above the floor F is AE. The sketch also shows that the range-finder distance, TA, is longer than the horizontal, map distance, TD.

Table I.

When Sight Distance is 1,000 Feet

Angle	*Horizontal Distance* (cosine x 1,000)	*Vertical Distance* (sine x 1,000)
3°	999	52
5°	996	87
7°	992	121
9°	987	156
11°	982	191
13°	974	225
15°	966	259

If the sight distance is more or less than 1,000 feet, multiply by the number of feet and mark off three decimal places; for example, if the angle is 9° and the sight distance is 330 feet, the first step will be 330 times 987 or 325721, then marking off three places, 325.721 or 326 feet; the vertical distance will be 330 x 156 equals 51480 or 51.480 feet.

To get back to Station 1 and cave mapping: Point A can now be relocated on the sight line if the corrected horizontal distance is significantly different from the range finder distance. It should also be marked "1 + 35" if above Station 1 or "1 — 35" if below.

Now select other points and after checking the orientation of the table, repeat the direction sighting, range finding, clinometer sighting, the calculation of difference in elevation and horizontal distance correction of each in turn. This may seem like a tedious chore but once learned it goes quickly and automatically.

After spotting in a dozen or more points, correctly located as to distance and elevation, there comes the problem of sketching in the cave outline. Which part of the cave wall will you select? Usually the procedure is to imagine a horizontal plane and approximate its intersection with the walls, drawing the outline with your various located points to guide the line. Sometimes one outlining line is not enough. Some tunnels are trenched and the location of the trench in the floor of the tunnel may be significant. A finer or a broken line can be used but the feature so represented should be distinctly labeled. Another person reading your map can't be allowed to guess; he must be told.

Now you are ready to move to Station 2.—Before moving, check your table and location carefully. Is everything level and oriented as it should be? Can you find the exact spot again? Have you located where Station 2 is to be and do you have it marked both on the ground and on your map? If everything is in order, move your plane table to Station 2, set up, level and orient for the new series of sighting shots. To confirm the correctness of your table orientation and to be sure you have not reversed your orientation put your sighting device on the line from Station 1 to Station 2 and sight back. Does Station 1 fall exactly on the line of sight? If not, something is wrong; you should correct the error before you go further. If the direction is right, take a range-finder reading to check the distance. It is particularly important that your primary stations be correctly located otherwise the secondary points will not be in their proper relation to each other.

After you have checked the position of Station 2 by back-sighting on Station 1, look for some of the points sighted from Station 1. Sight to these same points and measure their distance with the range finder. You now have *three* locations for each point: the sight and distance from Station 1, the sight and distance from Station 2 *and the point where the two sight lines intersect.* This last point has been located by the method known as triangulation. (See Figure 2.) Unless you are more accurate than most human beings these three points will not quite coincide,—

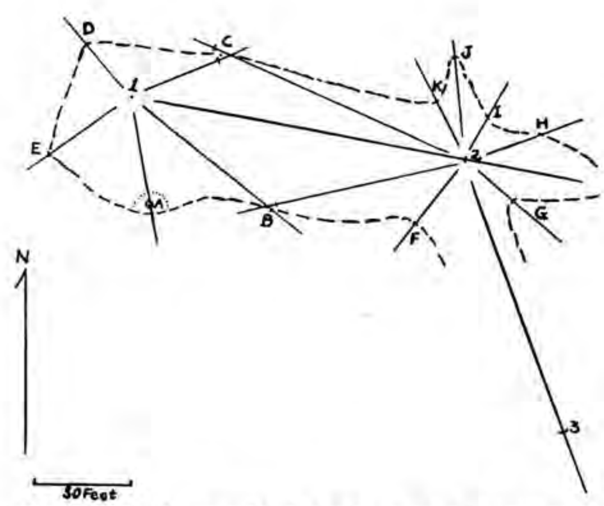


Fig. 2. Partly completed sketch map of hypothetical Pig Cave, showing sight lines from Stations 1 and 2 and the outline sketched in. Note the triangulation for points B and C, Magnetic North arrow and the bar scale.

almost, but not quite. The correct position is somewhere between the three points; the resolution of this problem is highly technical but in ordinary practice the correct position can be approximated by drawing a triangle between the points and estimating the center of the triangle. Usually you can correct your points by inspection.

Now that you have established Station 2, backsighted, triangulated, corrected your points and made other necessary adjustments such as modifying the shape of the outlines, begin locating new points as you did at Station 1. Pick up the loose ends of the outlines and continue them as far as you can around and beyond Station 2. Then move on to Station 3.

By this time you should have selected one or more places where the walls, roof and floor show either characteristic shapes or special features which you wish to represent in a cross section. Such a section is the outline which the cave would make on a vertical plane cutting through the cavern. In a sense it is a vertical map. Sometimes the section line will run through one of the primary stations; however those stations are selected mainly for wide visibility and the sections for their profiles. So don't expect to use the stations for making the sections, but establish special points.

When you have selected a point where you wish to draw a cross section, set up the plane table as if you were at a primary station. Locate yourself on the map. Select and sight the section line and draw it on the map, marking it "Section I". Select a blank area on the map, put a pencil dot near the center of the space to represent your observation point and draw a horizontal line through the dot. Now with your clinometer or slope board sight to the critical points (i.e. changes in slope or special features) close to the section line and read the angles. With your protractor lay off each angle from the horizontal line, the dot serving as the center. Next with the range finder (or tape) measure the distances to the same points; scale them off on the sight lines. Now you are ready to sketch in the section, using the critical points as a guide. (See Figure 3.) As you sketch you may need to take another shot or two to fill in an uneven part of the section. It is better to have too many points than not enough. Be sure that you mark the sides of the section by letters or compass directions so that it is not reversed.

If you draw more than one cross section, it is a good idea to line them up on the paper so that the elevations agree, from one section to the next. This procedure will give vividly the up hill or down hill trend of the cavern. Sometimes a lengthwise section of the cave should also be shown.

At this point, if you have stayed with it, you are beginning to develop some self-assurance. You will feel that you can skip some of the checking and re-checking. Perhaps you can, but watch out. One incorrect station orientation, and your map is worthless. It is better to take a minute to check than to waste the work of several hours or days. Once a mistake is incorporated in the map it is very difficult to locate it and even harder to readjust the part of the map that follows.

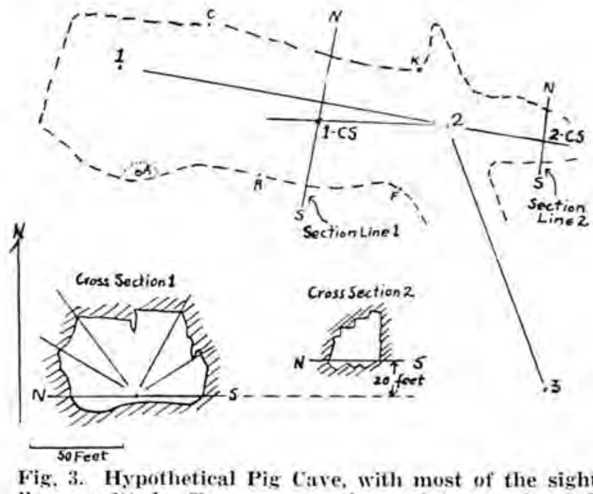


Fig. 3. Hypothetical Pig Cave, with most of the sight lines omitted. Two cross-section points are located, 1-CS and 2-CS, also two section lines, 1 and 2, with the ends marked with approximate directions. Cross section 1 shows the sight lines and range points. Both sections show direction marks, N and S. The difference in observation-point elevations is indicated. The same scale is used for each section as for the sketch map.

III.

The contour sketch map adds to the map the continuous element of elevation and thus aids the imagination in picturing the cavern. Contour lines are lines drawn at specific levels. In the outline mapping it was suggested that the outline be sketched in as if a horizontal plane intersected the cave walls. A line so drawn is in reality a contour. In contour mapping several such levels or horizontal planes are used, each successive one separated by the same distance, i.e., the contour interval.

In making a sketch map with contours you proceed exactly as described in the outline mapping until the outlining stage is reached. Then comes the selection of an appropriate contour interval, that is, the vertical distance between the imaginary horizontal planes which intersect the walls and objects of the cave. This choice is like selecting the scale. The more contours (the smaller the contour interval) the more accurate is the resulting map. But a map can be so overcrowded with lines that it is not legible; and a good map, like a good story, can leave something for the imagination to fill in provided the critical changes are definitely clear. A little experience will soon indicate what constitutes an appropriate contour interval for a specific cave. Possibly a ten-foot interval is a good one to try at first; you can see rather quickly whether your map will fail to show sufficient detail or perhaps whether a 20-foot interval will suffice.

A highly precise contour-map maker will go to some trouble to determine the exact elevation above sea level of some point within the cave. Contours can then be drawn with reference to this bench mark and the cave map can be compared directly with maps of the ground surface overhead. If a barometer is available the elevation of Station 1 can be determined within a few feet which for many purposes is accurate enough.

However, if nothing is known about the absolute elevation you can still proceed with contour mapping. Select some point as the reference point for elevation. This is known as your datum point or datum. Assign some arbitrary elevation to it: 0, 500, 1,000, any number. Something larger than zero is usually chosen simply to avoid minus numbers when you go to a lower elevation. The easiest thing to do is to select Station 1 as the datum point and, unless an absolute datum has been established by a bench mark, that is usually a sensible way to start. You can always tie in your datum with the outside world and that is a good thing to do, by using the methods already described.

There are two ways to find out where a contour line should be drawn: (1) by direct observation and (2) by interpolation. The first is simplest but is sometimes hard to do; the second requires a small amount of mathematics. Both methods can be used together.

The direct observation method can start by assuming that the top of the plane table at Station 1 is datum. Lay the hand level on the table and, being sure the bubble indicates level, scan the cave. Everything cut by the cross-hair is on the datum contour. Select a number of recognizable points, sight their direction with your sighting device, draw the sight lines on the map; use the range finder to find their distances, mark these on the sight lines from Station 1. Then observing the changes in shape of the walls, sketch in a line connecting all of the points at datum elevation. This line is your first contour. Unless a dark passage or an entrance interrupts the line it should be a continuous line and close on itself. It is essentially a horizontal section.

Drawing the second contour may not be so easy, since you have to find a spot where the table top is just 10 feet (or whatever contour interval you have selected) above (or below) where it was at Station 1. The ideal situation would be to have a spot directly over Station 1 but this is usually impossible. The new set-up must be tied into Station 1 by direction and distance and might be designated "Station 1-X". Having gotten set-up and oriented, repeat the hand level scanning, find points on the datum-plus-10 (or datum-minus-10) level, sight and range them, plot them on the map and sketch in contour number two. Can you go on from this point for the third, fourth and remaining contours?

The method of interpolation makes use of all of the points previously located on the map. Their position and elevation in respect to Station 1 are already determined but probably the elevations do not match the elevations chosen for your contours. However, the known elevations can be used by interpolation in this way: If there is a uniform slope between two points, whatever fraction of the distance you go between the points you will also have climbed (or descended) the same fraction of their altitude difference. For example, suppose point M is +35 feet and point N is +25, then half way between the two points it will be +30 feet *if the slope between them is uniform*. (See Figure 4A.)

