BULLETIN SEVENTEEN

OF THE NATIONAL SPELEOLOGICAL SOCIETY
Official Associate of the American Association for the Advancement of Science

IN THIS ISSUE, informative articles on caves, including:

December 1955

BULLETIN SEVENTEEN

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THE NATIONAL SPELEOLOGICAL SOCIETY

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

IN THIS ISSUE . . . . . . December, 1955

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

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

Associate	$ 3	Sustaining	$ 10
Regular	$ 5	Institutional	$ 10
		Life	$100

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 unlocking the truth of the world underground.

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 controlled by a Board of Governors. The Board appoints the national officers. The Board also approves 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 Grottos. They stimulate and coordinate activity and increase the interest, enjoyment, and productiveness of cave exploring.

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 at a nominal charge.

FOREWORD

With this issue of the Bulletin, The National Speleological Society rounds out 15 years of publications. As I write, I have the Society's publications around me and paging through them is a review of the evolution and growth of The National Speleological Society.

Bulletin One appeared in 1940 (now available in a reprint published in 1955) and its main feature was the Constitution of the District of Columbia Speleological Society, which a year later became The National Speleological Society. This constitution, with only minor changes with respect to subdivision of executive duties, is the one that guides the Society in its action today. It is of interest that the purpose of the Society is "to advance in any and all ways possible the Science of Speleology." The Board of Governors throughout the 15 years has realized that speleology attracts three distinct groups—those who visit caves mainly for the thrill of it; those whose interest in caves is that of a hobbyist with a specific subject to be pursued; and, those who are scientists who, either as a part of their profession or as a sideline, have turned to cavern investigations.

With the Society membership divided into three groups, the Board of Governors has interpreted the phrase "advance in any and all ways possible" to mean the integration of all three groups in a common effort. This integration always has presented problems, and the solution is reflected in the scope and format of the Bulletin.

The first four issues of the Bulletin presented articles on cave descriptions, primarily of caves in Virginia, West Virginia, and Maryland. This localization of interest directly reflected the small, closely-knit aspect of the Society at that time. With Bulletin Five, issued in October, 1943, articles of general interest were introduced and individual cave descriptions and Society news were relegated to the newly established "Newsletter." In 1948 the first Bulletin of a regional nature was issued, covering Texas. At this time, local units of the Society began their publications. This resulted in a transition in the "News" as the descriptions of individual caves or caving trips were transferred to the Grotto publications, freeing the "News" to serve as a primary source of information on the Society's activities, policies, and problems. From 1948 until 1952 the Bulletin trended toward the scientific, culminating in Bulletin 14, published in 1952. In that year the "Occasional Papers" were established to handle the scientific aspects of speleology. The subsequent Bulletins have been either general or regional in nature.

Bulletin 17, as the contents indicate, is one of a general nature and is in keeping with the current policy of maintaining a balance commensurate with membership interests in the Society. The officers of the Society, the directors, and the Bulletin editor hope that this will be the last annual Bulletin. Plans call for making the Bulletin a semi-annual or a quarterly publication in 1956, of which one issue would be regional and the others general in nature. The frequency of publication will depend primarily upon the receipt of articles suitable for publication. Plans for the "News" and "Occasional Papers" also call for increase in size or frequency.

I extend my congratulations to Roger Brucker for a job well done on this issue, his first editorial assignment of the Bulletin.

WILLIAM E. DAVIES,

President, The National Speleological Society.

Caverns of St. Tomas

By ANTONIO NUNEZ JIMENEZ and KENNETH A. SYMINGTON

Members, Cuban Speleological Society

Of all the 1000 or more caves of Cuba, the Caverns of St. Tomas constitute the largest integrated system. Eight named caves interconnected with at least four actively forming stream passages penetrate the Quemados Sierra, located in the country's westernmost province. The Cuban Speleological Society's systematic survey and exploring efforts haveplaced the system among the longest known cave systems in the world. For beauty, the cave ranks with the finest to be found anywhere.

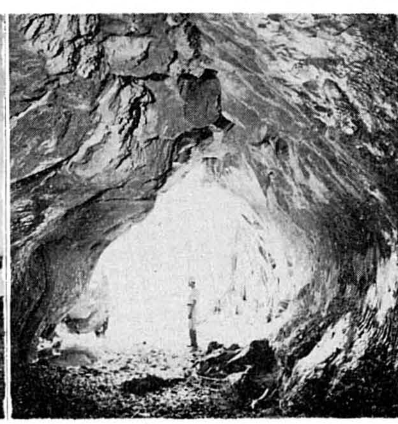
"The whole island of Cuba appears to be a labyrinth of caves beneath the surface, and its soil to rest upon an extensive vault."—*M. Rodriguez Ferrerer—1847.*

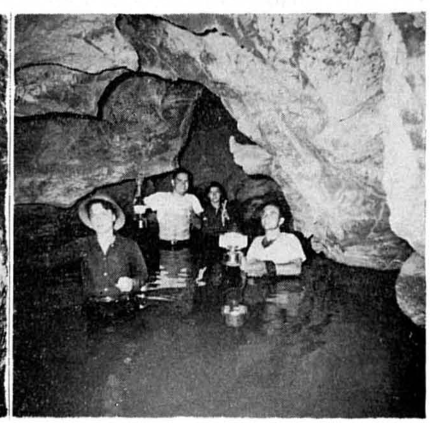
The above description, written by a noted Spanish traveller and explorer of the nineteenth century is not simply another opinion. It is a geological fact that the calcareous formations of Cuba, extending throughout most of the country, contain impressive caverns which have been studied since the eighteenth century, but in a systematic manner only since 1940, when the Cuban Speleological Society was founded. Since that time, more than 1000 caves and grottoes have been explored, spread over the archipelago of islands which forms Cuba. Innumerable Indian artifacts have been found in their recesses, as well as species of eyeless fish and shrimp living in underground lakes and streams. Secondary cave formations of impressive beauty, such as the helictites of Bellamar Cave, and fossil remains of the Cuban pleistocenic fauna are among other material so far collected.

SOME INTERESTING CUBAN CAVERNS

In the Maisi region, located in the eastern end of the island, the Patana Cave is well known for the abundant fauna in its subterranean rooms. Dark corridors, where a temperature of 104°F is found the year round, are literally covered with strange spiders, scorpions, and large worms. To complete this picture, the cave's roof sustains thousands of bats which disband as soon as they see the light from the explorer's lamps, creating an absolute chaos in that hot inferno.

In Guantanamo, Oriente Province, the great Rio Guaso Caverns are found; in Mayari, the Seboruco Cave, containing archaeologically valuable silex tools fabricated by primitive island habitants; further west, in Banes, the Cave of the Four Hundred Roses has more than one-half mile of passages. The Province of Camaguey is



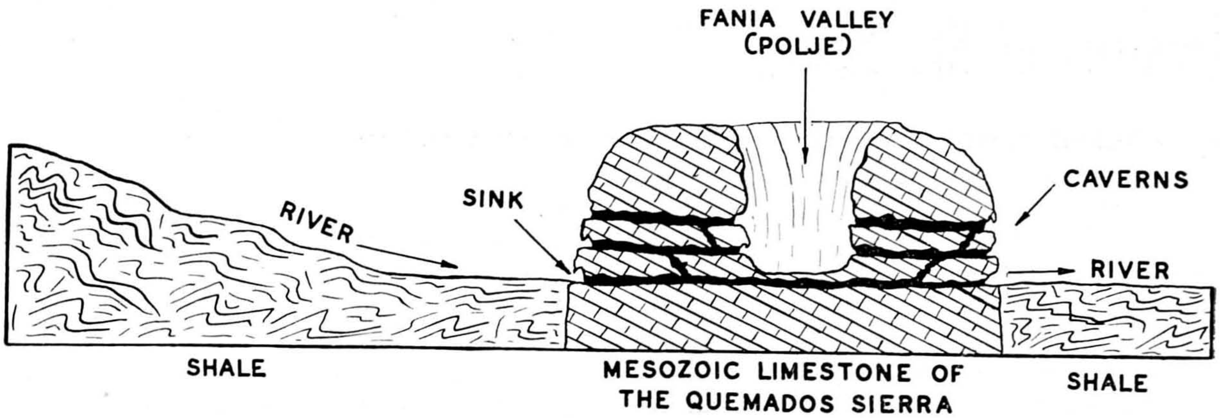


All photos by A. N. Jimenez

View of the Quemados Sierra in western Cuba.

Entrance to lowest passage of St. Tomas cavern.

The party advances along an underground river.



Geological section of the Quemados Sierra showing the contact of the shale (where the river runs superficially) and the limestone, where the river flows underground, forming the St. Tomas cave system. Three levels are shown here; other cave levels actually exist.

also rich in caves, the best known of which is the Cubitas Cave, with approximately one and one-half miles of beautifully decorated galleries. The Gaguanes Cavern, in the northern coast of Las Villas Province, is unexplored beyond the one and one-half miles we have visited. The best known cave of Cuba, the Bellamar Cave in Matanzas Province, has been carefully studied by the Cuban Speleological Society. Surveys show that it is 6850 feet in length, with four superposed galleries following a fault in a bed of Miocene limestone. The crystalline formations of the Bellamar Cave have been recognized as some of the most beautiful examples in the world by European mineralogists, largely because of their dazzling transparency.

Not far from Bellamar, the Society has carried out explorations in the Carbonera Cave, where an Indian burial consisting of three skulls arranged in a triangle, with a fourth one in the middle, has been found. The corresponding skeletons were completely separated from the skulls, an extremely unusual occurrence which has been studied by anthropologists from the University of Havana. Along the southern plateau of the western provinces of the island, hundreds of sinkholes similar to the famed "cenotes" of Yucatan are located. These formations usually have a pool of clear water in the bottom with species of eyeless fish found occasionally.

The ranges of the Sierra de los Organos, in Pinar del Rio Province, are noted for the peculiar "Mogote" formations, low rounded hills with vertical slopes, literally honeycombed by underground passages and river channels, most of which have remained unvisited by scientists up to the present day.

These, then, are some of the major areas of cave bearing karst topography in Cuba. Longest known cave in the country is St. Tomas Cavern, named for its proximity to the St. Tomas River which is closely connected with the origin of the area's large caves. More than five miles of passages have been mapped, making it the longest in the West Indies, Central and South America. Up to the present, the longest known cave in this area of the world was the Lapa de Brejo Cave in Brazil, measuring three and three-fourths miles.

LOCATION AND GEOLOGY

The St. Tomas Cavern is located in the Pinar del Rio county, near the western reaches of the Sierra de los Organos, perhaps the oldest mountains in Cuba, whose deposits date back to the Jurassic and Cretaceous Periods. The stratigraphic structure clearly reveals that the old cretaceous strata in which lie the passages of the cave are of the overthrust type; i.e., where the older rocks have been covered by younger strata under violent tectonic pressures. These forces caused multiple cracks, joints, and faults which later facilitated the passage of the subterranean waters and the superficial rivers across the Sierra, giving rise to the imposing galleries of the cavern system.

In general, the St. Tomas Caverns are systems

of parallel passages and channels, oriented from north to south and perpendicular to the Quemados Sierra (one of the divisions of the larger Sierra de los Organos.) There are also several superposed galleries, ancient river beds which have now been abandoned by the fluvial waters. These are much older than those through which the St. Tomas River is actually flowing. It is important to point out that the Quemados Sierra is surrounded by shale deposits, a rock which is more vulnerable to erosion than the harder calcareous rock in which the caverns are found. The Quemados Sierra itself rests on a base of shale. As such, it is termed a "klippe" or "rootless" mountain by German geologists.

ORIGIN OF THE CAVE

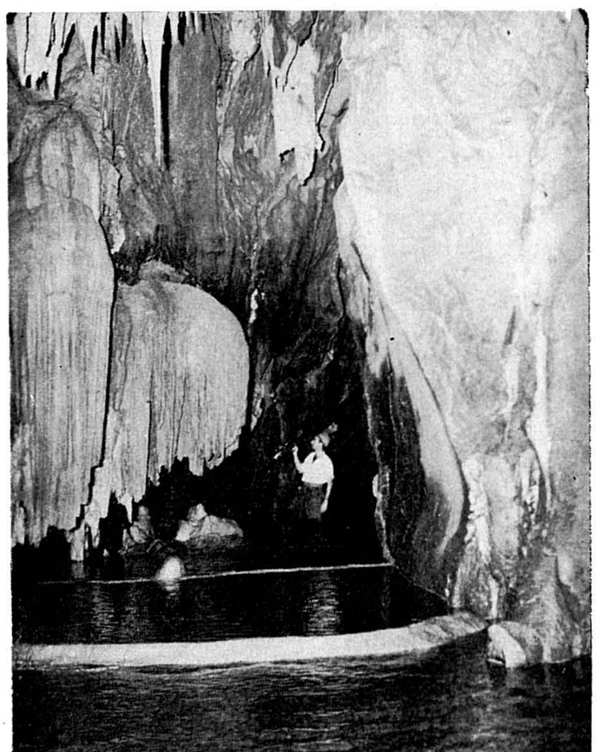
Since the publication of the studies made by Grund in 1903, and Davis in 1930, many hypotheses on cave formations have emphasized the importance of the water table and its fluctuations. Such factors have, in our opinion, no strong bearing on the origin of the St. Tomas Caverns. How then did the system originate? Here is a tentative explanation.