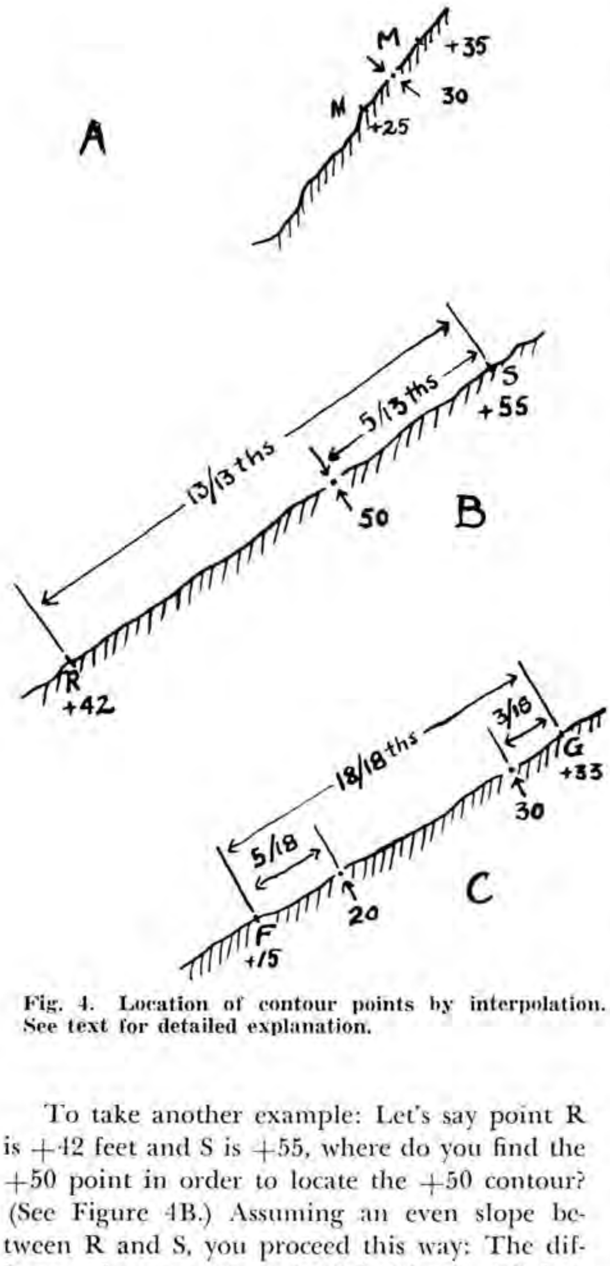


Fig. 4. Location of contour points by interpolation. See text for detailed explanation.

To take another example: Let's say point R is +42 feet and S is +55, where do you find the +50 point in order to locate the +50 contour? (See Figure 4B.) Assuming an even slope between R and S, you proceed this way: The difference between 55 and 42 is 13; the 50 foot point is then 5/13 of the way from 55 to 42. So on your map, measure the distance between R and S and place the point for 50 feet 5/13 of the distance from S. Be sure it is 5/13 from S, not from R.

Now a more complicated problem: Suppose point F is +15 and G is +33. If your contour interval is 10 feet, two contour points lie between F and G; how do you locate them? Again, if the slope is uniform, it is easy. (See Figure 4C.) The difference between F and G is 18. The 20 foot point is 5 above 15, so it will fall on the line between F and G 5/18 of the distance from F. The 30 foot point is 3 less than G, so it will be 3/18 from G toward F.

That condition of interpolation—*if the slope is uniform*—is of course seldom met when you are dealing with the walls of caves. It serves, however, as a first approximation; you can proceed on the assumption of uniform slope and after comparing the actual slope with the imaginary uniformity you can adjust the contour point. In order to aid your ability to estimate the correct positions it may be good practice to sketch, occasionally, the profile of the cave wall to scale and measure off where the contour points come.

It is in estimating the positions of the contour points and in sketching in the lines connecting the points of equal contour elevation, that the real skill and art of the map maker are required. At the start it is best to plot many points, more than you think you need, in order to develop your contouring sense.

IV.

For an illustration of what can be done using the two methods together look at Figure 5. This shows a sketch map made with only the instruments mentioned. Note that the contour interval is 25 feet but the contours are accompanied by cross sections which help the map reader imagine the fissure form at the south end merging into the tunnel form at the north end. The presence of sea water in the cave was ideal for establishing the elevation datum.

Possibly a few general remarks should be made about how to ensure that your completed map will be of value both to you and someone else. With your map in your hand, go quickly through the cave, checking the general orientation. Does your map show that the turns bend in the same direction as they actually do? Do the contours indicate up hill and down the way the cave goes up and down? Next consider the shapes and sizes. Does one section of the map represent that part of the cave as small; is it really small? Sometimes general checks of these kinds will unearth surprising and disconcerting errors in your map.

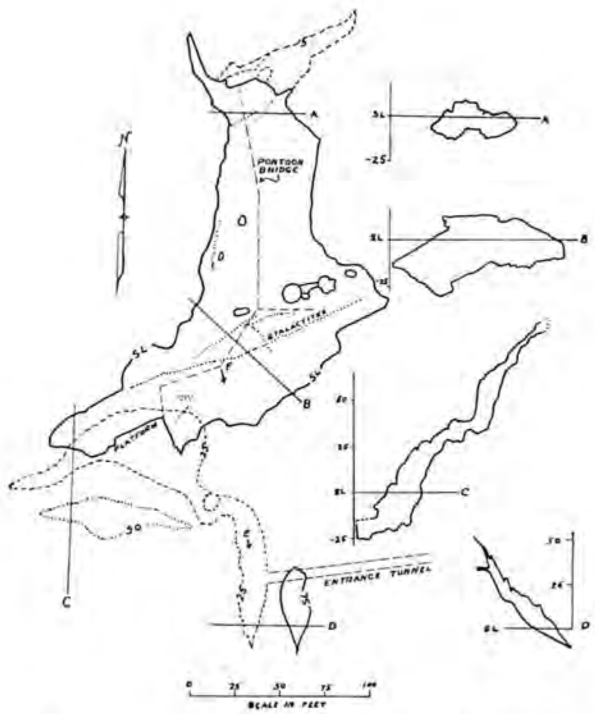


Fig. 5. Sketch map made in August 1948, using both contours and cross sections. Contours were drawn for sea level (SL), + 25 and + 50; at the extreme north end of the cave a + 5 contour was put in to show a low-ceiling branch. Using an odd contour is ordinarily not good practice.

Since you will wish to keep the original map as the basic record, you should make a tracing of the outlines and sections, omitting the sight lines and other working lines and notes. Such a tracing can have any degree of professional finish you wish to put on it. It can be blue-printed at a nominal cost and copies can be made available to your friends, to N.S.S. files or any who are interested.

To be of help to another person the finished map must show the scale, the directional orientation and the contour interval. If you assumed an elevation datum, used a barometer, or established a bench mark, whatever you did should be made crystal clear so that the map reader will know how to judge the elevations. Sometimes it is important to know the date of mapping, so a date should be shown.

When all is said and done, it is not the professional finish that counts, all the fine drawing and perfect lettering will not make up for an inaccurate map. It is better to take time to achieve accurarcy than to dress up the appearance. However, legibility is second only to accuracy when it comes to usefulness. What good is an accurate map if it can not be read? So as you try mapping and come to enjoy it, remember others may find data and characteristics of importance in the cave on the basis of your map.

How to Make a Slope Board

Place a celluloid or cardboard protractor on a ¾″ - 6 x 6 board about a half-inch from one edge with the straight edge of the protractor as nearly parallel to the edge of the board as you can possibly get it. Mark every five degrees (or every one degree) around the semi-circle. Tie a small weight to a piece of string, put a thumb tack in the center point of the semi-circle, make a loop in the string to slip over the thumb tack so that the weight hangs below the board and you have made a clinometer or slope board. Remember that you will sight along the top edge of the board and that you want to observe the angle between the top of the board and the horizontal. You are measuring that angle by having a weight on a string which always hangs vertically, that is, at right angles to the horizontal; so the zero point is at the bottom of the semi-circle and you number both ways around the semi-circle to 90°. Now to make that clear, hold the sighting edge level and the string will hang straight down over the 0° mark. Then turn the board so that the sighting edge is vertical; now the string will hang parallel to the sighting edge and be over the 90° mark. When you tilt the board at 45°, the string should hang at 45°.

Formation and Mineralogy of Stalactites and Stalagmites

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Stalactites and stalagmites are shown to be formed from over sixty minerals and several other substances by a precipitation of the mineral, by solidifying from its liquid state, and by several less common means. Factors affecting their rate of growth, and their shape include the rate of incoming flow, rate of evaporation, chemical composition of the solution, and the size of the stalactite or stalagmite, according to the author of this most interesting article.

Introduction

Stalactites and stalagmites have been known for many centuries. Since Olaus Wormius (1654) first used the terms and defined them (Murray, 1901), work has been done to determine their origins and the physical constants controlling their growth. From Plot's statement (1677) that "such Stones are made of nothing but such water as it drops from the roofs and caverns of the Rocks and therefore are called Stalactites" to the ideas on the molecular breakup of calcium bicarbonate in solution has taken several centuries.

From the literature of the Greeks and Romans there is little to be found on cave phenomena. The Greeks used the stalactital limestone in some of their sculpturing, but references to the caves and dripstone are difficult to obtain. Roman and Greek coins have been found in limestone caverns in southern Europe; temples to Pan, Bacchus, and other gods with their associated oracles were also in such caves; so it is therefore certain that stalactites were viewed.

Stalactites, other than calcite, were first mentioned by Woodward in 1695 (Murray, 1901), who stated "Spar and other crasser Minerals . . . form Stalactites or Sparry Iceycles hanging down from the Arches of the Grottoes". This was the first article written in English on the subject, the previous ones having been written in the scientific Latin of the day. In the third edition of the Encyclopedia Britannica (1795) is the first mention of the nature of the "other crasser Minerals", gypsum being described as "stalactital".

The purpose of this paper is to report the occurrences of stalactites and stalagmites, especially other than calcite, and to note the factors affecting their growth. As used here a stalactite is an object of deposition in a hanging position, yet, also included, are the types which grow with no consistent orientation with respect to gravity (see plate 4); a stalagmite is a growth caused by a drip. Actually the definition of stalagmite is the same as the Wormius original (1654, Greek, that which drops), but the one for stalactite (1654, Greek, oozing out in drops) is slightly broadened from its first definition.

General Description

Stalactites are generally long, pointed, or tapering pendants from a roof of a cave, mine, or arch. Calcite, halite, marcasite, sphalerite, and most others are commonly found with a hole in the center, a hole varying in diameter from eight to one-tenth millimeters (the limit of the eye's resolution power); in the eccentric stalactites of Glory (1936) the largest hole was 0.008 millimeter, the hole usually being much smaller. The stalactites formed from freezing of liquids and those formed with a great abundance of water (the sulfates) are usually not hollow.

The crystalline aspects of the stalactites also differ. Usually stalactites are cryptocrystalline to finely crystalline. Occasionally they are coarsely crystalline as in marcasite (1/4 inch long crystals), spinel (3/4 inch octahedrons), and calcite (1/2 inch crystals). Often they are amorphous as in opal.

A fast-growing stalactite tends to be long and thin, while a slow-growing one becomes fat and stubby in the same length of time. This is due to seepage by capillarity of the solution through the walls of the stalactite and deposition on the outside (Allison, 1923).

Stalagmites are usually slower to form than stalactites. Often totally lacking due to running water on the floor of the cavern, they differ in shape considerably. A very slow-growing stalagmite is just a knobby mound, while, as the rate of growth increases, the top becomes cup-shaped and the sides smooth. Lava stalagmites resemble the drip-castles children build on the seashore.

Fig. 1. (Top) A group of lava stalactites from Kaumona Cave, Mauna Loa Volcano, Hilo, Territory of Hawaii. Longest is 5 inches. From geology collection of University of Southern California. (Lower left) Artificial spinel stalactite from Vitrifax Corporation, Los Angeles, California. (Lower right) Eccentric stalactites from Courniou Cave in France, (from Glory, 1935).

Mineralogy

The mineralogy and occurrence of stalactites and stalagmites is given in Table 1. Numbers in parentheses refer to the bibliography which is arranged in chronological order, so that the highest numbers indicate contemporary publications while the lowest ones indicate dates as far back as 1797. The absence of a reference number indicates that the source was a personal communication or experience of the author. If the number is preceded by a dash the place of the occurrence is not given in the publications which were reviewed.

Mixtures of two or more minerals are not uncommon. Limonite, marcasite, pyrite, sphalerite, and galena form stalactites together (Dana, 1926), and, sphalerite and galena stalactites are reported by Posepny (1873) from Central Europe. Limonite and mimetite, (Curtis, 1884), and, mimetite and pyromorphite (Kurr, 1859) are found in alternating layers. Milton (Milton and Johnston, 1938) reported pickeringite and epsomite stalactites; also Milton reported, in the same article, finding a small stalactite one to two centimeters long, and one-half to one centimeter in diameter, with a yellow center and brick-red outside, composed of very fine bands of alunogen, epsomite, gypsum, copiapite, and rhomboclase.