The mountain on which the caves are located consists of hard limestone rock with numerous faults and extensive joint cracks. These have facilitated the entry and circulation of surface waters from the rivers in the adjoining valley, which flow generally in the same direction as that of the faults and diaclases of the mountain. Before reaching the limestone Quemados Sierra, however, the rivers flow over soft beds of shale, which are more easily eroded than the harder mountain limestone. As a result, the softer, superficial shale river bed is worn faster than the subterranean limestone bed. The difference in level between these two beds forces the river to form a new subterranean passage, lower than the original one, following the openings afforded by the cracks and faults in the mountainside. The work of solution-erosion will renew the formation of a cavern at a lower level. The above process repeatedly taking place has produced a series of superposed caves extending across the width of the Sierra and connecting the two valleys on either side. The elevation of the Quemados Sierra due to tectonic forces also, of course, influenced the formation process outlined above.

The higher caves, such as the Salon Cave, Table Cave, and Candle Cave are the older members of the system, while the lower ones serve as channels through which the rivers are now flowing. Between these two levels, there are several intermediate caverns which are inundated only in times of flood, when the water level reaches them.

ONE OF THE WORLD'S GREAT CAVES

When we began to explore the Quemados Si erra in 1954, only the Salon Cave was known to the local residents, since they held picnics and outings at the cave entrance. The subterranean river was known to exist but no one had ventured to follow it into the Sierra. Many other entrances of caves which are interconnected inside the Sierra have since been discovered. In the five miles of mapped passages so far explored, many side galleries and connections have yet to be explored. In any case, the importance of the St. Tomas Cavern rests on the fact that it is the longest known integrated cave system south of Florida.



Dammed pools interrupt navigation by rubber boat.

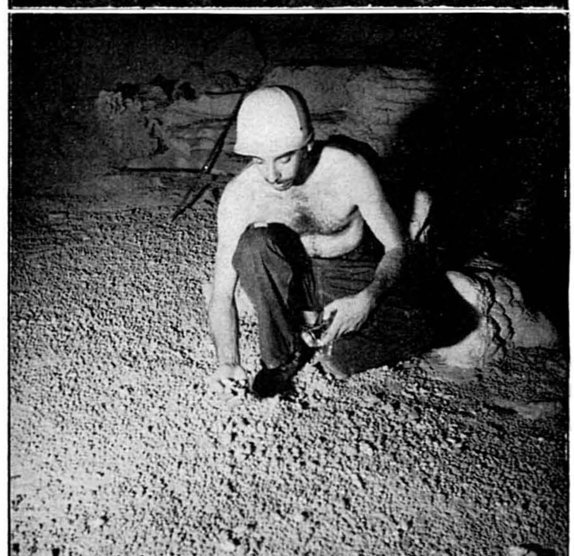
A TRIP TO THE CAVERN

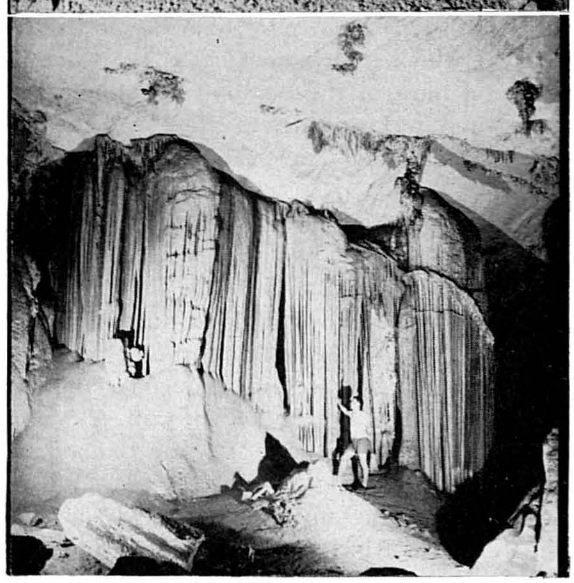
The trip from Havana is made leisurely until we reach Ponce, a small village in the midst of the vertical cliffs of the Sierra de los Organos. A jeep waits for us and in a few minutes, we are driving through the lower reaches of the Sierra; verdant tobacco plantations and exotic tropical vegetation surround us everywhere. Soon we reach a spot near the Quemados Sierra itself, from where we see the dark cave entrances in the cliffside. The unloading of the packs, rubber rafts, headgear, compasses, lamps, instruments, and other equipment takes only a few minutes and we are soon starting the climb to the entrances.

Upon reaching the main opening, we find ourselves in a large, softly lighted room with a steep 50-foot precipice near the back wall, at the bottom of which the river flows quietly in its course. Ropes and ladders are tied to projecting stalagmites and we descend into the hole, finding that the water is cool and crystal-clear and only knee-deep. As we start to walk into the mountain against the current the depth increases so we inflate the rubber rafts. The river runs over a series of pool dams, formed of pink calcium carbonate, which contrast with dazzling white stalactites, palettes, and the dark blue walls of marble with white calcite veins.

NAVIGATING UNDER THE MOUNTAIN

We need the rubber raft where we can see no bottom. Great longitudinal cracks in the cave ceiling reveal the geologic conditions which permitted the river to carve out such gigantic passages. Several hundred feet from the entrance, a tributary joins the main stream, increasing the volume of water. We cannot avoid thinking what a tragic end would await us if we were to be trapped here in a flood. Every few minutes we stop to raise the raft over the irregular dams blocking the passage.

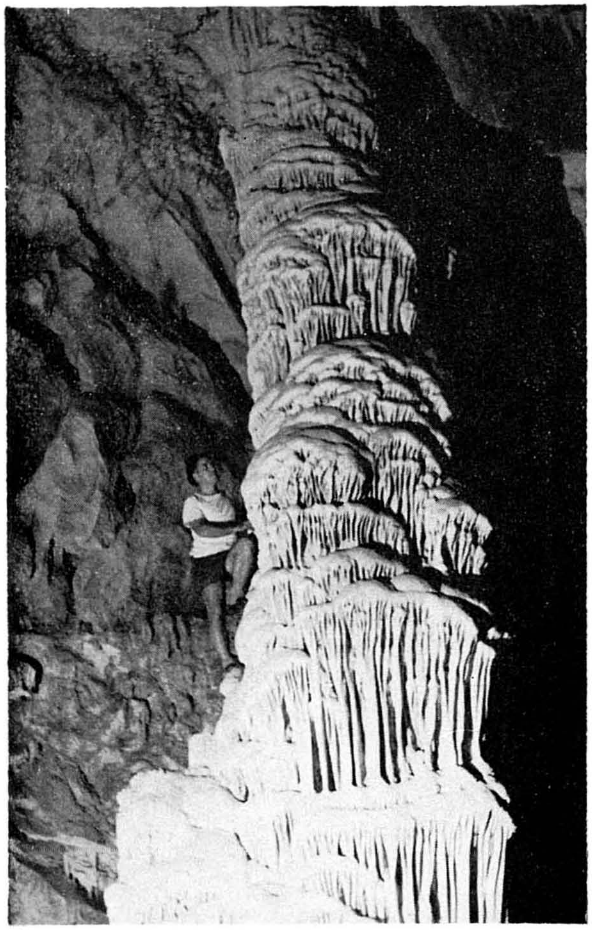




TOP—Stalactites adorn the ceiling of Incredible Cave.

CENTER—A. N. Jimenez inspects cave pearls on a dry pool floor.

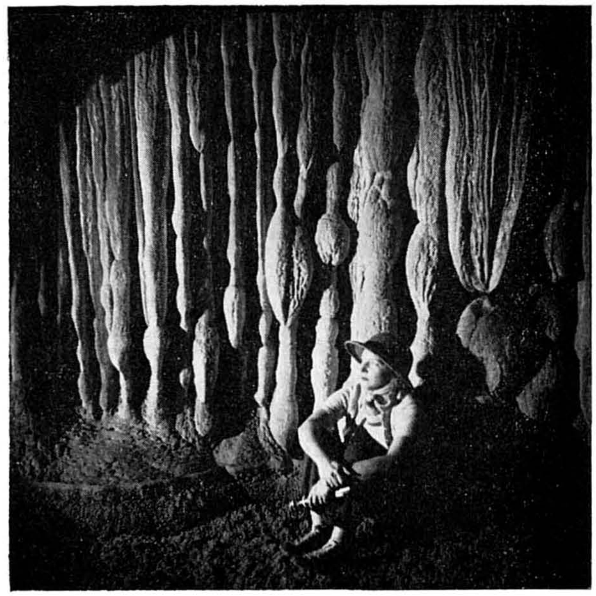
BOTTOM—Flowstone formations are topped by palettes, on the right.



Kenneth Symington climbs one of the huge columns found throughout the cave.

The dammed pools, stalactites, and flowstone formations are soon left behind. The scenery now consists of huge piles of rocks and debris through which the water trickles. We leave the rafts and most of the equipment behind at an improvised dock in order to climb over the massive fallen boulders and slabs of rock.

Passing over the chasms, pools, and breakdown, we can see an opening to our right which lets some daylight filter in. The light, we soon learn, comes from a small karst valley open in the heart of the mountain forming a perfect polje, roughly 500 feet in diameter. The luxuriant vegetation is drenched in rain. A cyclone is approaching Cuba and, fearing a flood, we quickly retrace our steps back to the main entrance, postponing any further navigation along the St. Tomas River for the day.

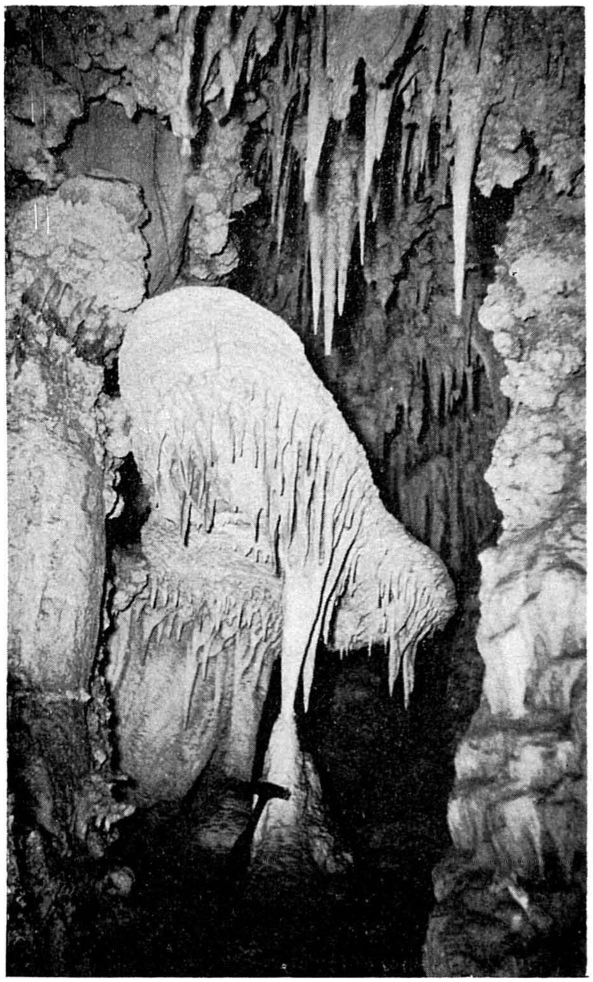


Unusual stone "cacti".

Exploration continued on December 25, of 1954, when we repeated our previous exploration and then continued along a passage which branched out to the right a short distance from the valley. This new gallery led up to a point where the surface of the water and the cave roof approached to within two feet of each other. After several unsuccessful attempts to pass beyond this point, the party finally managed to swim through, only to return shortly afterward, since long hours in overcoming obstacles had almost exhausted our gasoline supply.

A third attempt to completely traverse the cavern was made on the 1st of January in 1955, when we were better equipped with rations, an ample supply of waterproofed flashlights, and several cans of gasoline for our lamps. A camp was established after about one and one-half miles of steady advance, where we decided that a few members of the party should remain as a safety measure, while the others would advance and try to reach the end of the cave.

Progress now became difficult. The main passage was only about seven feet high while a maze of side passages endlessly confused us, leading us to cul-de-sacs and narrowing down to mere cracks. At certain spots the river was shallow; we had to carry the rubber raft on our shoulders. This operation became so tiring that we



One of the most beautiful of the many palettes found in the St. Tomas system.

decided to deflate the boat altogether and proceed either on foot or swimming across the occasional pools which barred the way. Cave formations in this section were few but extremely beautiful. We saw cave "flowers" and extremely thin stalactites, and we collected several species of eyeless shrimp. The river bed was covered with pebbles and boulders, which when hurled against each other in the spring floods gradually assume their rounded appearance while perhaps contributing to the enlargement of the cave passages.

At a point two miles from the entrance, the aspect of the cave again changed radically. The narrow flooded passages gave way to a high, smooth cave, with a floor so even and uniform that a car could be easily driven along it. We advanced in that seemingly endless corridor after a brief stop for lunch, since it had been more than five hours since we had anything to eat. Suddenly, in a wide opening to our right, we saw the branches and leaves of some trees by the glow of our flashlights!