In British Columbia calamine was seen (Walker, 1917) to fill centers and to coat the outside of other stalactites; southeast of there in the Butte district of the United States, stalactites composed of almost any chemical combination or solid solution of water and, copper, zinc, or iron sulfate have grown in mines to lengths exceeding eight feet (Weed, 1912).

"A peculiar tubular galena ore (Rohrenerz) which formed around pre-existing stalactites of dolomite" (Posepny, 1873) is found in the central Europe lead-zinc deposits in "fossil" karst topography, being very similar to the lead-zinc deposits in the central United States.

Ice commonly forms icicles and stalagmitic growths in winter, but from a lava cave in Oregon a peculiar bamboo-like stalagmite (hollow with "septa") grows in the summer in a cave too warm at the ceiling to permit icicles to form (Dake, 1936).

It is not uncommon to find stalactites in such an environment that the major factors affecting their direction of growth are other than gravity. The resulting stalactite grows in a manner apparently independent of gravity forming corkscrews, knots, and many other fantastic shapes. Marcasite and calcite (Kemp, 1921) grow this way and the Abbé Glory (1936) devoted an article to "eccentric" calcite stalactites found in France (see Figs. 1 and 4).

Methods of Formation

LIQUID

Solidifying.—Several liquids make stalactites and stalagmites by direct freezing of the liquid. Icicles are the commonest of this type, yet despite their common occurrence, little has been done to establish their crystalline structure or to learn the factors that affect their growth. Spinel and moissanite (carborundum) form from their vapor collecting on the furnace roof in which they are melted, the vapor collecting, condensing, and dripping, forming a coarsely crystalline stalactite. These differ from magnesium stalactites in that the spinel and moissanite have a tip rounded as though from a solidified drop, while the magnesium is sharply crystalline, as though partially precipitated from the vapor directly.

Lava forms both stalactites and stalagmites from the hot liquid (see Figs. 1 and 3), although some of the stalactites previously thought to be lava have been found to be black siliceous sinter (Brigham, 1909); the latter type were found forming in a hot, but not flowing, lava tube in Hawaii in the flow of 1881.

LIQUIDS AND SOLIDS

Unstable Gaseous Member in Solution.—Due to the instability of carbonic acid, H_2CO_3 [1], especially as the solution temperature rises, and also as the concentration of other members of the solution change, the carbonates are especially susceptible to this type of deposition. In general, the mineral carbonates have solubilities of the same degree of magnitude, varying from cerussite (0.0001 g/100 ml.) to magnesite (0.007 g/100

[1] Solubility of H_2CO_3- 0.355 grams per 100 ml. at 0° Centigrade; 0.097 g/100ml. at 40° C.; 0.058 g/100 ml. at 60° C.; all figures here and following are from the Handbook of Physics and Chemistry, 1947

[2] Calcite solubilities—0.0014 g/100 ml. at 25° C.; 0.0018 g/100 ml. at 75° C.; but, 0.13 g/100 ml. at 9° C.; and. 0.077 g/100 ml. at 35° C. in H_2O saturated with CO_2.

Fig. 2. Halite stalactites from Bristol Dry Lake, San Bernardino County, California. Longest stalactite is nine inches long.

Table 1

STALACTITIC AND STALAGMITIC MINERALS

Mineral	*Formula*	*Occurrence*
NATIVE ELEMENTS		
Sulfur	S	saltdomes, Louisiana and Texas (43); Lake Co., Calif. (57).
Arsenic	As	—(53); probably Santa Cruz Co., Ariz.; —(31).
Magnesium	Mg	artificial, from B. M. I., Las Vegas, Nev.
Moissanite	CSi	artificial, from Vitrifax Corp., Los Angeles, Calif.
SULPHIDES		
Galena	PbS	Galena, Ill. (31); Carinthia, Austria (8); Upper Silurian dolomite of Mississippi Valley (10).
Sphalerite	ZnS	Galena, Ill. (31); Oswego Mine, Joplin, Mo. (12); Carinthia, Austria (8);—(27).
Wurtzite	ZnS	—(53).
Pyrite	FeS_2	—(32); Missouri (31).
Marcasite	FeS_2	Galena and Trenton limestone of Upper Valley (30); Galena, Ill. (31); Mo. (12).
Melnikovite	FeS_2	—(32).
HALIDES		
Halite	NaCl	Salt Mines, Merkers, near Stassfurt, Germany (58); Bristol Dry Lake, San Bernardino Co., Calif. (59); Orensberg (?), southeastern European Russia (50).
Embolite	Ag (Cl,Br)	Broken Hill District, New South Wales, Australia (16).
OXIDES		
Opal	$SiO_2 \cdot nH_2O$	Pottsville and Waynesburg ss., Morgantown, W. Virginia (44); northern California (34).
Arsenolite	As_2O_3	—(53).
Ice	H_2O	stalagmites, Malheur Cave, Burns, Oregon (46); icicles, worldwide.
Corundum	Al_2O_3	"stalagmites"—artificial jewel manufacturing.
Hematite	Fe_2O_3	Hartville Iron Ore Range, Wyo. (20).
Spinel	$MgAl_2O_4$	artificial, Vitrifax Corp., Los Angeles, Calif.
Diaspore	AlO (OH)	artificial, and—(53, 31).
Goethite	FeO (OH)	Brazil (25).
Limonite	$Fe_2O_3 \cdot nH_2O$	Holbrook Mine, Bisbee, Ariz. (25); Oriskany Mines, Botetourt Co., Va. (26); Sicily (6); Butte district, Mont. (23); Shasta Co., Calif. (57).
Gibbsite	$Al(OH)_3$	Richmond, Mass. (5, 53).
Psilomelane	$MnO_2 \cdot nRO \cdot nH_2O$	New South Wales, Australia (16).
Calvonigrite	Fe, Cu psilomelane	—(53).
Wad	———	Nizhne Tagilsk, Ural Mts., U.S.S.R. (53).
Chalcophanite	$(Mn,Zn)O \cdot 2MnO_2 \cdot 2H_2O$	Passaic Mine, Ogdensburg, Sussex Co., New Jersey (53).
Sassolite	$B(OH)_3$	—(53).
CARBONATES		
Calcite	$CaCO_3$	Innumerable limestone and dolomite regions. A few famous caverns in the United States are Carlsbad Caverns, N. Mex.; Mammoth Cave, Ky.; Caverns of Luray, Va.; Black Hills, S. Dak.; elsewhere in the world, Jenolan, New South Wales, Australia; Gailenreuth Cave, Franconia, Germany; Kirkdale, Yorkshire, England; Causses district, France; Adelsberg, Carniola, Austria; Caldy Island, England; Aggtelek Cave, Hungary; Postumia, Italy; Grottoes of Belgium.
Dolomite	$MgCO_3 \cdot CaCO_3$	Carinthia.
Magnesite	$MgCO_3$	Sicily (6).
Aragonite	$CaCO_3$	England (52).
Smithsonite	$ZnCO_3$	Missouri (12); — (31).
Cerussite	$PbCO_3$	Missouri (12).
Malachite	$CuCO_3 \cdot Cu(OH)_2$	Morenci, Greenlee Co., Ariz., (azurite layers).
Azurite	$2CuCO_3 \cdot Cu(OH)_2$	Morenci, Greenlee Co., Ariz. (malachite layers).
Hydrozindite	$2ZnCO_3 \cdot 3Zn(OH)_2$	Missouri (12).
Lansfordite	$MgCO_3 \cdot 5H_2O$	Nesquehoning Mine, near Lansford, Carbon Co., Penna.; changes on exposure to Nesquehonite (31).

STALACTITIC AND STALAGMITIC MINERALS

(Continued)

Mineral	*Formula*	*Occurrence*
SILICATES		
Calamine	$H_2Zn_2SiO_5$	Salmo, B. C., Canada (24); Granby, Mo. (12).
Prehnite	$H_2Ca_2Al_2(SiO_4)_3$	Paterson, New Jersey.
Allophane	$Al_2SiO_5{:}nH_2O$	— (31).
Melite	$Al_2Fe_2SiO_5 \cdot 1H_2O$	Saalfield, Thuringia, Germany (53).
PHOSPHATES, etc.		
Pyromorphite	$(PbCl)Pb_4(PO_4)_3$	— (7).
Mimetite	$(PbCl)Pb_4(AsO_4)_3$	Badenweiler, Germany (7); Nussiere, Dept. of Rhone, France (7).
Vanadinite	$(PbCl)Pb_4(VO_4)_3$	Ahumada and Las Lamentos, Chihuahua, Mexico.
Turanite	$Cu_5V_2O_{10} \cdot 3H_2O$	Ferghana district, Turkestan, USSR (54).
Volborthite	Hydrous Cu, Ba, Ca vanadate	Ferghana district, Turkestan, USSR (54).
Tyuyamunite (Tayamunite)	$CaO \cdot UO_3 \cdot V_2O_5 \cdot nH_2O$	Ferghana district, Turkestan, USSR (54).
Hopeite	$Zn_3(P_2O_8) \cdot 4H_2O$	Salmo, B. C., Canada (24).
Pharmacolite	$HCaAsO_4.2H_2O$	Schwarzwald, Andreasberg, Harz Mts., and Erzegebirge, Germany (7).
Roesslarite	$HMgAsO_4.2H_2O$	Reichersdorf, Hessen-Nassau, Germany (7).
Spencerite	$Zn_3(PO_4)_2 \cdot Zn(OH)_2 \cdot 3H_2O$	Salmo, B. C., Canada (24).
Turquois	$H_5(CuOH)[Al(OH)_2]_6(PO_4)_4$	— (31).
SULFATES, etc.		
Mascagnite	$(NH_4)_2SO_4$	Mt. Etna, Vesuvius, Italy (31).
Barite	$BaSO_4$	Raddusa, Sicily (6); Matlock and Youlgreave, Newhaven, England (31).
Anglesite	$PbSO_4$	— (31); Missouri (12).
Gypsum	$CaSO_4 \cdot 2H_2O$	Cave of the Swords, Naica, Mexico; Las Vegas, Nevada; — (4); lava tubes, Hawaii (21); Comstock Lode, Nevada (47).
Epsomite	$MgSO_4 \cdot 7H_2O$	Comstock Lode, Nev. (47); The Geysers, Sonoma Co., Calif. (57).
Goslarite	$ZnSO_4 \cdot 7H_2O$	Rammelsberg Mine, Goslar, Germany (7); Cornwall (7); Butte, Mont. (23); Lyon, Dept. of Rhone, France (31).
Melanterite	$FeSO_4.7H_2O$	Butte, Mont. (23); Harz Mts., Saxony, Saxony, and Schwarzenberg, Germany (7); numerous localities, California copper mines.
Pisanite	$(Fe,Cu)SO_4 \cdot 7H_2O$	Butte, Mont. (23).
———	$(Zn,Cu,Fe)SO_4 \cdot 7H_2O$	Butte, Mont. (23).
———	$(Zn,Cu)SO_4 \cdot 7H_2O$	Butte, Mont. (23).
Beiberite	$CoSO_4 \cdot 7H_2O$	Beiber, Hessen-Nassau, Germany (31); Landon, Calif. (57).
Chalcanthite	$CuSO_4 \cdot 5H_2O$	Mt. View Mine, Butte, Mont. (23); Bisbee, Ariz.; Markleeville, Calif.; — (26); numerous other copper mining districts.
Boussingaultite	$(NH_4)_2SO_4 \cdot MgSO_4 \cdot 6H_2O$	The Geysers, Sonoma Co., Calif. (57).
Pickeringite	$MgSO_4 \cdot Al_2(SO_4)_3 \cdot 22H_2O$	Comstock Lode, Nev. (47).
Cupro-Alum	$CuSO_4 \cdot Al_2(SO_4)_3 \cdot 22H_2O$	Anaconda Mine, Butte, Mont. (23).
Alunogen	$Al_2(SO_4)_3 \cdot 16H_2O$	Comstock Lode, Nev. (47).
Alums	— (28).	— (28).
Copiapite	$Fe_4(OH)_2(SO_4)_5 \cdot H_2O$	Comstock Lode, Nev. (47).
Rhomboclase	$Fe_2O_3 \cdot 4SO_3 \cdot 9H_2O$	Comstock Lode, Nev. (47).
Glockerite	$2Fe_2O_3 \cdot SO_3 \cdot 6H_2O$	Goslar, Harz Mts., Germany (31).