We had come out on the other side of the Sierra after traversing more than two and one-half miles of underground passages. The moon was shining and a great quiet prevailed over the pine forests which cover the valley on the eastern side of the Quemados Sierra. Four hours later we reached camp, after returning by a mountain trail which crossed the Sierra over the huge dark caverns below. Here we joined the rest of the party which we had signalled to return.

SUMMARY OF LENGTHS

Since space does not permit a description of the many other explorations carried out in the lateral caverns interconnected with the one just described, a summary of the lengths of the caves forming the St. Tomas system is given below.

Name	*Length (feet)*
1. Candle Cave	1900
2. Guano Cave	2140
3. Dacal Cave	328
4. Salon Cave	3100
5. Fernando Cave	147
6. Table Cave	2950
7. Palette Cave	1475
8. Incredible Cave	1640
9. Subterranean Stream No. 1	2200
10. " " No. 2	5650
11. " " No. 3	2290
12. " " No. 4	2460
13. Connection between streams 1 and 3	164
Total	26,444

Editor's Note: Just before press time, the authors announced that 12 additional caves have been connected with the St. Tomas system, raising the total length of surveyed passages to seven and one-half miles.

Saltpetre Mining Tools Used in Caves

By BURTON FAUST

Most speleologists realize that caves aided the cause of the United States in the War of 1812 by providing saltpetre, a vital ingredient of explosives of the time. But the earliest recorded uses of saltpetre date back more than 4000 years. In the course of his cave studies, the author has fitted together a comprehensive picture of the tools and methods by which the compound was extracted from cave earth. In general, form followed function, consistent with tool material available and existing technology. The material presented clearly shows the development of the industry up to a time when it vanished as a form of human activity, leaving little behind but the tools themselves as one measure of man's progress.

The recovery of saltpetre from the earth of caves is a simple operation although standardized procedures developed only over a long period of time, as the result of much investigation. The study of the sources, formation, recovery, purification, and uses of saltpetre occupied the attention of a number of the early chemists, and even some alchemists, among whom were Marcellin Pierre Eugene Bertholet[1], Antoine Laurent Lavoisier[2], Roger Bacon[3], Georgius Agricola[4], John Bate[5], William Clarke[6], and Henry Stubbe[7], to name a few.

The beginnings of the utilization of saltpetre are shrouded in antiquity. The earliest uses appear to be as a diuretic, a carminative, a refrigerative, a meat preservative, and an antiputrifactive or embalming material. These date to around 2100 B.C., and are recorded on ancient clay tablets recently unearthed in the country of the Sumarians[8]. They tell the story of the production, recovery, and of these uses of saltpetre.

In the recovery operations, the basic physical-chemical theory involved follows closely the law of differential solution. In effect, this is the recognition and utilization of the different solubility factors of different salts in different temperatures. In its simplest form the method of recovering saltpetre from the cave earth and refining it for use comprises the following steps:

1. Placing the cave earth in tubs, barrels, or vats and covering the material with water.
2. Allowing the mud, thus formed, to stand for one to three days during which time the calcium nitrate is leached and dissolved by the water.
3. Draining the solution from the container.
4. Treating the leach-brine, thus obtained, with potash that was usually procured by leaching wood-ashes in a similar manner: (This operation changed the calcium nitrate to potash nitrate and caused the precipitation of the calcium as an hydroxide).
5. Boiling the solution of potash nitrate to increase the concentration by evaporating part of the water.
6. Separating by partial crystallization the common salt and other minerals that are less soluble in water.
7. Decanting the hot supernatent liquid which contains the greater percent of potash nitrate.
8. Allowing the hot liquid to cool which will cause much of the potash nitrate in solution to precipitate.
9. Redissolving the recovered crystals in a smaller volume and recrystallizing the potash nitrate after which the crystals are washed with cold water; or,

(9). Melting the crystal in a pot over a fire and removing the scum that forms on the melted material; then,

10. Pouring the melted material into a container in which it will cool into a hardened partly-crystallized chunk.

This last step provided a material known as grough-saltpetre which was generally shipped to

the powder factory for further treatment.

Man uses tools to produce any substance. The material available of which such implements are constructed and the use for which they are employed will condition their form. Since saltpetre miners and refiners were no exception to this general statement, let us consider some of the tools and equipment utilized to produce a usable saltpetre from the earth of caves.

One general observation can be made at the outset: Most of the tools and other equipment used were made of wood. There was limited use of metal tools, evidenced by existing pick-marks and what appear to be scraper-tracks and spade or shovel-traces. However, very few metal tools have been found in any of the caves. Probably at least two reasons account for this situation. First, metal was scarce, hard to obtain, and therefore expensive. Second, the few metal tools available were precious, since they could be used for many jobs for which wood tools were not satisfactory. Therefore it is reasonable to assume that the miners took their metal tools with them when they left the cave. There is possibly a third, although minor, reason. Metal tools make a harsh, grating, and disconcerting racket when scraped along rough rocks and stones.

Before any digging or mining in a cave was possible, it was necessary to have light. Extant evidence indicates that the most commonly used light-source was flaming fat-pine faggots; however, it seems safe to assume that flambeau or some other forms of torches were used. It was known practice to soak dried cat-tail heads in animal fat or pine pitch for use as torches. It was known procedure, by the Indians at least, to cut sections of hollow plant stalks or reeds, fill the hollow portions with melted animal fat which hardened upon cooling, and thus provide a combined wick and source of fuel. Sometimes bound bundles of oat-straw were used. Spectroscopic study of certain black deposits from saltpetre sections of Clark's Cave indicate that these deposits are organic in nature. It is logical to conclude that soot from torches and other lights constitutes at least a part of the samples that have been analyzed.

While existing conditions in a particular cave were determining factors in the equipment the miners used, the basic tools remained similar and rather uniform in type throughout the whole industry. If the passages in which the deposits were located were large in comparison with the size and height of a man, and the petre-dirt was friable and loose, a shovel was about all that was necessary in the mining operation. However, if the passages were small, low, and narrow, the miners were forced to use other tools. In such cases, wooden paddles ranging from the size of a man's hand, having a handle portion ten to twelve inches long to some of approximately ten by 12 inches in size with a handle portion about two feet long, were commonly used. Many collected samples show considerable deviation from these dimensions. Such differences appear to have been largely the result of personal taste.

Observations indicate that paddles of various sizes and shapes were used to scrape the petre-dirt from ledges and cracks in which the material was lodged. If available paddles were too large for particular spots, it was not uncommon for the miners to use long-shanked, chisel-pointed scraping and digging sticks, an inch to an inch and a half in diameter and from six to 30 inches in length.

Occasionally it was necessary to split a rock from the cave wall either to allow easier access to a deposit of petre-dirt or to permit a man to move forward along a deposit seam. For this purpose a glut was usually employed. This tool is a large, rather blunt-nosed wedge of wood as large as five inches in thickness and from 12 to 16 inches in length, cut from a log. To use this tool it was necessary to have a large mallet or a small maul with which to drive it. Both these tools

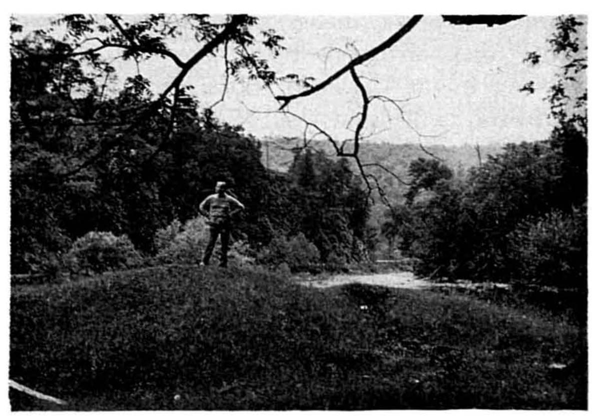


Photo by Marie Hansen

Piles of leached cave earth. The vats were located near the banks of the stream.

were made of hickory, osage orange, dogwood or some other tough, split-resistant wood. The mallet heads were generally cylindrical in shape, about four inches in diameter and from six to eight inches in length. A short handle, eight to ten inches long, was usually wedged in a diametrically-augered hole that passed through the center of gravity of the head.

Even with the best of minnig tools available, the petre-dirt was of no use until it reached the processing equipment. This involved a great variety of transportation means and the existing situations in a particular cave conditioned the methods and means employed. If the cave was sufficiently large and accessible, oxen-drawn carts were used as, for example, in Mammoth Cave and the Great Cave on Crooked Creek in the Rockcastle region in Kentucky[A]. In others, such as Sauta, in Alabama, a tramway or railroad was constructed over which a mule could pull a track-guided car of petre-dirt to the cave entrance.

Among the uncommonly found tools are metal picks, metal scrapers, push-pull boxes, wooden-stick grapples, and sieves. Evidence presented by pick-marks indicates that blades of different widths were used. Those observed in Tony's Cave measure nearly three inches in width. Such marks seen in Clark's Cave are about two inches in width. Those found in Burnsville Saltpetre Cave (Breathing) are not more than in inch across. Shovel-traces the writer has seen measure four to five inches in span.

One metal pick that has been found is a two-bladed mattock-type implement. The head is approximately 12 inches long and about two inches thick, with one blade perpendicular to the long axis of the head and the second blade transverses to the same axis. Midway between the blades, an eye is formed through which a 30-inch handle is passed and wedged in position. Thus a dual-purpose tool is provided. One blade served as a digging and dirt loosening tool and the other, which is blunt-edged, was available as a wedging and lifting tool. This blunt-edged, wedging-blade would also serve as a sledge to break rocks so they could be moved more easily.

At least two scrapers have been found, both of which present evidence of great use. One, in the possession of the writer, is about four inches broad and three inches high with an oval opening about an inch and a half wide forming an eye at the top of the blade, in which a 24-inch handle is mounted. The blade of this tool is about one-fourth inch in thickness and appears to have been made by heating a flat piece of wrought-iron in a forge, folding it in half, and uniting the halves into a single piece by means of a hammer weld, then working the plate into a the eye for the handle was punched.
hoe-shapel piece. By means of a swedging tool

Another rare piece of equipment is a push pull box. The one in the writer's possession is a rectangular box with inside dimensions of 12 inches long, eight inches wide, and four to five inches deep. It is formed of rough split boards fastened with so-called cut-nails available during the 1860's. Near the top at one end is a hole through which a fiber thong was threaded when the box was found. Apparently this box was used to haul petre-dirt through an opening too small for a man to negotiate easily. Evidence indicates that one man pushed the box through such an opening with a long stick. A second man would fill the box at the petre-dirt deposit, then by pulling the thong, the box could be brought to a more accessible spot where it could be emptied into a container that was carried to the surface. The box was then returned for another load.

Another different and also uncommon piece of equipment is a form of grapple. The sample the writer has is shaped like a wishbone with one leg about six inches long and the other leg about five feet long. Apparently this implement was used by lowering the short end through a small hole in the cave floor to a lower level. Another man working there would hook a bag of petre-dirt between the legs and the top man would haul the load to a more accessible spot after which the petre-dirt would be taken from the cave.

Since the labor required to remove the petre-dirt from the cave was arduous and tedious and the rocks were of no value, it was a common practice to sort the loose rocks from the dirt. Larger rocks were removed by hand picking. Evidence of this is found in the many walls laid adjacent to the diggings and the rubble piles in the general areas of the petre-dirt deposits, such as are found in great abundance in Clark's Cave.

Sieves constructed in a variety of forms were used to remove the smaller rocks. Some were rectangular, ranging in size from one to two feet in width and two to four feet long and three to six inches in depth. Others were roughly cylindrical or bucket-shaped in form, four to six inches deep and 16 to 24 inches across the top, and had hand-holds adjacent to the top. The bottom, or the screen portion, was made by interlacing wires across the opening or by punching holes in a flat piece of sheet metal, thus making a collander-like bottom. Either form would retain the rocks and allow the finer material to pass. There is much evidence of extensive use of sieves in Clark's Cave.

When it was not possible to use animal-drawn carts or cars to move the petre-dirt to the processing point, it was necessary to use other means. From all evidence observed, the miners carried the dirt in bags slung across a shoulder, or dragged them through the crawlways. These bags were generally similar to the present day burlap, jute, or gunny sack.

Another extremely interesting and unusual piece of equipment used by the "Petre-monkeys", in the possession of the writer, is what may be called a bag-holder. This particular sample resembles a stirrup in form. It is made of a flat-sided, rounded-edged piece of wood nine inches long, one and one-fourth inches wide, and three-fourths of an inch thick.. In each end and in the bottom, metal prongs have been driven. Over the top, a U-shaped, rounded, and smoothed piece of wood has been arched. Adjacent to the ends of the flat-sided piece, holes have been bored. Into each one of these holes one end of the U-shaped arch has been inserted and fastened. Thus a triangular isosceles-shaped structure is obtained with the crotch angle rounded. Apparently this tool was used by placing a bag on the ground; inserting the tool within the mouth of the bag; hooking the prongs into the meshes of the bag adjacent to its mouth; stretching the bag over and around the arched top; holding the bag and tool in one hand; thus, holding open the mouth of the bag into which the petre-dirt could be pushed.