NONMINERAL STALACTITES AND STALAGMITES

Substance	*Occurrence*
Lava	N. Calif. (34); Kaumaona Cave, Mauna Loa, Hilo, Hawaii; Hawaii (11); Samoa, Italy (55); Flagstaff, Ariz. (33).
Mud	Elrod Cavern, Orleans, Indiana (40), stalagmites only.
Siliceous Sinter	Mass. (5); Lava tubes, Hawaii (19).
Sand	Coos Bay, Oregon (13), stalactites only.

Fig. 3. A peculiar pair of lava stalagmites joined at the top to form one. From Kaumona Cave, Mauna Loa Volcano, Hilo, Territory of Hawaii. Collected by Gordon MacDonald and now in the geology collection at the University of Southern California.

ml.). Also they all seem to show the result as typified by calcite[2], a very radical increase in solubility with the addition of carbon dioxide to the water. This means that the formula for the deposition of limestone by the bicarbonate method is adequate to account for the deposition of the rest of the carbonates:

$R(HCO_3)_2$ outside heat RCO_3 CO_2 H_2O
R= many common ore metals including zinc, lead, copper, iron and magnesium.

Unstable Solids in Solution.—As the solutions in caves and mines are generally complex, it is obvious that one of the members of the solution will be less soluble than the others under a given set of conditions. Thus, many of the sulfides[3] present in the complex solutions of the lead-zinc mining districts of the world are commonly deposited as stalactites.

The marcasite-pyrite-melnikovite group is of especial interest as it is not unusual to find these three crystal variations of FeS_2 in a single stalactite, reflecting the changing temperature and acidity. Similarly the sphalerite wurtzite group is found, including an amorphous variety analogous to melnikovite (Allen et al., 1912; Palache et al., 1944).

Others of the insoluble group are the silver haloids[4] lead and barium sulfates, and, apparently, those oxides not deposited from colloidal suspension. Gibbsite ($Al(OH)_3$) is deposited from alkaline solutions derived from aluminous rocks. Some silica and iron oxides are deposited from solution in the presence or absence of certain organic acids (Bayles, 1935).

Unstable Solvent.—Water, evaporating, and thus concentrating the solution, is the only solvent unstable enough to evaporate under most prevailing conditions and also available in nature. The extremely high solubilities[5] of the sulfates, boron hydroxide, arsenic trioxide, and sodium chloride seem to indicate that this is the only way in which they could be precipitated. The concentration on the surface of a drop increases very rapidly from evaporation, so even a solution well below the saturation point could have precipitation on the drop surface.

Colloidal Suspension.—Many oxides of silicon, iron, manganese, aluminum, and several other elements are so slightly soluble as to be stated often as insoluble; their deposition as stalactites is difficult to imagine except as a release from colloidal suspension. The solution and deposition of silica does take place, but the deposition of opal, itself a gel, seems to indicate that at least here a colloid was formed (Bayles, 1935).

Particles in Suspension.—A peculiar stalagmite has developed from drops of water splashing in mud, forming small craters which grow as dripping continues. The stalagmite obtains material for growth from the center of itself, the falling drop splashing mud upon the sides, thus depositing the mud on the sides and top of the stalagmite (Malott, 1933).

[3] Solubilities—ZnS, 0.000065 g/100 ml. at 18° C.; PbS, 0.000086 g/100 ml. at 0° C.; FeS_2, 0.00049 g/100 ml. at 0° C.

[4] silver haloids—about 0.0005 g/100 ml. at 0° C.

[5] Solubilities—$ZnSO_4$, 663 g/100 ml. at 100° C.; boracic acid, $B(OH)_3$ or H_3BO_3, 39.1 g/100 ml. at 100° C.; arsenolite, As_2O_3, 11.5 g/100 ml. at 100° C.; NaCl, 39 g/100 ml. at 100° C.

REPLACEMENT

Curtis (1884) and Posepny (1873) believe that galena can replace calcite and dolomite stalactites, both geologists having worked extensively in the lead-zinc districts of the United States and Europe. The iron minerals commonly form stalactites and also form pseudomorphs, and, in the Tri-State district of the United States, limonite, marcasite, and pyrite stalactites are found in the same vugs, so it is not surprising that Curtis (1884) found examples of limonite replacement after iron sulfide stalactites.

Stalagmite and Stalactite Growth

The factors affecting the growth of stalagmites are much simpler than those affecting stalactites. A simple outline will be used to describe their growth.

FACTORS AFFECTING STALAGMITE GROWTH

1. *Incoming solution*
   a. rate of drip [6]
2. *Formation of a precipitate*
   a. air circulation [6]
   b. relative humidity [6]
   c. temperature [6]
   d. chemistry of the solution
   e. concentration of the solution
3. *Orientation of the growth*
   a. position or change of position of source
   b. direction of air circulation
4. *Size*

There is little need for explanation of the above outline since the discussion on stalactites in the following section covers the individual items thoroughly. Allison (1923) has worked out formulae to determine the age of any stalagmite from the items footnoted in the above table. Also in Allison's article are excellent sketches and discussions on the growth of calcite stalagmites and stalactites.

[6] These were used in Allison's growth formula. (Allison, 1923)

FACTORS AFFECTING STALACTITE GROWTH

Incoming Solution.—The size of the original feeders, and the rate of flow through these feeders, a combined effect of ground water saturation, permeability, and porosity are the major factors affecting the incoming solution. Seasonal and longer period variation in rainfall may change the flow, as also may local physiographic changes affecting the water table. Also the diversion of flow commonly takes place due to cracks found in the sides of the stalactite, by breaking or falling of the roof of the cave, or by other means affecting inflow of the liquid.

Formation of a Precipitate.—This group may be further subdivided into four groups, 1) rate of evaporation, 2) formation of the drop, 3) chemistry of the solution, and 4) adherence of the precipitate to the stalactite.

The rate of evaporation of the solvent, water, is directly affected by the air circulation, temperature, humidity, and osmotic pressure. The air circulation is merely the amount of air moved past the stalactite rather than the direction of air movement spoken of later. The osmotic pressure is between the drop of liquid and the air through the membrane formed by the precipitate on the surface of the drop. The extent that this restricts active evaporation depends upon the chemistry of both the solution and the precipitate.

The rate of formation of the drop may also restrict the formation of a precipitate. A slow rate of dripping will have a better chance to deposit a precipitate than a faster rate. The major factor controlling the rate of dripping is, of course, the rate of flow, but with a given rate of flow the drop rate may still vary. The forces of capillarity tending to hold the drop on the stalactite, the surface tension controlling the size of the drop, closely-constant gravity pulling the drop down, and viscosity affecting all and varying with the complexities of the solution; all of these will cause the drip rate to change.

The chemistry of the solution affects the precipitate and with the changing conditions of acidity, temperature, and solution source, the end precipitate changes markedly. The solubility or suspensibility of the various substances, ionic, colloidal, or otherwise, will affect the final pre-

Table 2

RATES OF GROWTH OF STALACTITES

Calcite Stalactites

Location	*Time measured*	*Longest measured*		*Rate*[1]	*Source*[2]
Adelsberg Cave	30 yrs.	0.06"	(growth)	0.0002"/yr.	(9)
Moravia	11 yrs.	3-4 cm.		0.125" /yr.	(9)
Ingleborough Cave, Devonshire, England	———	——		0.295" /yr.	(17)
Wilson Dam, Muscles Shoals, Florence, Ala.	———	15.2"		3.04" /yr.	(35)
Concrete Culvert	2 yrs.	3.5"		1.75" /yr.	(35)
Coal mine (nearby?)	———	——	minimum	0.47" /yr.	
Lead mine tunnels	———		maximum	6.8" /yr.	(35)
Brick Arches, Ft. Delaware, Del.	40 yrs.	24.0"		0.8" /yr.	(37)
Brick Arches, Ft. Pickins, Fla.	40 yrs.	5.0"		0.17" /yr.	(36)
Roofs, Ft. Morgan, Ala.	———	10.0"		0.25" /yr.	(36)
Below limestone balast on bridge	———	8.0"		0.14" /yr.	(38)
Gulf Island Dam		12.5"		1.04" /yr.	(39)
On pipe	———	5.1"		0.28" /yr.	(42)
28 stalactites on arches	7 yrs.	8.63"		0.54" /yr.	(42)
11 of above still growing	1 yr.	——		0.53" /yr.	(42)
4 longest	8 yrs.		maximum	2.68" /yr.	(42)
One stalactite	8 yrs.	——		0.95" /yr.	(42)
North Bridge, Edinburgh, Scotland	102 yrs.	11.50"		2.30" /yr.	(42)
Ft. Delaware, Del.	30 yrs.	1.5"	diameter	0.015" /yr. in diameter	(17)

Other Minerals

Location						
Chalcanthite	———	———	0.5"	diameter	0.016" /yr. in diameter	(37)
Other sulfates, Comstock Lode, Nevada		———	several feet		1.5"/month	(26)
Halite, Bristol Dry Lake, Calif.			over eight feet, several feet/yr.			(10)
Halite, laboratory, Univ. So. Cal., Los Angeles		1 day	10"		——	(59)
Lava, Kileaua and Mauna Loa, Hawaii		several days	2"		2"/day over 1"/week	(author) (21)

[1]Growth in length unless specified
[2]Numbers refer to bibliography

cipitate. Another factor, crystal seeding, tends to inhibit the change in precipitation caused by a change in pH or temperature. This last factor may cause a precipitate to continue to settle from solution: for instance, in a solution of copper, iron, and sulfate ions, iron sulfate, when the temperature, pressure, and pH indicate copper sulfate should fall from solution, will continue to precipitate because the iron sulfate crystals are present to grow on and there is no copper sulfate to seed the solution.

The adherence or coherence of the precipitated material to the tip is affected by forces on an atomic or molecular level, including the forces of cohesion and adhesion between the solids and liquids present at the tip of the stalactite. The surface tension of the drop will also change the system of these forces. The adhesion of the solid to liquid will carry the precipitate down with the drop; adhesion of solid to solid will determine whether the precipitate sticks to the stalactite tip.

Orientation of Growth.—The orientation of growth is somewhat a development of the crystalline structure of the dripstone and the average wind direction in the cave. In some cases these have assumed a greater role than gravity, another and the usual major factor, and the result is to get a stalactite growing in weird fashion, counter to gravity. The direction from which the air generally blows causes evaporation to take place predominantly on that side of the drop. If the wind is strong enough to blow the precipitate to the leeward side, the stalactite grows away from the wind; otherwise the stalactite grows into the wind.

Size of Stalactite.—Size may not seem important, but if the liquid flow is kept at a constant rate at the head of the stalactite as it grows, the flow at the tip will diminish. This is due to friction in passage and to the absorption of the liquid through the walls and subsequent deposition on the outside. In experiments conducted in the fall of 1948, it was seen in halite stalactites that the outside diameter at the top of the stalactite increased, despite the total absence of any solution passing down the outside, and, that, with the addition of sodium dichromate to the solution, needles of dichromate began to form along the entire outside. Thus the amount of liquid available at the tip decreases, so there would be a maximum size for any stalactite, a size which it seems is seldom reached.

The above groups of factors affect stalactites deposited from solution. These factors have been discussed without extensive regard to their relative importance as it is somewhat apparent that some factors have but a negligible effect upon the end result. Some of the factors will cause misshapen stalactites but would not change the speed of growth of the stalactite. Upon the correlation mathematically of these factors into a

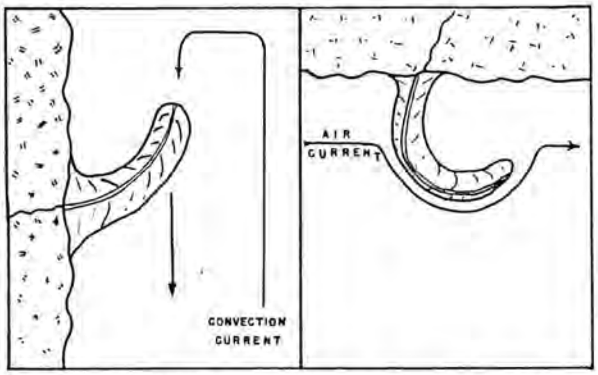

Fig. 4. Stalactites curved in growth due to wind prevailing in direction shown, (after Glory, 1936).

formula which checks with the data gathered, the absolute importance of each factor may be determined.

Other stalactites than those formed by solution may fit into the classification by elimination or addition of a few items. The major point in those of solely liquid deposition is the freezing point in relation to the temperature of the surroundings.

Conclusion

Any mineral which is soluble, which may be carried as a colloid, or which may melt under the given conditions can form stalactites and stalagmites. Seventy-one substances, including sixty-seven minerals, are known to occur as such. Most of them are infrequent, but some are common. The commonest are, of course, ice and calcite. The sulfates and sulfides of iron, zinc, copper, and lead are common, and the oxides of iron, silicon, and manganese are much less so. The rest are probably rare.

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CLYDE A. MALOTT, 1887-1950

Dr. Clyde A. Malott, authority on caverns, subterranean drainage and other karst features, passed away August 26, 1950. Dr. Malott received his academic training at Indiana University and was appointed to the faculty of the Indiana University Department of Geology and Geography, where he served with distinction for thirty-one years. He was acting chairman of that department from 1941 to 1945. He was an inspiring teacher and was extremely popular with his students. Dr. Malott also served on the Indiana, Ilinois and Oklahoma geological surveys at various times.

Dr. Malott's major interests were in the fields of physiography, stratigraphy and petroleum geology. He was author of some forty technical papers, many of which dealt with caverns and underground drainage systems. The pit-marked land of southern Indiana, where placid streams disappear and riotous storm waters are swallowed up and disgorged from mysterious subterranean routes, was the area of his most interesting researches. His invasion theory of cavern development won him national recognition. Dr. Malott knew Indiana well and had many records of his observations. He was consulted freely by geologists, students and laymen alike on a great many different aspects of Indiana geology. His own research undoubtedly suffered greatly because he unselfishly took time and effort to share his wealth of knowledge with others.

Dr. Malott was a member of the National Speleological Society and Sigma Xi and Fellow in the American Association for the Advancement of Science, Geological Society of America and Indiana Academy of Science.

EXPLORATIONS IN BALL'S CAVERN

Schoharie County, N. Y., 1831-1949

By CHARLES J. HANOR AND OTHERS

All photos by Tri-County Grotto

First Account of Ball's Cavern[1]

The first intimation of the existence of the cave is derived from Mr. Ball upon whose land it occurs. He had observed a conical depression in the soil to the depth of 12 feet, which terminated in an irregular perpendicular fissure in the lime rock 10 feet in length and 6 feet in breadth. In September 1831 Mr. John Gebhard, a gentleman to whom the taste for mineralogy and geology in his neighborhood appears to be principally due, in company with Mr. Hubbard and Mr. Branch made arrangements for ascertaining the extent of the cavern. The two latter gentlemen were lowered by ropes down a perpendicular descent, to the distance of 75 feet; when the opening assumed an oblique direction to the south, although it still continued somewhat precipitous. Having disengaged themselves from the ropes, and prepared the necessary lights, they descended about 55 feet through a passage varying in width from four to ten feet. Here the descent became perpendicular for 15 feet, after which they proceeded as before about 30 feet, when they reached the bottom. The cavern here is only about ten feet in width, but of great height, on one side of which is a small stream of pure limpid water, running in a southerly direction. Passing under an arch so low as scarcely to enable them to stand upright, they followed the stream about 20 feet, when they penetrated by an opening just large enough to admit a man of ordinary size, into an apartment 20 feet in diameter, and above 100 feet in height. Its sides were covered with crystalline masses of calcareous spar and the roof by stalactites dripping with water. The effect of the torches upon this apartment is described as being very brilliant. The skeleton of a fox (as it is supposed) was subsequently found in this place; it must have fallen through an opening above and found its way here, where it probably perished from hunger. Leaving this apartment, they pursued the course of the stream for about 20 feet, through an opening from eight to ten feet in width, when their progress was checked by a considerable body of water, into which the brook emptied. These adventurers were now compelled to return to the surface.

In October, the investigation was renewed by Mr. Gebhard, Dr. Foster, and Mr. Bonny, who had prepared a boat to navigate the water which had checked the progress of the first expedition. Fixing a light upon the prow, they commenced their voyage by passing through an arched passage in the rock so low as not to admit their standing erect in the boat. Having proceeded about 50 feet in a southerly direction, they altered their course to the left around an angle in the rocky passage, and found themselves in water about 30 feet in depth, and so limpid that the smallest object might be seen at the bottom. The course of the water was varied by the projections of the passage, which gradually, expanded to 20 feet in width, being of a height sometimes not discoverable, and at others only sufficient to enable them to pursue their way. Thus they proceeded about 300 feet, when they arrived at a rugged shelving ascent, on the right shore of the lake, and beneath which its waters disappeared. Leaving the boat, they landed upon this sloping ascent, and advancing 20 feet they entered an aperture in the rock resembling a door when they found themselves within an amphitheater, perfectly regular and circular in form. Its diameter is 100 feet, and its height is supposed to be still greater. The floor descends on all sides gradually to its center, while the roof is apparently horizontal. Its walls are described as rich in stalactic decorations. Great numbers of bats, disturbed by the intrusion of the adventurers, were seen flying about the cavern.

Subsequent visits led to the discovery of five additional apartments, communicating with the amphitheater, all of which however are small and none remarkable, excepting one in which the circulations of currents of air or of water, or probably of both, produces sounds like the Aeolian Harp.

Safety first!—Speleologist, distrustful of ancient wooden ladder, uses new rope ladder for descent into Ball's Cavern, Schoharie County, New York.

Returning to the lake, where the adventurers landed, it was noticed that upon the north side of the perpendicular entrance to the amphitheater there existed a low narrow aperture, through which a stream issued. The opening above water was only 14 inches high, but its dimensions were seen to be greater within. A boat was constructed to suit this opening, through which it was pushed containing a single person in a recumbent posture. After a few feet the passage enlarged enough to allow the navigator to assume an upright position; and he proceeded to the distance of a quarter of a mile, the width of the passage varying from 5 to 20 feet. Here the water was 30 feet in depth, and losing sight of the light he had left at the commencement of his voyage, in consequence of a turn in the passage, he advanced in a new direction for about 60 feet, when he encountered a semicircular dam of calcareous tufa, over which the water broke with a slight ripple. Drawing his boat over the obstruction he proceeded as before, when he met a similar barrier. In this manner he passed 14 of these dams, which varied in height from 2 to 12 inches above the surface of the water. The obstructions being passed, he soon reached the extremity of the water, where quitting the boat, he entered a low narrow passage, which soon became connected with a spacious room, at least 50 feet square. The rock is represented as here passing into a kind of greywacke, in consequence of which few incrustations were visible in this apartment. The floor was covered by large blocks of rocks, which had been apparently precipitated from the roof, and the sound of a distant waterfall was heard from this place.

Mineralogical Report of Ball's Cavern[2]

The most extensive deposits of calcareous spar are at Ball's Cave, situated about four and a half miles northwest of Schoharie Courthouse. This was first explored in September, 1831, by John Gebhard, Esq. and other gentlemen. This cavern abounds in stalactites and stalagmites of great size and beauty, with occasional crystals of the calcareous spar. The specimens are sometimes of snowy whiteness, and often of a highly crystalline texture, although regular forms cannot be observed.

The greatest length of the cavern, as far as it has been explored, is about two-thirds of a mile. It contains fourteen rooms, ten of which branch off laterally from the main passage of the cavern; and two lakes or pools, the surface of the one in the northern passage being ten feet above the level of the other, and both containing water varying in depth from two to thirty feet. Stalactites and stalagmites have been found in it, which are of the purest white, usually varying from three to eighteen inches in length, and from one to seven inches in diameter. One of a much larger size was removed entire, and is now in the possession of John Gebhard, Esq. Its base, which is of an elliptical form, is three feet six inches at the largest diameter, with a plane surface underneath; but its upper surfaces rise regularly on all sides to the center, from which there is a column of fifteen by ten inches in diameter and seventeen inches in height. At the upper part there is a horizontal projection, from which are suspended forty-one stalactites from one to five inches in length. The weight of the entire mass is about four hundred pounds.

Reference to Ball's Cavern[3]

Ball's Cave, in Schoharie, about two miles northeast from the courthouse, is one of the most interesting that has been found in New York.

It was discovered and explored ten or twelve years ago, by Messrs. Gebhards and Bonny of Schoharie. The spaces are in some parts very large, in others very small, as in most all caves. A stream of water flows through the cave, and there are several small cascades. A boat is kept for the purpose of exploration. The gentlemen who have explored the cave, have given a description of it which was published in the papers of the day. The cave is chiefly remarkable for its extent and beautiful stalactites and stalagmites.

The stalagmites of Ball's Cave, in Schoharie, are among the most beautiful I have ever seen; resembling in translucency, color and delicacy, the finest bleached wax or spermaceti. Mr. J. Bonny, and the Messrs. Gebhards, of Schoharie, have many fine specimens; and in the collection of John Gebhard, Esq. may be seen a stalagmite from that cave, of the weight of two hundred pounds or more, which excels any thing of the kind for its beauty that I have ever seen. Stalagmites are sometimes used for ornamental marbles; and those of Ball's Cave, could they be produced of sufficient size, would be highly prized for this purpose.

Additional Reference to Ball's Cavern[4]

Ball's Cave was first explored in 1831 and was at that time one of the few caverns known in this country. Originally discovered by Mr. Ball, the proprietor of the land, it subsequently passed into the hands of W. H. Knoepfel, who announced his intentions of opening the cavern to the public in 1854. The project however was abandoned and the condition of the cavern is today what it was 75 years ago. It is most readily approached from the road which ascends Barton hill north of the limestone out-crops. Just after crossing the Schoharie-Schenectady boundary line a private road leads southward to the house of Charles H. Van Pelt. From here a wood path of about half a mile in length brings one to the cave entrance. This is merely a wide fissure in the Coeymans beds which everywhere in this region are strongly fissured. The main cavern is dissolved out of the Manlius strata, and its greatest depth being about 60 feet. Sink holes are numerous in the region about the cave.

Cook Report of 1906[5]

Ball's Cave is the only one of the group which is accessible. The entrance is a vertical shaft in the Coeyman's limestone located on the north side of Barton Hill, 3/5 mile southeast of the point where the road to Quaker Street crosses the county line. It is reached by a wood road from the house of Edwin Dietz and admits one to a cavern which, as far as can be seen, has dissolved out of the basal Manlius beds.

A steep descent from the bottom of the shaft leads to a point in the cave about midway between the limits of exploration in either direction. At some seasons the whole cavern is full of water but usually the down stream (southwestern) half can be traversed without a boat. This part extends for 200 feet to a mass of fallen fragments which must be climbed in order to reach what has been spoken of in the meager literature of the cave, as it's chief attraction, a large room named the "Rotunda" or "Amphitheater". Nothing remarkable was found in the chamber and published descriptions which have pictured it as "rich in stalactic decorations" have

UPPER: Bats in Amphitheater.
MIDDLE: Large calcite block in Spring Room.
LOWER: S. Keenan, C. Hamlin and C. Gifford in Broken Room.

been drawn from perfervid imaginings rather than from facts.

This room and the passages beyond it lie at a level higher than that of the principal channel which is buried by clay and fragments. The cave stream appears as a spring in the last chamber reached and disappears again almost immediately beneath a mass of limestone precipitated from the roof.