Now and then it was necessary to lift the petre-dirt from pits. Under such conditions, it was a practice to provide a winch. Sometimes this was done by constructing a log frame, similar to a saw-buck, over the mouth of the pit. A smoothed wood cylinder, of uniform diameter and longer than the distance between the side frames, was mounted horizontally between the support legs and above their intersections. The cylinder was supported on bearing blocks and held directly over the pit. Crank-handles were fixed on each end of the horizontal log. A rope fastened to the cylinder would wind in a spiral around its circumference as the cylinder was rotated, thus lifting a load to the surface. Occasionally, the support frame was modified and the horizontal cylinder was supported on vertical bearing blocks which were held in an upright position by angle braces.

Tally-marks records are found in many petre-dirt pits. In the case of deep excavations, different sets of marks may be seen at different elevations above the existing floor, apparently because these marks were made as the excavation progressed. The significance of such records is not clear, but they probably represent units, possibly bags, of petre-dirt removed from the particular pit.

Since much petre-dirt was found in pits and consequently not readily accessible, steps or ladders were built to reach the deposits. In case the slope along the work route was not over 45°, flat stones were used for steps. An excellent example of stone steps is found in Buchanan Cave. If the pit walls were too steep for steps, then various forms of ladders were used.

Probably the simplest form was made by taking a log ten to 12 inches in diameter and notching steps into one side. The steps were cut at such an angle that when the log was placed in position, the step-treads would be approximately level. This log-type of ladder generally was the most practical to use in ascending or descending steep, small openings. One use of this form is found in the Big Bone and Arch Caves system.

Another form of single-pole ladder was made by augering holes through a log along a longitudinal line and driving pegs into the holes so they extended on both sides of the log. Thus a tree-like ladder was formed up which the men could climb by stepping from one peg to the next on opposite sides of the support pole. A ladder of this type was found in Sinnet Cave.

Photo by Burton Faust

One form of ladder found in Trout Cave.

A slightly different form was shaped very similarly to a wish-bone. This type was made by splitting a sapling, about four to five inches in diameter, from one end to within a foot of the other, and spreading the split end apart. Cross-pieces were fastened between the split portion to provide steps. Thus a ladder with a single pole at the top and a substantial double support at the bottom was available. This type served admirably to provide an access to a narrow crack in an upper part of a passage. A ladder of this type was found in Madison's Cave.

Other ladders were similar to present day forms. These ladders comprised straight, strong uprights through which matching holes were augered. A number of smaller pieces of wood, equal in number to the number of pairs of holes in the uprights were prepared by whittling their ends so they would give a tight fit when driven into the holes. Thus by means of a pair of uprights and a number of crosspieces for rungs, a ladder was readily made. There was considerable range in the lenghts of these ladders. The writer has seen some as short as five feet and as long as 20 feet. These were generally constructed so they could be easily dismantled into their component parts and moved through narrow passages and reassembled at a new location.

Probably the most elaborate form of ladder and one of the best examples of workmanship is illustrated in a specimen found in Great Salt Petre Pits in Tennessee. This particular type was made by squaring one side of each of two logs about ten inches in diameter and approximately 35 feet long; cutting slots about two inches wide and at a predetermined angle in the squared faces (in the example mentioned, the slots measure 13 and one-half inches on centers) ; providing pieces of planks about two feet long that would slide into the notches; augered two-inch holes completely through the logs about every ten feet of their lengths; moving the disassembled logs and planks to the desired location in the cave; assembling the ladder by spacing the logs in an upright position the necessary distance apart with the slots approximately level; sliding the plank-ends into their matching slots; inserting the round crosspieces into the augered holes; and pinning them in place to prevent the logs from spreading and to hold the component parts in assembled relation. Thus a form of step-ladder was made for places where a permanent installation was needed for heavy traffic.

These were the typical forms of ladders. Combinations of the basic forms were used and local conditions necessitated considerable variation in installations. One interesting general observation may be made as evidenced by inspection of many different ladders and installations in many different caves: the more elabroate the design, the better the workmanship, and the better the state of preservation.

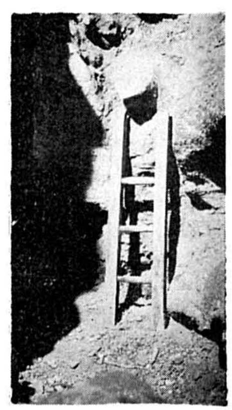


Photo by Burton Faust

More elaborate ladder in Clark's Cave.

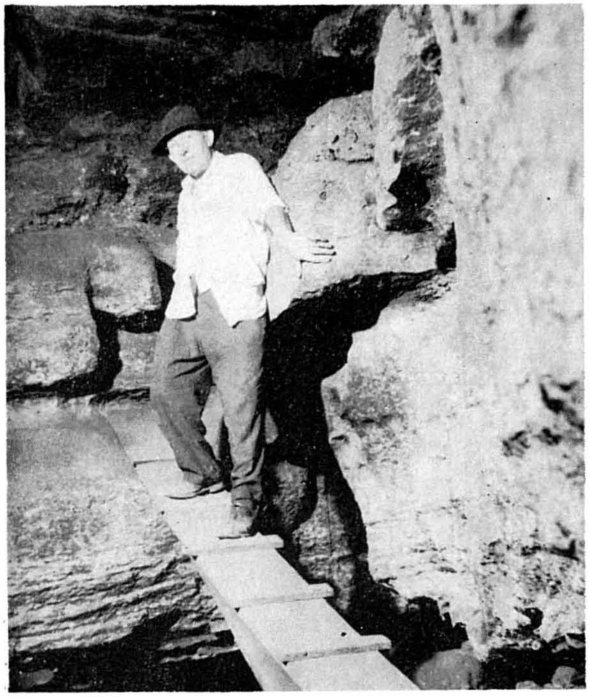


Photo by Burton Faust

Plank foot-bridge showing use of cross cleats to aid traction.

Often it was necessary to traverse pits or chasms to reach the petre-dirt deposits. If it were not possible or practical to fill the pit with rocks and provide a walkway, it was a common practice to construct bridges. In some instances, a bridge was built by the use of one or more logs to form a stringer construction to support a plank over which the miners could walk. Sometimes, if the plank were laid on an angle, cleats were fastened to the top surface to provide footholds to keep the men from slipping. On occasions it was necessary to build an elaborate trestle-work structure to provide support for walkways. In a discussion of walkways as well as ladders, few general statements can be made since the means employed and the practices followed were governed by local conditions. All extant evidence indicates that everything possible was done to ease the lot of the miners in the salt-petre caves.

In some instances, the cave entrances were sufficiently close to the deposits that the men could carry the petre-dirt directly to the processing point. In other instances, the caves were too high in the mountains and the approach slopes too steep to make such a means of transportation practical. At locations such as Clark's Cave and Trout Cave, another expedient was utilized. A chute or trough extending from the cave entrance down the steep slope to a lower elevation was constructed. The petre-dirt was dumped into the trough at the cave entrance, where it rolled or slid down the hill to a supply heap for the processors. Sometimes it was necessary to push or drag the dirt to keep it moving[B].

Photo by Burton Faust

Slab rock steps along a miner's path in Buckhannon Cave.

After the petre-dirt had been mined and transported to the recovery plant, entirely different types of equipment were used.

Major Raines, in his "Notes", lists the "Articles wanted to make saltpetre on a small scale."

One ordinary iron pot for boiling; three or four tubs, pails, or barrels cut off; two or three small troughs; some coarse bags or a wheelbarrow to bring the earth from the cave, and four strong barrels with one head in each—empty vinegar whiskey, or pork barrels are very good—are about all the articles required for a small saltpetre manufactory. To these, however, must be added some ash barrels to make potash lye, as it is better that this should be made at the same time and place, the ashes from the fire under the pot for boiling assisting in the production.

Let us follow Major Raines' instructions in the steps for recovering saltpetre from the cave-earth and then consider some of the variations in operation that were introduced into the procedures at different caves.

First bore a hole about the size of the finger through the head or end of each barrel near one side, and fit a wood plug to each hole—then set the barrels on some pieces of timber near each other, the heads down, and the hole of each projecting over the timber. Put some twigs into the bottom of each barrel, and on these place straw or hay about half a foot thick when pressed down; then, having brought some of the earth from the cave, and broken up all the lumps, fill each barrel full without pressing it down. Put the plugs into the holes tightly, and fill up each barrel with as much water (hot water is best in winter) as it will hold; allow the whole to remain until next day, then pull out the plugs, having placed a tub or pail under each, and pour all the water from the first barrel into the second barrel, and all the water or liquor which drains from this barrel must be poured on top of the earth of the third barrel, and finally the liquor which drains from this last barrel must be poured into a tub or other vessel. Now having previously made some strong lye from wood ashes, pour a small stream of it into the tub and stir it well; immediately the clear liquor will become muddy, and as long as the lye continues to curdle or cloud the liquor, it must be poured in; of course you will have to wait now and then for the liquor to settle to see if it requires more lye. No more must be used than is necessary, for it not only wastes the lye, but is an impurity which the refinery must afterwards get rid of. We will suppose that the proper quantity of lye has been used, and the liquor allowed to settle or drain through cloth until it becomes clear; it is then poured into the pot and boiled away until a drop taken up by the end of a stick becomes hard or solid when let fall upon cold metal or upon a plate.

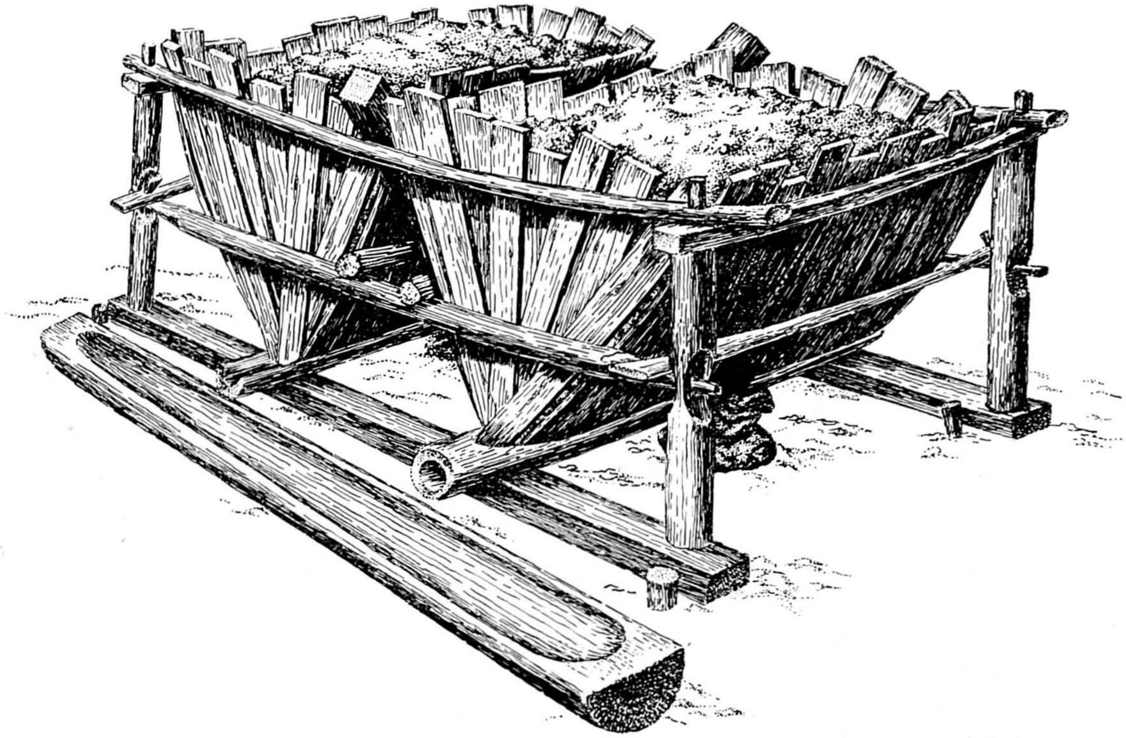
The liquor is now to be dipped out of the pot and poured into a cloth placed over a tub or barrel, and allowed to strain through into the tub below and become cold. As soon as the liquor begins to cool, crystals of saltpetre will commence forming, and when cold the liquor left—called mother liquor—must be poured off from the saltpetre back into the pot with the fresh liquor for boiling, as it still has considerable saltpetre in it. ....

The saltpetre formed by the foregoing process must be first allowed to drain well, and then placed on cloths stretched before the fire or out in the sun to dry; when the drying is completed, it is to be put into sacks or barrels, and is ready to be transported to the Government Agent at Nashville, Lieut. M. H. Wright, C.S.A. ordnance officer, who will pay for the same on receiving the bills of its shipment on the railroad.

The above instructions prepared by Major Raines were for production on a small scale. This procedure had been followed for many years by small producers and plantation owners. One such noted producer was Nicholas Cresswell[10], who, even though a Tory, used almost exactly this method to make saltpetre in Alexandria, Virginia, for sale to the Colonists during the Revolutionary War. However, Major Raines also prescribed procedures to follow for production on a large scale. He suggested the use of large vats rather than barrels in which to leach the cave-earth.

There are several general types of leaching vats. The most commonly used was of a generally V-shaped form constructed in a manner similar to the following description:

Four posts about six feet long were prepared by squaring one end and augering a longitudinal hole about eight inches deep in the center of the same end. About two feet below the squared or top-end, a slotted eye about two inches wide and four iches long was augered and chiselled through the post. Two logs about four to five inches in diameter and a little over seven feet long were squared and shaped on each end to fit the eyes of the posts. Holes were dug in the ground on each corner of a rectangle in which the posts were to be set. After one post was set and tamped solidly in position with the eye opening across the shorter side of the rectangle, a second post was positioned at the adjacent corner of the



Drawing by Carolyn Bartlett

Restoration of a double leaching vat. Note the two types of spouts which conduct the leach-brine to the storage vat.

shorter side of the rectangle. However, before the second post was tamped, one end of the previously shaped logs was inserted into the eye of the set post and a hole augered through it on the outer side of the post through which a wood-peg was driven to hold this log and the post in tight contact. The other end of this cross-log was placed in position in the eye of the untamped post, augered, and pinned in place. This set the distance between the posts before the second post was tamped. In a like manner the two posts at the opposite end of the rectangle were positioned. Next, four logs were prepared to be placed atop the posts. This was done by cutting logs of appropriate length, squaring the ends, and augering holes in the squared portions, placing them in position on top of the posts, and driving wood pegs through the holes in the logs and into the holes in the tops of the posts. Thus a solid, three-dimensional, rectangular frame was formed.

A straight-grained log about ten inches in diameter was split lengthways and two semi-circular pieces obtained. The half-log was grooved and hollowed along its center from one end to about a foot from the other, thus forming a trough with one end open. This trough was centered parallel to the long axis of the rectangle and held by flat rocks about a foot above the ground with the closed end a few inches higher than the open end[C].

Next boards[D] were placed with their lower ends resting within the groove of the trough and their upper ends leaning against the top rail of the longer side of the rectangular frame. Thus, a large open-ended V-shaped trough was formed. A log about three to four inches in diameter was placed lengthways through the frame and rested atop the cross-rails that spanned the short ends of the frame. This log was pushed close to the outside portions of the slanted boards and fastened in place by lashing or wood-pegs. In a like manner another log was located adjacent to the opposite side of the V-shaped trough. These logs provided additional support and stiffening of the trough. The ends were closed by placing other

boards across the openings. This last step gave a large V-shaped vat with a drain in the bottom. A layer of twigs with a covering of straw was ready to use.

Other forms of leaching-vats were used, only one of which is described here. This type was constructed in a manner similar to the following: A proper foundation was prepared on which was placed a series of parallel strong logs about a foot above the ground. From front to back, these parallel logs were successively higher. Half-logs with rounded trough-like grooves cut in their plane surfaces in a longitudinal direction were laid in close parallelism across the tops of the support logs. A second layer of half-logs, grooved in a like manner, was laid with the grooved faces down, spanning the edges of the lower layer. The two layers of grooved half-logs formed a sloping, tight, rectangular platform or bottom in which the lower layer served as drains and the top layer as closures and guides for fluid. Sides which were usually from three to five feet high were constructed above and within the confines of this platform or bottom. This produced a large capacity leaching vat such as was used in Mammoth Cave and the Big Bone-Arch Caves system.

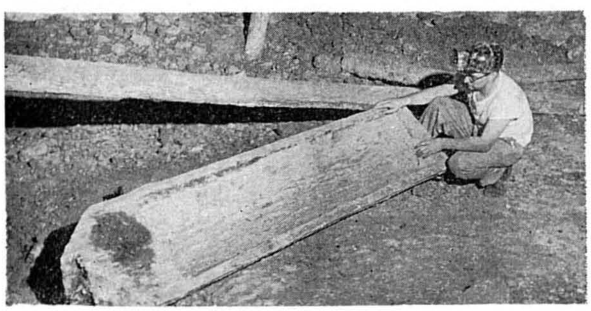


Photo by Roy Davis

Collecting trough made by hollowing log.

Since Major Raines recommended that the amount of water used to leach the cave-earth be kept to a minimum "otherwise there will be much time and fuel lost in useless boiling of a weak liquor; this is a common error at the caves, and causes the saltpetre to cost more than is necessary in time, labor and fuel,"[9] the leach-brine was made to percolate through three or four leach-vats so it could become more thoroughly saturated with the calcium nitrate, before further treatment. This was accomplished in various ways. Sometimes, the leach-brine that had been collected in watertight troughs, vats, or tubs was transferred to the next leaching-vat in buckets. Sometimes the vats were located in a cascade plan and the leach-brine that drained from the bottom of one vat would flow to the top of the next vat. An installation of this type was used in Buchanan Cave. Evidence has been discovered that pumps similar to the Colonial fire pump were used.

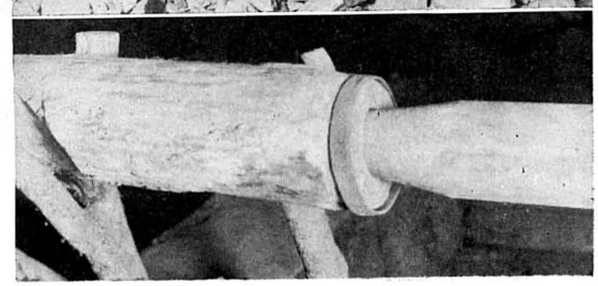


Photo by Russell T.Neville

TOP—One hollowed log pipe line brought water into cave; the other conducted leach-brine from the cave.

BOTTOM—Joint in wood pipe line. Note metal band reinforcement.

On occasions it was more convenient to locate the leaching-vats in the cave in close proximity to the petre-dirt deposits. When that was done, the water was often brought into the cave through a pipeline and the leach-brine pumped to the surface to the boiling kettles. The remains of such installations can be seen in Mammoth Cave and in the Big Bone-Arch Caves systems. When water was available in the cave, it was carried to the leaching vats. Occasionally a dam was constructed across a cave stream and sufficient head produced that the water could be carried to the leaching-vats in a flume. The ruins of such an installation are found in Tony's Cave.

Evaporating equipment usually comprised a hemispherically-shaped iron kettle or a square-sided, flat-bottomed, shallow pan similar to a sugar or molasses boiler. In either event the evaporating vessel was supported by a flange around its top in a furnace or fire-box which generally was constructed of flat rocks laid in the form of a cylinder or box. An access opening was provided in one side of the furnace, through which the fuel was fed to the fire; a flow flue or stack, on the opposite side of the firebox, served to provide draft for the fire and to conduct the smoke above the heads of the workmen.

After the leach-brine has been concentrated to the point that the crystals of salt-petre have formed, Major Raines advised:

If the crystals of saltpetre are wet and brown, and will not keep dry, it is because too much lye from the wood ashes has been used; this can be removed by nearly filling a tub or barrel with the saltpetre and pouring cold water on it, as much as the tub will hold, and after remaining about one hour, the water can be drained off from the bottom, when it will carry with it most of the lye; this wash water must be poured into the lye of the wood ashes so as not to lose the saltpetre which it contains[8].

While the above procedures will recover the salt-petre from the cave-earth, there still remains the very important step of refining it before it is ready to be used to make gunpowder. Major Raines suggested that the articles required on a small scale are:

Two evaporating kettles or sugar pans capable of containing about 40 gallons each; one kettle or boiler holding not less than twenty-five gallons; one barrel arranged with a hole and plug at bottom, and covered loosely with two thicknesses of bagging, or coarse cloth, at its open end, forming a bag for straining; one shallow wooden trough six feet long, three feet broad, and nine inches deep, for cooling; one wooden rake; one spade or shovel, having a long handle; one wooden straining box or trough, three feet three inches long, twenty inches broad and six inches deep, with several small holes in its bottom—this box is placed on the top of the long trough, at one end; one wash barrel, having a second bottom pierced with holes about three inches above the true bottom, this second bottom is to be covered with coarse cloth—between the bottoms a hole and plug are made; one cask to receive wash water; one cask or barrel nearly filled with water to receive all the refuse Saltpetre, and in which the old filtering cloths are thrown to dissolve out their Saltpetre; one cask or large barrel to receive mother liquor; one platform scale or set of steelyards; together with some bucket, drying cloths, etc.[9]

In using this equipment in the refining process Major Raines directed the operators to:

Weigh out two hundred and twenty-five pounds of Saltpetre and put it into the kettle or boiler, with sixteen gallons of water; light a fire under the kettle and let it boil—not too briskly, however—for about two and a half hours, removing the scum that rises to the surface, which should be thrown into an empty barrel. Cold water must be thrown in occasionally to keep the liquor to the same height in the kettle, for it must not be allowed to boil away. After the boiling is finished, allow the fire to die out, and dip out the liquor—not allowing it to cool—into the cloth on the top of the straining barrel, whence it is allowed to run into the long cooling trough; here it is constantly agitated by raking it forwards and backwards by means of the wooden rake, until it has cooled down to about blood heat, which will take probably two hours or more. Dur-

Photo by Standiford Gorin

Boiling kettle in Saltpetre Cave, Scottsboro, Alabama.

ing the time of cooling, large quantities of fine needle-shaped crystals of nitre will form in the liquor, which are to be taken out by means of the long-handled spade, and thrown into the draining trough on the end of the cooling trough. When the liquor has sufficiently cooled down, run it off into a cask sunk into the earth for that purpose, by means of a hole and plug in one of the lower ends of the cooling trough.

The crystals of nitre in the draining trough will now commence looking white as snow, and are to be left to drain until next day, when the nitre is removed to the washing barrel which should be cut off at such a height as shall be about half filled with crystals.

This barrel is then gently filled with cold water to the top, and allowed to remain one hour, when the plug is taken out, and the liquor which is nearly saturated with nitre—holding in solution all that remained of the mother liquor—is allowed to drain off into the cask kept for that purpose. The nitre thus made is nearly pure, sufficiently so for nearly all purposes, and can be made into gunpowder. To make the finest quality of Powder, however, the crystals must be TWICE WASHED *before being taken from the washing barrel, cold water being poured in each time until the barrel is full, and after remaining one hour each time, is to be drawn off as before, and the nitre well drained and then dried; the crystals now are entirely pure, and can be used for the best quality of gunpowder.*

The foregoing is the process, on a much larger scale, pursued at the Government Refinery, under the direction of the writer. . . .[9]

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Notes

A. This cave has been reported by Dr. Samuel Brown, of Transylvania Medical School, to be of such size that a team of oxen would pull a cart entirely through the cave without a driver in attendance.

B. A certain amount of evidence has been discovered that a bucket line on a circulating rope was used, on occasions, to transport material. However, it is not possible, at this writing, to support this conjecture.

C. Sometimes the lower end of the draining trough was left closed and a hole augered through that portion. This hole served as a drain for the liquid as it accumulated in the trough. Other minor variations in this point of structure have been observed. However, the basic idea is the same.

D. The term "board" generally was limited to a flat piece of wood rectangular in cross-section and usually not more than four feet long. Boards were made by splitting short, straight-grained logs using a frow and a mallet. Longer and larger pieces of similar shape were called planks and were generally sawed.
Some of the simple tests for authenticity of such material are as follows. If the board was split, there will be no saw marks. In planks, cut about this period, the saw kerf will be substantially perpendicular to the long edges of the plank. Generally, such a plank will have a short portion at one end that has not been sawed but will show the effects of spreading the plank from the log and splitting it to separate it. Footbridges in Clark's Cave and Trout Cave show such marks

Magnetic Cave---the Wonderful Hoax

By **WILLIAM R. HALLIDAY, M.D.**

Cave folklore can seldom be traced to its origin, much less be "explained away" to persons who accept it as fact. The cave that goes "all the way to .... (supply the name of any distant city)", or the cave that goes "under the river" can never compare with the fabrication of Magnetic Cave, product of ingenious gray matter. The author is well known as an explorer of California caves and is intimately acquainted with the locale of the supposed "cave". He sets forth a probable account of the circumstances behind the hoax, thus illuminating the dark recesses of one of the most interesting pieces of all cave folklore.

To anyone engaged in research in the newspapers of the last century it soon becomes painfully evident that journalistic veracity was then judged by standards which were entirely different from those of the present. Especially outside the largest cities, it was apparently the custom when news was short, to invent it. Even today this practice is not unknown, but in those days it was so common that the reader is forced to consider each cave item with considerable suspicion. When skillfully done, these hoaxes may be exceedingly effective. The now-famous Cyclopean Cave hoax of Colorado, for example, was reprinted in good faith in a reputable guidebook, and eventually in N.S.S. *Bulletin Nine.*

Very rarely, instead of attempting to make the story seem completely plausible, the reporter adopted a tongue-in-cheek attitude, and produced a story which must have seemed hilarious to the local readers. Even today, some of them are convulsively amusing to those familiar with the caves of the area and local history and traditions.

The Gold Rush times of the Mother Lode country of California were particularly likely fields for the development of such stories. It was full of real caves to prompt the imagination of the desperate reporter. Literary quality was relatively high, with such writers as Samuel L. Clemens (Mark Twain), Bret Harte, and William Wright (Dan DeQuille) at least briefly employed in newspaper work in this general area. Practical jokes and general lightheartedness were the keynote of the period, and even the best-known writers were not above occasionally pulling the public's leg. The most popular local organization was E Clampus Vitus, a semi-secret fraternal organization, which aside from its serious charitable functions, was devoted to horseplay. One of its aims was to "take in" everyone. This was applied in two ways. The unsuspecting public was "took in" by all kinds of hoaxes, and new members were "took in" to the organization with all kinds of horse-play. The great advantage of being "took in" as a member, in fact, was that the new member never had to be "took in" again.