The upstream (northeastern) end of the cavern contains water which in places is as much as 7 feet deep. The stream is retained as a series of pools behind natural dams of tufa formed apparently as deposits from flowing water. Three hundred and thirty feet from the beginning of the water this end of the cave expands into a chamber at a higher level beyond which the passage is small and so filled with water and soft clayey mud that it is practically impassable.

Explorations in 1929[6]

Now let us transfer our explorations to another cavern, Ball's Cave as it is known locally. This, likewise, has a perpendicular entrance in which the light of day is soon left behind as the visitor climbs down and down, sending the rays of his searchlight ahead into the darkness to point out perils of any missteps from rocky ledges that form the downward path of progress. After reaching the bottom one follows for a long distance a winding passage cut from solid rock,—now walking erect,—now bending and occasionally crawling on hands and knees,—the Bright Stars, finally disclose an upward ascent which leads into a huge amphitheatre.

Here we spent considerable time investigating its many wondrous features, a large marble white stalagmite over against one wall; myriads of tiny stalactites slowly forming from drip-water on the ceiling; crystal pools with tiny white formation stones in the cavern floor; a mineral spring on one side that discolored its rocky bowl with a reddish-brown pigment; a shiny subterranean vine-plant that sent its tendrils crawling hither and yon; our Bright Star always disclosing some new and entrancing detail at each turn of the light.

At one end of this amphitheatre was a tremendous mound of dry earth and clay. Upon climbing to its summit, we observed another passage branching off, close under the roof, some thirty feet higher than the passage we had followed into the amphitheatre. This new top passage was low and we crawled along it for many yards, Bright Stars illuminating the path ahead of us. Suddenly the path seemed to come to an abrupt end, with a sheer rock wall blocking it off. When we came close to this wall, however, we discovered at the bottom a small hole, just large enough to wiggle through. After a bit of debating and peering ahead with our Bright Stars, the passage seemed quite intriguing, so we lay flat upon the rock floor and, by means of toes and elbows, we wriggled along.

Even now, I hesitate to think what might have happened if our searchlights had not been of the safe and dependable Bright Star make for, after struggling forward some twenty feet, the floor ahead of us seemed to blot out into inky blackness,—there was no floor! We found ourselves looking down from the top of a fifteen foot ledge where the path had suddenly stopped. With Bright Stars shifted over the edge of this ledge, footholds were disclosed and we climbed down into a large room on one side of which we heard plainly the sound of running water, directly over our heads.

Explorations by Tri-County Grotto in 1949[7]

This is the third in a series of articles appearing in the Schoharie County Journal and Cobleskill Times regarding exploring of caves in Schoharie County. They are written by members of the National Speleological Society who are making an extensive exploration of the caves in this area.

Probably the earliest known cavern of Schoharie County was Ball's Cavern. The first exploration was made in September, 1831, by John Gebhard Esq., Dr. Joel Foster, and John S. Bonny.

This cavern, truly, must have been magnificent during the exploration period of the nineteenth century. Today the beauty of the cavern must be found in the far nooks and recesses where the formations have been out of reach of prying hands for the past hundred years.

The cavern is located on the Wilber Homestead at Barton Hill. The farm having been in the family since its first occupant, Gideon Wilber, Esq. As we were conducted through the fields, en route to the cavern; Steve Wilber, the present owner, pointed out to our party the location of the first house. It was of logs and stood about half way between the cavern and the present modern farm dwelling at the main highway.

We were told of the hundreds of people who have come from all sections of the United States and even Europe to visit this cavern during its existence. Steve Wilber and Charles Wilber, now elderly gentlemen, have spent a great amount of their time in the cavern. They probably have the most first hand knowledge of their cave than any of the articles that have been written. Charles Wilber, during his caving days, set off charges of black powder in attempts to open more of this Schoharie Cavern.

John Wilber, a cousin to Charles has furnished me with a great amount of information about the Wilber Homestead, and it was through him that my acquaintance with Steve was made. I shall always remember my acquaintance with the Wilber family as much of the historical information of the County has been compiled from their accounts.

My first visit to the cavern was during the summer of 1938. My two companions and I dragged a small kyack down the sink-hole entrance and floated it on the lake and pushed along to the "Rotunda".

During the summer of 1948 I led a Boy Scout Troop to the cavern. With a rubber raft we managed to cross the lake to the "Rotunda".

In September of 1948 I was on a National Speleological Society outing to the cavern and followed the south passage for about 500 feet until I was stopped by a small passage filled with fine sand. The total distance of the passage was dry at the time; quite a difference from my first and second trip when we were compelled to push ourselves along by our hands on the ceiling in a rubber raft. The water was probably five to six feet deep at the time.

The latest exploration of the cavern was on June 11, 1949 by Tri-County Grotto. Chester Lasell, Leslie Shaw, Stewart Keenan, Jr., and Burton Cole compiled the final data for a report to the Albany Museum.

Just inside the Wilber wood-lot is a 45 ft. sink-hole entrance. As one looks down the entrance, the familiar cool air hits your face. The remains of an old log ladder still protrudes from the hole. A convenient log has been placed across the rim of the "sink" and our rope ladder was attached. We tried to play the ladder down the shaft without its entanglement in the old ladder but found that it would be necessary for one of our party to free it foot by foot on the way down.

As I had been to the cavern three previous times it was my turn to act as safety and contact man outside. Stew Kennan was the first to make the descent and freed the ladder on the way. After about 15 minutes Chester Lasell and Leslie Shaw accompanied him and I lost contact, knowing that their journey into the depths had started.

At the foot of the shaft a steep dip slants downward for another 30 feet to the floor of the cavern. During the descent large rocks, loosened from the ceiling, must be scaled to reach the floor. We have found this condition in several caverns and believe that the earthquake in 1929 left its mark on these caverns. Standing in a dry creek-bed at the bottom of the shaft a shelf can be seen on either side from which the water comes and goes.

By lying flat and crawling under the left-hand shelf you find yourself in the Southwest Passage. This is a water worn passage approximately 10 feet in height that winds and twists for 110 feet until it enters a high room. By climbing up a steep rocky wall a huge room is entered. This is called the amphitheatre because of its vastness. The room is approximately a 50 foot oval with the ceiling about 30 feet in height at the apex.

There is a huge mud bank in the center of the room and if caution is not taken a fast slide in slippery mud will carry one smashing against the limestone walls. At the north end of this amphitheatre a passage leads into another room where a spring has formed on the floor. Here rests a large white flowstone block that bears the blows of many hammers. It must have been huge at the time of the first exploration. This same passage goes on for another fifty feet but becomes plugged with mud, clay and debris. Probably if enough time was spent in exploration a greater distance could be penetrated.

At the base of the mud bank is a small hole entering the floor and it is here that the stream flows during high-water. It would take a long time to clear the mud and clay from this room but I am of the opinion that if this project was started and completed an extensive cavern would be uncovered. From the amount of water disappearing in this room it would warrant more passage under the mud. Near the south wall of the amphitheatre a leafless, blood red plant was found growing out of the clay bank. The plant is about seven inches in length and has several small feelers from the main stem. In place of leaves are a system of small hairy feelers along the stem of this underground vine. It is sensitive to light and evidently grows entirely in the absence of light. In the south wall of this room is another passage 15 feet from the floor that turns and takes the explorer into the Broken Room. This was so named because of the condition of the walls. They are all cracked and laid every which way on top of each other.

The ceiling appears very loose and it is here that one gets a feeling of closeness. You dare not touch the walls or ceiling for fear that the whole passage might give way. You go through this passage and room without a sound and a complete breath is not taken until you have gotten clear on the return journey. After about another 150 feet the passage narrows down to a small circle just large enough for a small person to fit tightly.

As the floor of this passage is of fine sand and gravel, it is very hard to negotiate. The sand pushes up in a heap ahead of you and there is no way to push it behind. Thus the passage was left and is still marked unexplored. On the return journey to the shelf, a right hand passage just under the shelf, will lead one to the Fox Room. This is a high crevice-like passage, probably a chimney to the surface. It was so named because in 1831 Mr. Gebhard found the skeleton of a fox in this chamber.

Sometime later there was a cave-in just missing an exploring party. It has been in a semi-closed condition ever since. Members of our party got into this room and hid from the rest of the group and played a game of hide and seek. Voices could be heard and a beam of light could be seen on the other side of the shelf but it was quite a while before the secret was unlocked.

The best and most unusual part of Ball's Cavern is the Northeast Passage. It is in this passage that cave exploring becomes a game of nerves and very exciting. There are fourteen lakes in the Northeast Passage, 50 feet to 4 feet in length. Each lake is backed up by a natural dam of tufa. They are semi-circular in shape and as smooth as glass. It is as if a mason had taken a trowel and moulded them.

Our party crawled under the right hand shelf and found themselves in a passage entirely covered with water. They waded to the first dam and stood upon its base shining their lights ahead spotting the next dam in their beams. The water was crystal clear and very blue in color. It looked to be only two feet in depth but from previous experiences they knew it was about 10 feet deep. The temperature of the water was 45°F.

The only way to go was to swim. Let me remind the reader, that this was no easy matter. The individual had to swim with his clothes on his body. He had to swim with his boots or his shoes. The most important thing was that he had to swim with an open flame carbide light on his helmet. If this light should get the least bit of water on it the flame would be extinguished. To the members performing this feat I feel that they have had a once-in-a-lifetime experience. Their zest and zeal to gain information on the Northeast Passage will be long remembered in the caving annals of Tri-County Grotto. If their beams had been extinguished the last ray of light would have vanished in the darkened passage. I would not fancy swimming in the dark in a winding passage of sharp stone sides.

Through fourteen lakes and over 14 dams our explorers went until they reached the Square Room, at the end of the Northeast Passage. A distance of about 300 feet had been gained through ice cold water. Their hands and feet were numb but still they continued, exploring two more passages, until they were satisfied that the farthest limit had been reached. A few formations were seen in nooks and small passages.

Still cold, they had to return through the same passage and swim the lakes again. After about an hour and a half in water they emerged at the base of the rope ladder. Tying the safety line about their waist they climbed to the surface, a tired and wet group of "spelunkers". The sunshine soon got their blood back to normal and after walking around they found that they could still use their arms and legs.

Asking them if they enjoyed their swim, the reply was, "Sure, we would do it again, after a few weeks rest."

(continued on page eighty-four)

EXPLORING AN UNDERGROUND RIVER

By JOHN DYAS PARKER

Department of Mollusks, Academy of Natural Sciences of Philadelphia

It all started with a routine bat study trip to Aitkin Cave near Siglerville, Mifflin County, Pennsylvania. We set up our camp beside a delightful trout stream on the Aitkin farm just about in the dead center of Pennsylvania. Suddenly we stood as if rooted to the spot for we heard a loud squawk from a duck that had aimlessly drifted past on the stream as we donned our cave gear. I turned just in time to see the duck swirl about in a tight circle and then be bodily sucked under. We ran to the place where the fowl had disappeared and then noticed that the trout stream ended in a seemingly quiet pool against the side of a hill. The overhanging brush had screened this phenomenon from us.

Of course this siphon indicated "Cave" in large letters to the six spelunkers present. "Well what are we waiting for," yelped Charlie Crutchfield.

Ellen "Peachy" Pietsch flung a stick into the water and we all watched as it swung in an ever-tightening spiral, then finally disappeared from view.

"Wait a minute," reminisced Bill Hertl, "Didn't Jim Gossett and Jerry Bloch report a water-filled fissure hereabouts last week?"

I quickly unzipped the topographic case, spilled out sets of reports, and singled one out. In Gossett's familiar scrawl I read: "Entered a tight fissure at base of tree 740 feet from entrance of Aitkin cave at 351° magnetic. Long narrow fissure almost pinches out. Descended to keyhole where we heard running water."

By this time Ruth Boyer and Bill Murphy were hauling the cave gear out of the Chevrolet carryall. The rest of us loaded up with the gear as soon as I had determined the area of the entrance by triangulation. Bill Hertl was the one who spotted the hole. "Here it is," he cried, "but only a cockroach can get through it."