Such were the circumstances under which two articles describing a remarkable cave appeared in the Sutter Creek *Independent* (Amador Co., Calif.) on May 6 and 13, 1874, and were reprinted in the Sacramento *Union* on May 8 and 14, respectively. They are here reproduced intact, with explanatory notes for the benefit of those not familiar with the geography, caves, or traditions of the area.

REMARKABLE DISCOVERY

In the great limestone range (1. LIMESTONE OCCURS LOCALLY IN FAIRLY WIDE, ISOLATED STRIPS IN THE WESTERN FOOTHILLS OF THE SIERRA NEVADA.) *which runs through the northern part of this county there have been found at different times a few cavernous formations of but little extent and no*

particular interest to the tourist or the scientific man. These caverns are generally nothing more than cracks or fissures in the earth, and easily and quickly explored even by the smallest boys (2. THIS IS THE KEY TO THE ARTICLE. THE EXTENSIVE, BEAUTIFUL AND DANGEROUSLY DEEP BLACK CHASM OF VOLCANO, STILL NOT FULLY EXPLORED, HAD BEEN KNOWN IN THIS EXACT AREA FOR ALMOST 20 YEARS, AND MANY OTHER NEARBY MAJOR CAVES SUCH AS MOANING AND CRYSTAL CAVES WERE OFTEN VISITED, OR AT LEAST WELL PUBLICIZED.) *We were informed by Linkit, a well-known farmer near Pine Grove* (3. NOTE THAT LINKIT'S INITIALS ARE NEVER GIVEN.)*, of a discovery upon his ranch which completely eclipses anything of the kind hitherto known upon the whole Pacific Coast Linkit's house is supplied with water from a spring which flows from the side of a large hill directly west of his barn. A few days ago the water ceased flowing, and after digging a short time with a pick and shovel to ascertain the cause of the trouble, Linkit suddenly loosened a large mass of soil which, in falling, disclosed a vast cavern. After returning to the house for light and assistance, he ventured into the cave, followed by his two sons, young men eighteen and twenty-two years of age. For four hours they wandered through the different apartments completely lost to all sense of danger by the novelty of the situation and the marvelous beauty of the stalactitic and other crystalline formations, with which nature had upon every side adorned the walls and roof of the numerous chambers.* (4. THE DESCRIPTION OF THE SPELEOTHEMS IS APPARENTLY BASED ON THOSE OF THE BLACK CHASM, BUT NO LENGTHY, HORIZONTAL LIMESTONE CAVE EXISTS IN CALIFORNIA.) *In one place, which they named the "Devil's Hole", a stream of bright green water leaped from a circular aperture in the ceiling of the largest room, into a chasm of irregular shape, and apparently of immense depth, large rocks dropped into it returning no sound after passing over the edge of the awful abyss. Upon the west side of a chamber nearly triangular in shape, perhaps one mile from the entrance, were found several square yards of neatly chiseled characters which must possess an almost fascinating interest for the scientologist, and may when decpihered, throw some light upon the supposed former occupation of this county by the Aztecs and their predecessors. Our limits will not admit a more extended description of this great natural wonder, but those who wish to visit the cave can get directions by calling at this office.*

Apparently a horselaugh was planned for anyone actually calling for directions, but it is probable that the reporter did not anticipate the state-wide interest aroused when the item was reprinted in the *Union*. When it became apparent that thousands of persons had fallen for the joke, it seems probable that the local residents, who were almost certainly well aware of the actual situation, saw a wonderful opportunity to pull the collective leg of the rest of the state. Consequently, the second account appeared a week later.

THAT WONDERFUL CAVERN

When on Wednesday morning last we published an account of the discovery of an extraordinary cave on the ranch of Linkit, near Pine Grove, we were troubled with some doubts as to whether the account given us by that gentleman were strictly true. Our duty to the public, however, compelled us to recite the particulars as they were given us, and to trust to future investigation for a corroboration or a disproof of their correctness. (5. AS IN THE FIRST ACCOUNT, THE TONGUE-IN-CHEEK ATTITUDE IS APPARENT IN THE OPENING LINES.). *Since the publication was made we have received numerous letters and telegrams from various portions of the state, asking for further particulars of the discovery, and such was the interest aroused in the matter that we felt called upon to ascertain beyond a doubt the truth or falsity of the marvelous account of Linkit. Being unable to be personally present at the exploration of the cave, we telegraphed to three citizens of the county, whose names we were well aware would be a sufficient guar-*

antee of any report they might see fit to make. These gentlemen were J. W. Jameison of Fiddletown, W. H. Stokes of Ione City, and D. W. H. Mason of Jackson, all of whom happened to be in Jackson attending to court business (6. IT WOULD BE MOST INTERESTING TO KNOW MORE OF THESE GENTLEMEN, ESPECIALLY THE NATURE OF THEIR COURT BUSINESS, OR ANY POSSIBLE CONNECTION WITH E. CLAMPUS VITUS.). *They all consented to make the investigation, and we received from them yesterday the following report of their discoveries:*

Pine Grove, May 10, 1874

Editor, Independent: At your request, Jameison, Mason and myself determined on Friday last to come to this place and make a thorough exploration of the wonderful cave lately discovered on the ranch of Linkit, about a mile and a half northeast of this place (7. THIS IS THE APPROXIMATE DISTANCE AND DIRECTION ON A MAP OF THE BLACK CHASM FROM PINE GROVE.) *We started from Jackson on Friday evening, accompanied by Alfred W. Tooms of 1204 Stockton St., San Francisco, who was exceedingly anxious to join us in the fascinating investigation* (8. A POSSIBLE SUCKER?). *Arriving at Linkit's house, we found the gentleman to be a prosperous farmer, moderately well-to-do in the world and, withal, very accommodating and gentlemanly. He kindly offered us the hospitality of his house, which, of course, we accepted with pleasure, and freely offered to conduct us on the succeeding day through the intricate galleries of the cavern. Yesterday, having first supplied ourselves with candles, rope, twine, compass, etc., we entered the cave, conducted by Linkit, who for several days previous had been engaged in exploring it. To prevent the possibility of getting lost, we attached the end of one of our balls of twine to a tree at the mouth of the cave, and unrolled the ball as we proceeded, thus furnishing us with a guide in returning, and also enabling us to accurately measure the distance traversed by us* (9. THE WRITER FAILED TO CONSIDER THE WEIGHT AND BULKINESS OF TWO MILES OF TWINE.) *For the first half mile the main gallery has a general course northeast and a descent of about 200 feet, there being nothing especially remarkable* (10. SUCH A PASSAGE IN A LIMESTONE CAVE WOULD BE NOT ONLY REMARKABLE, BUT UNIQUE IN CALIFORNIA.) *or even interesting in its appearance, it resembling more than anything else a tunnel or drift in a mine from which chambers of ore had been taken; sometimes widening out to 50 or 60 feet and then contracting for four or five feet. At this point, however, a sudden change takes place, there being quite a steep descent of about 150 feet, as the bottom of which commences a series of chambers, connected by short galleries, the whole series having a general course of about east, and a gradual descent. These chambers are beautifully decorated with stalactites and stalagmites, but I will not attempt to describe them, preferring rather to pass on to the distinctive features of the cavern, which render it the most wonderful natural curiosity on the face of the earth* (11. FALSE MODESTY WAS NOT ONE OF THE FAILINGS OF THIS PERIOD.) *One mile and a quarter from the mouth of the cave, and a short distance beyond the "Devil's Hole" where the stream of water leaps from the ceiling into an apparently bottomless pit, there is a very large chamber, the dimensions of which we are unable to determine, on one side of which there is a hot spring which emits at regular intervals, puffs of steam having a slightly sulfurous odor* (12. NO SUCH PHENOMENON EXISTS IN ANY LIMESTONE CAVE IN AMERICA.). *This chamber appears to be the end of the cave, but a close search revealed to us a small opening, through which we proceeded with difficulty about 100 yards. Here it opened out into a long but rather narrow chamber, the walls of which are not limestone, but a yellowish brown and black iron ore. Upon entering this chamber we noticed a most peculiar disturbance of the magnet, the needle continually vibrating from side to side, and frequently whirling around for a minute at a time, with a velocity which rendered it invisible* (14. FINE IMAGINATIVE WRITING.). *We also experienced a singular sensation—a sort of chill appearing to commence at the*

back of the neck and extending to the very tips of our fingers and toes. As we advanced in this chamber we found these singular sensations to increase in intensity until it became almost unbearable. We ventured on still farther, however, though it became evident that we could not long remain in this mysterious place. I omitted to mention that the walls and floor of this chamber, especially rocks therein contained, were highly magnetic, and became more so the further we advanced toward the north; one of the party who carried a hatchet had it suddenly wrested from him by a magnetic rock near which he passed, and the combined strength of four of us was insufficient to detach it. A pocket-knife, which accidentally dropped to the floor, had to remain there, none of the party having sufficient strength in his fingers to pick it up. Mason, who had put on for the occasion a pair of miners' boots, the soles of which were filled with nails, could walk with difficulty, and happening to step upon a portion of the floor unusually magnetic, found himself suddenly affixed thereto, and unable to move. He was compelled to withdraw his feet from his boots and leave them there (15. NO SUCH ORE EXISTS, AND UNTIL RECENT YEARS, EVEN ELECTRO-MAGNETS OF SUCH STRENGTH DID NOT EXIST) *, tearing up his coat and wrapping the pieces around his feet to protect them from being cut by the rocks. We had remained in this chamber about ten minutes when suddenly the chilling sensation began to increase, the feeling being as if a cold and piercing wind was blowing upon us, and becoming each moment more intensely cold. We hastily retreated and soon reached, feeling more dead than alive, the large chamber containing the hot spring. We then retraced our steps along the twine, and in a couple of hours emerged from the cave. We examined the supposed hieroglyphic characters mentioned in your paper of the 6th inst., and are of the opinion that they are not artificial, but have been formed by the action of water trickling over the face of the rock. The description of the magnetic chamber given you above is true in every particular and each one of the party will vouch for it. We were none of us excited or frightened until just before our exit from the chamber, notwithstanding the strange and mysterious phenomena well calculated to make us so. Those who wish to visit this part of the cave may do so, but none of this party ever will. We have had enough of it.*

Respectfully yours,

W. H. Stokes.

It is indeed unfortunate that all cave hoaxes are not in such memorably sprightly form. Speleological bibliographic research would be a happier as well as a simpler task were it so. As to the possibility that this might be a lurid tale based upon an actual discovrey, it can only be said that field investigation and local inquiry have revealed no trace of any such cave in the area pinpointed so closely. Those who are optimists are invited to search for it, but to most California speleologists, Magnetic Cave remains The Wonderful Hoax.

Caves and Related Features of Michigan

By **WILLIAM E. DAVIES**

Michigan, long noted for its great area underlain by limestones, is an example of the effects of total glaciation on an ancient karst area. The few solution caves that do exist are in marl of comparatively recent origin. The description of the giant sinks in the Thunder Bay area reveals a process of rejuvenation by which the caves of tomorrow are being formed.

Sometimes the incidental notes and observations made during field work seem to possess little value and one is often tempted to clear the books by removing all data not pertinent to a specific subject—so it seemed when scanning through some old notes made during a college field trip in Michigan in 1940. They merely noted Rainy Lake as a large sink that occasionally dried up and that a few large sinks lay west of the lake. At the time interest was in limestones rather than in caves they contained. Since the war ended the statement that there were no caves in Michigan, as generally voiced by most speleologists, seemed to make the random notes of more interest. During the summer of 1950 the chance came during a vacation tour to convert those brief sentences on sinks into something of use. By revising the old haunts, this time with an eye more for caves than limestone, a different picture of caverns in a "cavernless" State developed.

Geologic Setting—From a geologic standpoint Michigan is a huge basin with the rocks sloping gently from the edges of the State towards the center. Rocks of all types form the bedrock surface and include a thick series of limestones. The oldest rocks in the State are granites and related metamorphic complexes found in the western part of the Upper Peninsula. To the east and the south these rocks are overlain by sandstones of Cambrian age that in turn are succeeded by a vast series of limestones of Ordovician, Silurian, and Devonian age cropping out along the Lake Michigan and Lake Huron sides of the Upper and Lower Peninsula and in the southeastern corner of the State near Detroit. It is in these limestones that caves and related features are developed. In addition large sea caves are in the Cambrian sandstones along Lake Superior in the Upper Peninsula. (Fig. 1)

The center part of the basin contains beds that are younger than Devonian and are mainly sandstone. Some gypsum and limestone are present and show surface effects of solution in the Saginaw Bay area.

Outcrops of rocks in Michigan are comparatively rare. All of the State is covered by a mantle of clay, sand or gravel—a product of Pleistocene glaciation. Throughout most of the Lower Peninsula the glacial materials cover bedrock to great depth and normal topographic expression of bedrock is masked. In the northern part of the Lower Peninsula and adjacent parts of the Upper Peninsula limestones lie close to the surface and, though modified, the effects of solution show surface expression.

CAVES

Thirteen caves, most of which are sea caves, are known in Michigan. Solution caves are relatively rare, only three having been recorded in the state.

Bear Cave—Michigan's only commercial cave lies on the west shore of the St. Joseph river 3.5 miles north of Buchanan, Berrien County in the southwestern part of the State. The entrance to the cave is in a small wooden building located in a picnic meadow. The first 40 feet of the cave is a steep, winding stairway that has been constructed to connect with the natural cavern. (Fig. 2) At the base of the stairs a passage, 4 to 6 feet wide and 10 to 15 feet high, trends N60°E for 55 feet to a small room 20 feet wide and 30 feet long. (Fig. 3) A door at the north end of the room is the exit which opens on the bank of a small arm of the St. Joseph river. A beautiful waterfall drops from a marl terrace just north of the exit.

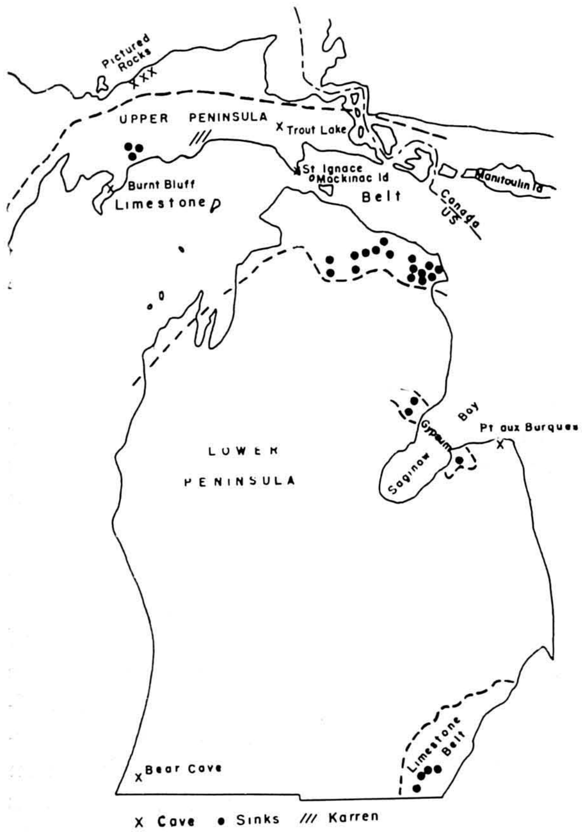

Fig. 1. Areas of solution terrane in Michigan.

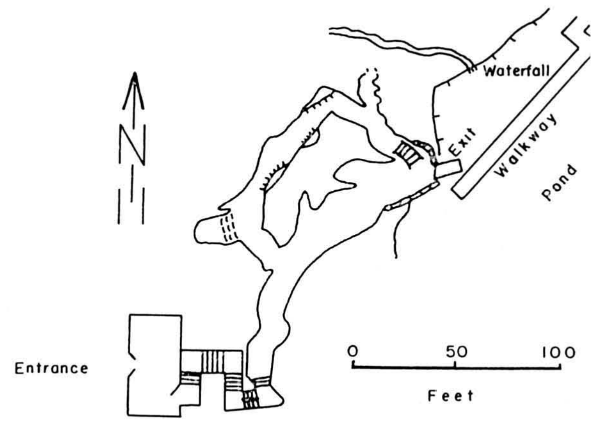

Fig. 2. Map of Bear Cave, Barrien County.

A small passage leads northwest from the end of the room and curves to the southeast parallel to the main passage with which it connects at the south end of the room. The southeast trend of the passage is developed along a prominent fracture in the marl. Formations line the walls and ceiling of the passage. Flowstone is abundant in niches and hollows in the walls while a few stalactites are on the ceiling of the short parallel passage.

The cave is developed in a marl deposit of Wisconsin (Pleistocene) age that forms a terrace 15 to 25 feet above the river. The original passages were 2 to 4 feet high but have been enlarged by excavating the floor.

The most interesting features in the cave are the imprints of fossil leaves, logs and animal bones that are found in the walls and ceiling of the passages. Also of scientific interest is the stratified glacial drift, consisting of sands and gravels that are interbedded with the marl. At the base of the entrance stairs the drift forms the lower four feet of the cave and contains boulders up to three feet in maximum dimension. Similar deposits but with smaller boulders form the lower part of the walls in the end room. The cave is of fairly recent origin since formation of the marl deposit as well as the excavation of the cavern has taken place since the retreat of the Wisconsin ice from southern Michigan.

Bear cave is apparently the only commercial cave that is developed in marl. However, similar wild caves are at Williamsport, West Virginia.

Bear Cave, owned by George Holmes, Buchanan, Michigan, was commercialized in 1936. The second passage was opened in 1940.

Fig. 3. View of Bear Cave, Barrien County.

Mackinac Island Caves—The caves on Mackinac Island probably boast of more "swanky" visitors than any other cave. Being easy of access, with good paths leading to them, the caves are inspected by many summer vacationists and casual tourists. Mackinac Island is formed of a breccia limestone—an old limestone undermined by giant caverns that ultimately collapsed forming huge masses of broken rock (breccia) which in turn was recemented as a limestone. The caves are not true solution caves but were developed by wave action of glacial lakes that were predecessors of our present Great Lakes.

Scotts cave is on the northeast side of the island near St. Clair Point. It is 145 feet above Lake Huron and is a result of wave erosion of Lake Nipissing. The cave is 15 feet long, 8 to 10 feet wide, and 9 feet high.

Skull cave, located at the south end of the island, 2000 feet north of Fort Mackinac, is similar to Scotts cave. It is 226 feet above Lake Huron and was developed on the former shore of Lake Algonquin. The cave received its name in colonial days when Mackinac Island was an important British outpost. Alexander Henry,[1] a fur trader, fled to Mackinac Island during Pontiac's Conspiracy and was hidden in the cave for the night by friendly Indians. Henry awoke the next morning to find his bed had been of human bones. The second night he chose to sleep in a nearby bush. On the return of friendly Indians he questioned them concerning the bones but all professed ignorance of them. It is possible the bones may be from ancient people who inhabited the area before the time of Indians.[2]

Other small sea caves on the island are Echo Grotto, Cave of the Winds, and Eagle Point Cave. Numerous sea arches, of which Arch Rock with a span of 80 feet is the most spectacular, are a result of cavern development by wave action followed by intensive erosion leaving only the arch.

St. Ignace Cave—A small solution cave lies in the bluff above Graham Street in St. Ignace. It is a small opening in breccia limestone that requires stooping and extends 30 feet to a pinch down. The cave slopes down 30 feet in its length.

Two caves have been reported near Trout Junction in the Upper Peninsula[3]. One of these was reported to be a natural bridge at Trout Junction. A road crossed the bridge and on each side were deep sinks with passages leading off. The passages were high enough to walk in, were 20 feet wide and a stream flowed in. A few hundred feet in the water was waist deep. The other cave was a low, stream cut channel 5 to 8 feet high with a Y shaped plan. At the end of the passage the stream plunged to a pool at the base of a shaft. Inquiry in 1955 at Trout Lake revealed that residents of the town have no knowledge of these caves and it is doubtful that they are now accessible.

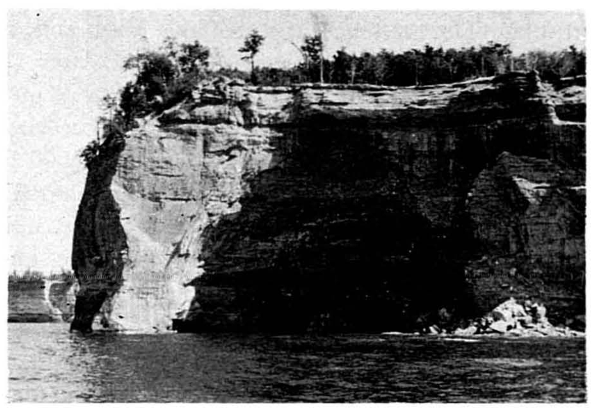

Fig. 4. The Grand Portal, Pictured Rocks, Lake Superior.

Sea Caves—At numerous points along Lakes Huron, Michigan, and Superior sea caves have been excavated by wave action. In the Lower Peninsula the largest are at Pointe aux Barques on the south shore of Saginaw Bay at its junction with Lake Huron. Here, in the Marshall sandstone, passages up to 20 feet wide and 6 to 8 feet high, form a maze extending several hundred feet. The caves are at lake level and a boat is necessary to explore them.

Caves of exquisite beauty are developed in Lake Superior sandstone (Cambrian) at Pictured Rocks along the shore of Lake Superior five miles Northeast of Munising. The Pictured Rocks are sandstone cliffs 50 to 300 feet high that drop shear to the lake's edge. The cliffs, ex-

1Henry Alexander; *Travels and adventures in Canada and the Indian Territories Between the Years 1760 and 1776:* New York, 1809.

2Stanley, George M.; *Pre-historic Mackinac Island:* Mich. Geol. Surv. Publ. 43, 1945, pg. 29.

3Anon. *Caves Found in Upper Peninsula:* Michigan Miner, Vol. 3, No. 10, Sept. 1901, p. 21.

tending ten miles northeast from near Munising to Chapel Rock, are colored by bands of red, yellow, green and gray rocks that are very beautiful. The waves of Lake Superior have undermined the cliffs at many places to produce caves of varying size. Five miles northeast of Munising is Miners Castle, a large sea cave cut at the base of a rock resembling a castle. Northeast of this area are several others—Colored Caves, Rainbow Cave, and the Indian Drum. Near the northeast end of the cliffs, 9 miles from Munising is Grand Portal, the largest of the Lake Superior sea caves. (Fig. 4) It is cut into a peninsula that extends 600 feet into the lake. The Grand Portal opens into the front of the Peninsula as a vaulted passage 100 feet high and 169 feet wide extending to an interior gallery 400 feet long. Three hundred feet from the front face a passage extends through the peninsula. The passages are at Lake level and a boat is necessary to traverse them. Water is shollow at the rear of the Grand Portal but quickly deepens to 50 feet at the entrance and drops to over 100 feet just beyond.[4] In 1906 a pillar at the entrance to Grand Portal collapsed and a large portion of the entrance archway fell forming a shallow, rocky reef across the entrance.

At the northeast end of the cliffs is Chapel Rock, a former sea cave now elevated 40 feet above the lake. It was a rotunda 40 feet in diameter with a cap rock supported by four massive columns. However, in July, 1955 the arch spanning the east side of the rotunda collapsed and much of the beauty has been destroyed.

The caves along Pictured Rocks are accessible by boat cruises from Munising during the summer. However, to see them in their fullest beauty they should be visited in winter for, in addition to the normal array of rock colors, ice and frost add to the spectacle. Surface water seeping through the ceiling covers the roof and walls with a myraid of transparent stalactites. Spray from lake waves freezes into fantastic forms inside the entrance. The frozen lake floor permits easy and close inspection. Caves similar but less spectacular than those of Pictured Rocks lie on the shores of nearby Grand Island.

Burnt Bluff Cave—Burnt Bluff is a prominent peninsula that juts into Big Bay de Noc on the west side of Garden Peninsula in the Upper Peninsula. The west side of the bluff, facing the bay, is a cliff 200 to 300 feet high. Twenty feet above the base of the cliff is a small passage large enough to permit walking, that extends about 100 feet. The cave is difficult of access as a ladder, formerly connecting it with the beach, is no longer servicebale.

Fayette Caves—Five miles northeast of Burnt Bluff on Garden Peninsula is the ghost town of Fayette. In the limestone cliffs along the lake, both north and south of the town, are a number of sea caves now elevated well above the present lake level. The caves are openings ranging up to 20 feet square and extending 20 to 40 feet into the cliffs.

Other Solution Features

While Michigan caves are limited in number and size, related solution features are developed to a spectacular degree. Sinkholes, disappearing lakes, and solution fissures of giant scale more than make up for the lack of interesting caves.

Sinkholes—Though relatively few in number sinkholes are of spectacular size. They are best developed in two widely separated areas. In the southeast corner of the State a belt of sinks in Upper Silurian limestones extends from near the Ohio line at Ottawa Lake north and curving to the east to Lulu in central Monroe County. The sinks are large, broad depressions up to a half mile long and a quarter of a mile broad. In wet seasons they fill with water to a depth of 18 or 20 feet but drain rapidly through small fissures. Ottawa Lake is a large sink two miles long and a half mile wide that formerly filled with water 50 feet deep in spring and slowly drained through subterranean fissures until late summer when the waters were only 25 feet deep with much of the lake a bare mud flat. Today most of the lake bottom has been reclaimed for use as pasture and deep standing water is uncommon.

Wells in southeastern Michigan have tapped subterranean limestone fissures and eyeless fish

[4]For a detailed description of Pictured Rocks see: Foster, J. W. and Whitney, J. D. Report on the geology of the Lake Superior Land District; Part II: Executive Doc. 4, U. S. Senate, Special Session, March, 1851.

The caves are beautifully illustrated by photographs in: Buel, J. W. America's Wonderlands: W. L. Richardsons and Company, Boston, 1893, pp. 333-336.

have been pumped from several of them.[5] Apparently large caverns and subterranean drainage systems underlie much of the southwestern and central Monroe County but the mantle of glacial drift obscures most surface connections to the passages.