We six cockroaches gawked at a slit-like entrance, then piled our gear before the fissure. Blankets, first aid kit, heat pads, collapsible stretcher, extra carbide, nylon mountain-climbing lines, a ladder and a host of other things made a large pile on which we sat and picked a leader. For some reason I was chosen.

I looked over my crew and felt pretty good for I realized that behind me I had five of the best all round cavers in this area.

Ellen Pietsch, still in her twenties, has many caves to her credit. She is present head of the Pathfinder committee for Phillygrotto and is a mineralogist of more than usual ability.

Ruth Boyer, as strong as she is shapely, is an old hand at tough caves. A nurse and a rope specialist, she has long been a leader and rope teacher for Phillygrotto.

Charlie Crutchfield has several years of caving behind him. A chemist as well as an infantry officer, he made a welcome addition to the party.

Bill Hertl, although still in his teens, measures 6 feet 6 inches and is as strong as an ox. His caving log belies his age, however, and I knew he was an old hand at rigging and first-aid evacuation problems as well as photography.

Bill Murphy, in his thirties is well over a foot shorter than the younger Bill but has proven himself a valuable leader not only in the N.S.S. but also in the Explorer Scout program.

First I sent notification to Mr. Aitkin of our change of plans and put a four hour time limit on our initial underground effort. Then I investigated the rigging requirements. I soon saw that to pass a person through the keyhole entrance to the lower section of the fissure we would have to dispense with everything but a safety line. I bent a line about me and Ruth slowly paid it out from her safetying position as I scrambled down with my back to one wall and my stomach wedged to the opposite side. My feet hung limply in the darkness below. Soon I became jammed and I saw that I must pick out the widest spots through which to slip my body. In this way I could thread my way back and forth on the side of the fissure, ever seeking a lower level, in much the same manner that a small boat pilot would thread his way across a shallow-water bay. The passage was too narrow for me to look straight ahead so I had to keep my face turned sideways. To twist my head from one side to the other I had to tilt it back until my face was straight up, then tilt it back down on the other shoulder.

The beam of my carbide lamp eventually revealed a natural solution crack running away from me at about a 60° angle. Working over to this I found I could chimney down the chute very easily. The only trouble was that I was not descending vertically and if I should fall, my safety line would swing me like a pendulum. I stopped to get my bearings. My carbide lamp was almost out for I had tilted my head so many times that the water had drained out and trickled down my neck. I pulled out my flashlight. I usually kept it tied about my neck but in such close quarters I had removed the thong lest I should hang myself. I had no sooner slipped it from my pocket and started to examine this pitch dark dungeon when I heard the "whisper" of falling rocks above the sound of the underground stream. I flattened out against the wall as a cascade of pebbles slid past. One of them hit my hand with such velocity that I dropped the flashlight. As it slid down I saw by its beam that the crack ended in thin air about 3 feet below me. There seemed to be a room shaped somewhat like an inverted funnel into which I was entering by way of the narrow spout. Further revealed was a clay bank about 10 feet below me and directly under the keyhole through which I had entered. There was a splash as my flashlight hit the water and then twilight as the beam filtered through. Finally even that died out as the light was swept on by the restless current.

I felt my way down to the end of the crack in which I was chimneying until finally my feet were dangling in midair. "Lets see," I mused. "If I step off I should swing to the right on the safety line. With luck I may land on that clay bank. If I miss it I guess I swing out into that room and bash myself against the opposite wall." I checked the knot on my safety line snuggled beneath my shoulders.

"Topside," I shouted, "I have to swing on the line." No answer but the roar of the water, now many times intensified by the freak acoustics of the dome shaped room.

I tried again. "Can you hear me?" Instantly the line tightened against my body. Well they could hear me even if I could not hear them. I relaxed my hold on the rock chute and took out my nylon hand line. If I could fasten that I could go down it and swing to the right to the clay bank. Suddenly there was a noise and the piece of rock to which I was clinging came off in my hand as I fell backward. The tight safety about me prevented any downward motion. However in working down the fissure I had traveled about 20 feet to the left. Now I swung in a 40 foot arc in almost inky darkness. I trailed my legs hoping to hit the clay bank but instinctively I knew I had missed it. I curled up my legs before me and also extended my arms in the direction I was going. Suddenly, in the dim glow of my almost dry headlamp, I saw a wall looming out of the darkness. I took the blow with my extremities and before I could recover I swung back. After I had begun to rise again I flung out an arm to my right. My body turned around just in time for me to fend off the opposite wall. Just how many walls I caromed off I do not know but I think it was the busiest minute of my life. I remember yelling encouragement to Ruth who was holding the other end of the bucking line. Finally the arc of my swinging became so small I no longer hit the walls. I just relaxed and "rode the rope" till I hung still.

"Lower away," I signaled with my whistle. Down I dropped for about 4 feet and then I hit the clay bank.

I took a plumbers candle from my pocket and lit it with a waterproof match. Its feeble glare revealed a steep mud slope dropping down to the bed of the stream. Unrolling a steel ladder I fastened it to a piton driven in the rock wall. Then, after again warning my safety, I climbed down a muddy slope and over a small precipice on the ladder. The floor proved to be little but streambed, 6 inches of water on loose rocks, and a few small pieces of breakdown projecting an inch or two above the water at this point.

I refilled and lit my lamp. Then I saw I was at the bottom of a fissure from 5 to 12 inches wide and about 50 feet long. Its bottom was a room about 30′ x 50′ with steeply-shelved sides covered with banks of mud. Its top was the keyhole; a dumbell shaped opening about 9 by 16 inches wide and about 90 feet above me.

Deciding that the best place to handle the descent was up on the clay bank I ascended the ladder, found good footing and then untied the rope. "Up line," I signaled with the whistle and in a moment I had severed my connection with the upperworld. This always creates a blue feeling even among experienced cavers so, like the boy who whistled in the dark to keep up his courage I started singing a lively polka at the top of my lungs. (The din of the water was terrific.) Soon a tenor was heard chiming in and I saw another form coming down. I then started yelling instructions to the climber for I could see where he was going and he could not. When he reached the end of the chute I threw him a line and brought him on down to the ledge on which I was standing. Murphy, for such it proved to be, went on down to water level before he "tied off". The line then went up for the next spelunker. Peachy had a hard time with the keyhole but made short work of the rest of the descent. My job of cavemaster was quite unenviable, for Peachy pulled a lot of dirt and gravel through the keyhole. As she and subsequent spelunkers descended they rained this material into my upturned face until I felt as though I had been stung by several bees. As Peachy was "tying off" Bill Murphy removed a thermometer from the water and sang out "Air 49°, water 45° F" as he entered it in the log book.

Bill Hertl and Charlie Crutchfield came down in jig time leaving only Ruth Boyer topside. She now dropped one end of the safety line to me and passed it around a tree before "tying on". Thus I safetied her from below. While I brought her down the two Bills searched for crayfish, isopods and snails. Peachie made a start on the mineralogy. Charlie started the search for salamanders and insects on the side walls.

Once Ruth and I were standing in the water with the rest of the gang we roped ourselves together with Charlie, the second in command, at the rear and me at the front. The other four were tied at intervals along the rope. At last we were ready for the underground river. Was it waiting for us?

Upstream our ingress was barred by breakdown through which the water filtered. Downstream the water ran through a tunnel about 3½ feet high. Down this the party crawled. At this point the water velocity was 4 m.p.h. according to Charley's slide rule computations. We had gone down this tunnel only far enough to exhaust our supply of jokes about the Paris sewers (about 30 feet) when we came to a junction. Another stream came through a water-hewn channel about 3 feet wide by 4 feet high. Where the two streams met was a blackish whorling mass of water. After calling Ruth to safety me I stepped into the pool in the interest of Science. The first step was that crucial plunge that wets the lower abdomen and the second step found me in up to my waist. I quickly took a bearing on the secondary stream and relayed the information to logkeeper Murphy. I had already noted that the walls of the cave were undercut where the water ran fast so I told the rest of the party to try walking near the edge of the wall. Most of them managed to get around this pool in only a few inches of water. We were all gathered on a mud bank waiting for tag end Charlie Crutchfield to negotiate the junction. He was doing fine when suddenly his overhanging underfooting crumbled beneath his weight. With a cry to his safety he plunged into the frigid water and disappeared from view. His hat went floating downstream to Peachy who fished it out as it passed. Murphy, his safety man, heaved on the line and jerked a completely soaked Charlie to a crouching position.

Sitting in water up to his chin, Charlie ran through a somewhat more than modest vocabulary. When he exhausted his stock of English he changed to French and then German. Ruth sat on the mudbank, relit his lamp for Peachy and as she restored the hat to its owner she said, "What a pity you don't know Spanish or Portuguese."

We took time here to study the situation. We found that from Charlie's pool flowed a much larger stream which moved rapidly through a channel about 4 feet wide and 6 to 10 feet high above water. Beside this was a mud bank which ran parallel to it but was separated by a thin wall which formed the right wall of the solution channel. The rock of this wall dipped at 72° so that on the mud-bank side of the partition both walls slanted at this angle. The floor was of cave clay. The ceiling was 6 to 8 feet above us. At most points the passage was about 3 feet wide. I chose this upper passage as it was dry.

We walked along with our feet on the floor and our hands flat on the sloping wall. In several places keyholes in the wall had formed sumps where clay had washed away. These funnel-shaped spots were very slippery and quite nasty to negotiate. We had crossed several when we heard a splash preceeded by the cry, "Safety", from Bill Murphy. Charlie and Bill Hertl both belayed their lines about their hips and soon we heard a sputtering sound. When it had subsided Ruth confided, "Now there is Spanish as it should be spoken."

About that time Bill's dripping head poked up through the funnel and soon he was shivering on the mud floor.

This passage abruptly ended in a mud slide about 75 feet from its beginning. We had noted that we were steadily climbing above the water level but we were quite surprised to see the bank was about 10 feet above the swirling water which surged about the bottom of the slide.

The walls at this point were too far apart to be used for chimneying so I decided to go down on the rope. Bill Hertl backed Ruth up on the line and after checking my gear I stepped off the ledge. I went down so fast I thought I was riding a rocket. With a splash I found myself sitting in about a foot of water. "Some safety," I commented acidly.

"Yep, it sure was," agreed Ruth. "Who wants to dig me out?" Then I noticed the force of my descent had driven her into the soft mud halfway to her knees.

Ruth spurned the line and set the pattern for future descents when she sat down with her legs dangling over the edge. With a cry of "Geronemo" she slid down the almost verticle cliff on her stern. There was a tremendous splash and there sat Ruth in a foot of water just as I snapped a picture.

Peachy followed Ruth's example, but as Charlie said she added a back layout. Evidently she brushed the wall in her slide so that she hit the water sideways. Although she landed in shallow water she rolled over and over into the main channel. Bill Hertl quickly arrested her with the safety line and Ruth and I retrieved her hat, flashlight and carbide refills as they swept past us.

Peachy climbed out on a rock that protruded from the current. She was joined on this foot square perch by Ruth and shortly later by Bill Murphy who stood partly on the rock and partly on Peachy's foot. The three held hands and leaned away from each other.

"Now there is a tableau," said Bill Hertl, and turning to look we really did see a sight. The rock shifted or disintegrated. There was a wonderful vista of flailing hands and feet as each tried to get on top of the other two. Then came the great plunge. At this point the water was 3 to 4 feet deep and the walls were about 6 feet apart. Everyone was snarled in his own or someone else's gear. Half the lights were out, and everyone was shouting. Both girls finally got over to the wall but little Bill Murphy was swimming around after gear till he had the safety line all fouled up.

We spent about 10 minutes unsnarling this mess but finally we were all straightened out and the party was assembled at the bottom of the slide.

We worked our way along first one wall and then the other, walking near the edge of the water on the thin overhang at or just below water level.

I was spreadeagled across the cave with my feet on one wall and my hands on the other wall when I felt the overhang crumble beneath me. Next thing I knew I was in inky black water and was rolled over on my back by a jerk on my safety line. When I came to the surface I saw Ruth holding the other end of the line. "Look at the sucker I just caught," she said to Peachy as she pulled me in.

We inched on down the passage which was alternately wide but fairly shallow, and narrow but deep. As we progressed the ceiling became lower and lower. Finally, after making a right angle turn we found the ceiling came down below water level to form a siphon. We gathered in 3½ feet of water at this point and discussed the possibilities of further progress. My calculations showed that we were about 100 feet from Aitkin cave but running parallel to it. The current was too heavy to enable us to duck under with any hope of getting back upstream. Also it was getting late. Then too, though the weather had been perfect when we came in I was still worried about what a rain storm would do if it were to catch us there. We decided to return to the surface.

We all plunged upstream with a will as all but Bill Hertl had been completely underwater at least once. The mud bank was a tough ascent but we climbed up each other's shoulders to reach the top. Within a short time we were again assembled in the entry room with its fissure running to the surface.

The safety line would not easily slip around the tree because of friction so I found it of little use. For this reason I decided to make the initial ascent instead of being the last one out.

After turning the party over to Charlie I made my way up to the ledge where I had landed after my pendulum-like ride. From there I had a ten foot climb to the solution crack down which I had descended. After 3 failures to achieve this I climbed up on Ruth Boyer's shoulders. She walked under the crack and I easily inserted my head and shoulders in it. After 15 minutes of hard chimneying I was sitting on the surface.

Ruth was next to ascend and she had a horrible time getting up to the crack I had just ascended. Three times I was holding her in midair. I had both feet planted against a big tree and was leaning straight out parallel with the ground. "Pull up," screamed Charlie's whistle, and try I did, again and again. Finally the rope went limp and I pulled it up snug against Ruth. She was coming up.

With Ruth to help, it was easier to pull Peachy up to the crack. Getting her through the keyhole was another matter. All three of us worked for many minutes before she was topside of that nasty squeeze.

The more of the party who arrived on the surface the easier the initial pull became. Finally even tag end Charlie was up.

We were busy filling out the log and sketching a rough sketch to help fill in another unknown spot on the map when Ruth said, "Look at Bill Hertl. He isn't wet above the waist. That calls for a kiss."

Bill beamed and braced himself as she approached. When at arm's length she reached in her Levis and pulled out a water soaked molasses candy which she presented to him.

EXPLORATION IN BALL'S CAVERN

(continued from page seventy-nine)

For the average swimmer that contemplates accomplishment of this same feat, TAKE CARE. The body must be conditioned gradually to take the cold temperature. It is not the good swimmer that may make it; but the swimmer that feels his way, realizing that his life hangs at the other end of the balance.

[1] American Journal of Science, Dr. Charles U. Shepard, Yale University, 1835

[2] Mineralogy of New York-Natural History of New York, Lewis C. Beck, M.D., 1842

[3] Geology of New York-Natural History of New York, William W. Mather, 1843

[4] Geology and Paleontology of Schoharie County, N. Y. State Mus. Bull., 1906, Amadeus W. Grabau

[5] Limestone Caverns of Eastern New York, Professor Cook, 1906

[6] Cave Exploring With Bright Star Flashlights, Arthur H. Van Voris, 1929

[7] Schoharie County Journal, Charles J. Hanor, July 5th, 1949

Who's Who in Bulletin Twelve

CHARLES J. HANOR is secretary of the Tri-County Grotto, Oneonta, New York, and was born near Seward, New York, just over the Schoharie County Line. His special interests in speleology are mapping, archaeology, photography and compiling data on existing caves of the country. He has written many articles for the local papers of New York State telling of the activity of the N. S. S. At present he is making a survey of the formations called "disks" that caught his attention while at Grand Caverns, Va. He has found these same formations in a certain line right up through Pennsylvania and is desperately trying to find if they again make their appearance in his native state. He is a strong advocate of cave safety and is trying to interest the New York grottoes to form an organized rescue squad. His regular work is surveying and mapping for one of the larger utility companies of New York State. He received his college education at Oneonta State Teachers College.

FORREST L. HICKS was born in Los Angeles, California in 1926. Beginning his mineralogical interest early, he won a mineral collection prize at a hobby show before he was thirteen. World War II interrupted his life and after sea duty on the Atlantic he returned to college studying geology at the University of Southern California. There, marine geology, sedimentation, and mineralogy were his main interests. As a graduate student he engaged in work on the Mojave Desert where he discovered halite stalactites and miniature karst topography in a playa lake. In 1949 the State of California hired him for work on bridge foundations, and in 1950 he returned to the University to work on his master's thesis. The situation in Korea has made it necessary for him to postpone his studies and return to the armed forces.

HAROLD B. HITCHCOCK is associate professor of Biology at Middlebury College and chairman of the department. His interest in caves is an outgrowth of his studies of bats. In 1939, while teaching at the University of Western Ontario, he began studying the bats of eastern Canada and has recently published his findings in the Canadian Field-Naturalist. The problem giving him most concern now is that of accounting for the scarcity of females among the little brown bats hibernating in the northeastern part of the continent.

LESLIE HUBRICHT is the Society's most active invertebrate zoologist. While serving on the staff of the Missouri Botanical Garden, St. Louis, he visited a large number of eastern and Ozark caves. In 1940 a research grant from the American Association for the Advancement of Science enabled him to explore and make collections in about fifty Missouri caves. Hubricht has been accompanied on many of his trips, and in his scientific writing has frequently collaborated with J. G. Mackin of the Texas A & M Research Foundation. Hubricht has discovered many new species of invertebrates, has named many forms, and has had quite a few named in his honor.

JEROME M. LUDLOW, NSS Bulletin Editor, was connected with the Brookings Institution at Washington, D. C. when that economic and governmental research organization was founded. He spent two years with a Chicago firm of consultants in municipal administration and seven years as chief clerk and research assistant with the New Jersey Taxpayers Association before joining the U. S. Geological Survey in January, 1940. An invitation from Charles E. Mohr to participate in an NSS field trip in April, 1947 resulted in his gradual change from a somewhat normal individual to a speleoeditor.

PATRICIA MERRIAM is a native of Los Angeles, California, and received a BA degree in chemistry from Pomona College. After a year's work in a chemical laboratory, she was attracted to the field of geology. Enrolling as a graduate student at the University of Southern California, she began a study of geology and received a Master's degree in that subject in June of this year. Her interest in ice caves arose during a course in Ground Water and her article is a portion of a paper written for that course. Marriage to a professor in the Geology Department at USC and the subsequent birth of a daughter has somewhat curtailed further work.

M. B. MITTLEMAN began to explore caves while studying at Ohio University. Since rare salamanders had been found at Carter Caves, near Grayson, Kentucky, only 125 miles from Athens, Ohio, it was natural that the young herpetologist should start his spelunking there. Eventually he went salamander hunting in caves from Virginia to Texas, including a good many in the Ozarks. "Budd" Mittleman earns a living in management engineering but has found enough time in the last ten years to make the expeditions, collections, and observations that have formed the basis for nearly 50 scientific papers. He has one of the best private herpetological libraries in the country. He lives in Larchmont, N. Y.

CHARLES E. MOHR first went to the Ozarks in 1935, in search of salamanders, and has been back four times. In 1946 he arrived in St. Louis the day the newspapers reported the discovery of the remarkable deposit of fossil peccaries in Cherokee or Brewery cave. A few hours later he was in the cave. He stopped by again later that year to dig a few bones himself. Mr. Mohr's spelunking began in Pennsylvania in 1930 and has taken him into some 500 caves from New England to Florida and west to New Mexico. He has made two trips to Mexico in search of vampire bats and other cave animals. A charter member of the NSS, Mr. Mohr became vice-president in 1946, and this year was elected president. He proposed and edited the Society's first regional bulletin, "The Caves of Texas," and is the author of numerous popular and scientific articles on speleology. Since 1947 he has been director of the Audubon Nature Center, Greenwich, Conn. A biographical sketch of the NSS president appeared in the February 1948 NEWS.

JOHN DYAS PARKER, a malacologist, became interested in caves while a geology student at Rutgers University. His hobby of spelunking has been pursued on three continents when he was a field geologist for Empire Mines and with the First Infantry Division. At present he works with marine snails, both fossil and living, under Dr. H. A. Pilsbry at the Academy of Natural Sciences of Philadelphia. Although he has provided a nice home for his wife and daughters in nearby Overbrook Hills, his heart is still in his native Florida where he, in fancy, still explores coral grottos deep in Neptune's Realm. He is a charter member of the Philadelphia Grotto and has been very active in that unit. He was elected to that Grotto's Board of Governors for three consecutive years, has headed important committees in that unit, and has been instrumental in training groups in cave safety procedures and rock climbing. He is Natonal Safety Chairman of the N. S. S. and is a member of its Editorial Committee. His loves in caving are underground mountaineering, mapping, photography, mineralogy, and—you guessed it—collecting snails!

GEORGE GAYLORD SIMPSON is chairman of the Department of Geology and Paleontology at the American Museum of Natural History. Among the more than 200 scientific articles which he has written are several important ones on cave fossils. In 1940, Dr. Simpson visited Craighead Caverns, Sweetwater, Tennessee, to study large tracks of an unknown animal. His painstaking investigation proved them to be footprints of an extinct species of jaguar. He also made a firsthand study of the "Bones in the Brewery" Cave in St. Louis in 1946, and has made a critical examination of most of the eastern cave fossils discovered during the last century. Dr. Simpson's reputation as a literary writer is borne out by his article from NATURAL HISTORY, reprinted in this issue. He has also published a technical report on his findings in the Brewery Cave.

H. F. STIMSON is a Yankee from Leicester, Massachusetts. He received his Ph.D. in physics at Clark University in 1915. Since May 1916 he has been a physicist at the National Bureau of Standards in Washington. His principal work there was first on the calorimetry of water and now is on precision measurements of temperature related to the International Temperature Scale. During the war he spent a good deal of time at proving grounds studying the performance of proximity fuses on rockets. His outdoor hobbies include camping, mountain climbing and color photography of wild flowers. While a graduate student at Clark in 1914 he received a gift of an engineer's transit from his landlord, an ex-civil-engineer. To this transit he has added a level and a vertical circle for cave surveying. David W. Appel, the principal helper on the Schoolhouse Cave Survey, graduated from college as a civil engineer and now, in addition to being a graduate student and instructor in hydraulic engineering at the University of Iowa, is Stimson's son-in-law.

DR. ALLYN COATS SWINNERTON has been Professor of Geology at Antioch College, Yellow Springs, Ohio, since 1922. He received his Ph.D. at Harvard that year and has held many important positions in his field including work for the United States Geological Survey during field seasons from 1920 to 1936. He has also taught geology at Stanford University and at Harvard and was consultant to the Tennessee Valley Authority. During World War II as a Major he was Director of the Army Service Force's Long Branch (N. J.) Signal Laboratory. His speleological interest is largely in physiography and the hydrology of limestone terranes. He is perhaps best known to speleologists for his paper on "The Origin of Limestone Caverns" published by the Geological Society of America in 1932. He is an Honorary Member of the NSS.

ALEXANDER D. THERRIEN has been interested in caves and underground rivers ever since he camped, as a boy, on a lake near Lost River in the Laurentian Mountains in Quebec, Canada, way back in 1908. However, he did not start any real cave crawling until 1919 and 1920 when he spent many weekends exploring some of the caves in the limestone bluffs along the Big Muddy in central Missouri. He is engaged in electrical work with a mid-western utility and visits at least one cave a year while on vacation. At present he is the Keeper of the NSS Scrap Books.

GORDON T. WARWICK, a British associate member was born in Derbyshire, England in 1918. He first became interested in speleology whilst reading geography and geology at the University of Bristol, where he was a member of the University Spelaeological Society. After six year's war service in the artillery he became a lecturer in Geography in the University of Birmingham in 1946. He lectures mainly in Geomorphology, and he is specially interested in limestone terrains. He is also interested in cave archaeology, being secretary of the Peakland Archaeological Society, which specialises in that work. His spelunking is mainly done with the Birmingham Cave and Crag Club or with Lewis Railton. In 1949 and 1950 he was elected chairman of the Cave Research Group of Great Britain, and in 1949 appointed British member on the newly formed International Speleological Congress Committee. He is at present engaged in editing and compiling a speleological glossary for the Cave Research Group, to whose publications he is a regular contributor.