In Huron County near Cassville and Iosco County on the Detroit and Mackinac Railroad due west of Alabaster several small sinks 10 to 15 feet wide and 10 feet deep are developed in gypsum beds of Mississippian age.

The largest development of sinks extends from Thunder Bay northwest towards Black Lake in Alpena and Presque Isle Counties. (Fig 5)[6]

The sinks are in limestone of Devonian age. Long Lake in northeastern Alpena County is possibly a result of sinkhole action on a giant scale. In spring when the overflow from the lake is large the larger part of the drainage reaches Lake Huron via Devils Lake and Long Lake Creek. In dry seasons the overflow ceases and Devils Lake is dry. The flow from Long Lake is then underground through a depression in the south arm of the lake.

Numerous sinks are developed in the northern

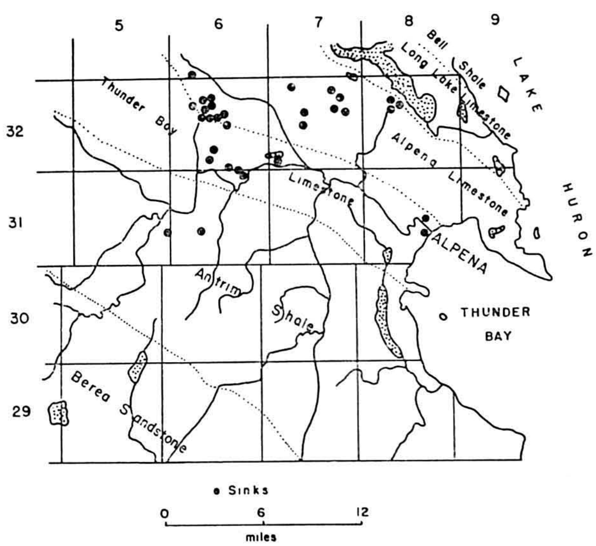

Fig. 5. Solution terrane, Alpena County. Modified from VerWiebe.

5Sherzer, W. H. Geological Report on Monroe County, Michigan: Mich. Geol. Surv. Vol. 7, Pt. 1, 1900, pp. 114-117.

6Poindexter, O. Floyd *Sinkholes in the Indian Lake Region, Schoolcraft, County and Other Michigan Sinks:* Mich. Acad. Sci., Arts, and Letters, Papers, Vol. 21, 1935, pp. 439-444.

part of Alpena County. (Fig. 5). Most of them are small shallow depressions three and one fourth miles north of Long Rapids is a group of large sinkholes. (Fig. 6) The sinks extend southeast from the county road and are in a heavily wooded area. However, frequent visits by sightseers have kept open trails that lead through the woods to the sinks. In this area there are six large sinks and several smaller ones. The

7VerWiebe, Walter A. *Stratigraphy of Alpena County:* Mich. Acad. Sci., Arts and Letters, Vol. 7, 1926, pp. 183.

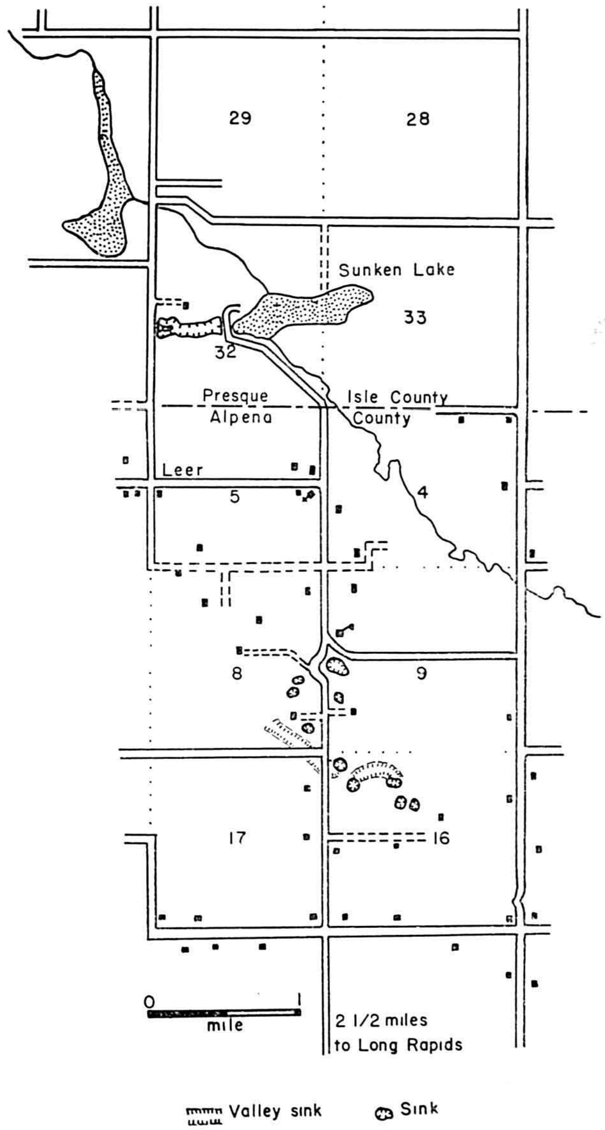

Fig. 6. Solution terrane in R6E, T32N, Alpena and Presque Isle Counties.

large sinks are 100 to 300 feet in diameter and 90 to 150 feet deep. (Fig. 7) Walls are vertical and expose bare limestone (Alpena Limestone). In some sinks large logs that fell in during lumbering operations 50 years ago cover the bottom. Small fissures open into the walls of the sinks but no caves were observed. In addition to the vertical sinks there are a long sink valley and several steep sided sinkholes in the area.

Fig. 7. Vertical side sink north of Long Rapids. Sink is 300 feet in diameter, 125 feet deep.

At Sunken Lake in Presque Isle County a mile northeast of Leer a large rock sink opens. The sink is in the western side of a large depression that is over 7000 feet long and 1500 feet wide (Fig. 8). During wet seasons it filled with water to a depth of 90 feet and the overflow was carried by a stream to Thundred Bay. During the summer water escaped via crevices in the south end of the large depression and the lake became dry. In the latter part of the 19th Century lumbermen threw brush and trees in the fissures to keep water in the lake. This was a temporary expedient as the fissures soon were cleared by escaping water.[8] The large depression is now dry year round as lumbermen later blocked the surface drainage to the sink to form Sunken Lake.

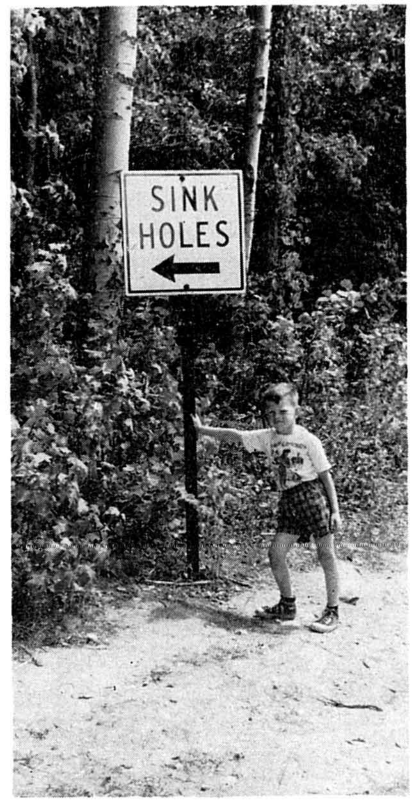

Fig. 9. Solution terranes are so rare in Michigan that even sinkholes rate a sign.

Sinkholes continue northwest to a point south of Millersburg, Presque Isle County where they attain maximum development. (Fig. 10) Rainy Lake, six miles south of Millersburg, is formed by three giant sinkholes. The lake is over a mile long and a half mile wide. The easternmost sink is 500 feet long and 50 feet deep. The center sinkhole is 2000 feet in diameter and over 120 feet deep. The north bank slopes gently but the south slope is almost vertical in the sink. The western sink is similar to the center one

[8]Rominger, C.: *Geology of Lower Peninsula:* Geol. Surv. of Mich., Vol. 3, pt. 1, 1876, pp. 46.

Fig. 8. Valley sink west of Sunken Lake.

but is only 80 feet deep. Normally the lake is full of water. However, it has drained dry twice (ca. 1903, 1926) exposing the giant mud-covered sinks. (Fig. 11) The water escapes rapidly through fissures at the base of the two large sinks. In 1936 the lake was full. In 1940 it was down 30 feet and in 1950 it was down 60 feet (Fig. 12). When visited in 1951 and 1955 it was full (Fig. 13). A mile to the east of Rainy Lake is Rainbow Lake, a water filled, funnel-shaped sink about 600 feet in diameter and over 100 feet deep. The water is clear, green blue and large trees dropped in the lake during lumbering can be seen far below the surface.

A line of sinks leads west from Rainy Lake to Shoepac Lake in southwestern Presque Isle. Shoepac Lake is a water-filled sink about 2000 feet in diameter. In early 1950 a large section of the southeast shore collapsed due breakdown of the lake bed. The collapsed area is 200 feet long and the deep hole into which large trees and much of the beach slumped can be seen deep below the surface of the clear blue lake water.

200 yards east of Shoepac Lake five giant, dry sinks string out to the east. The sinks range from 90 to 120 feet deep with almost vertical walls. They are about 600 feet in diameter and are surfaced with fine buff glacial sands. Grass and trees cover the slopes and bottom. A long valley extends east of the sinks towards Rainy Lake and its hummocky, rolling bottom indicates it may be a giant valley sink. Glacial drift, however, hides much of the evidence.

Sinkhole topography continues into northern Montmorency and Otsego Counties adjacent to Shoepac Lake area and several spectacular water-filled sinks up to 600 feet in diameter are in the Pigeon River State Forest. A mile north of Millersburg in Presque Isle County is a recently developed karst phenomenon. The east branch of Ocqueoc Creek disappears underground at the north end of a large swamp. Numerous small openings and large areas of broken limestone blocks give evidence of a former extensive network of cavern passages in the area. The water can be heard flowing beneath the wreckage of limestone blocks, tangled vines, and fallen trees. It resurges as a small stream 500 feet north of the swamp.

On Mackinac Island several small sinks lie in the upland area but are hardly worth of

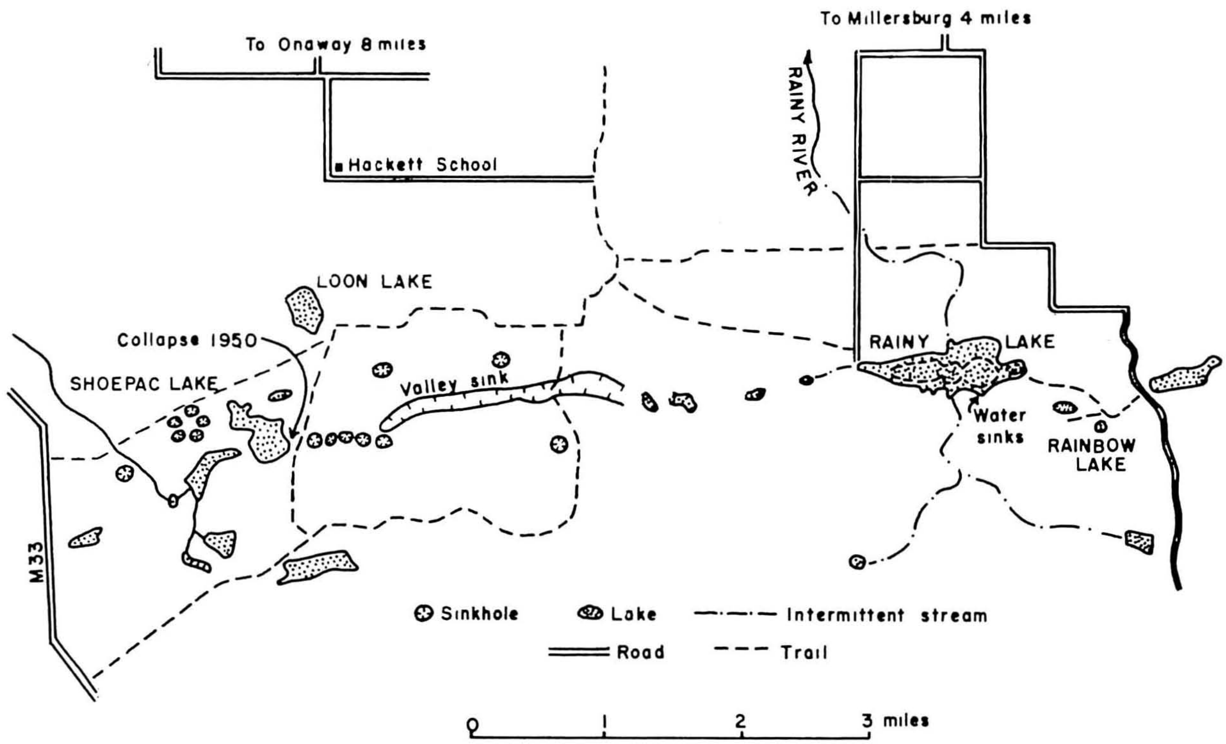

Fig. 10. Solution terrane, central Presque Isle County.

notice. Poindexter[9] ascribes the origin of Big Spring near Manistique in the Upper Peninsula to sinkholes. He notes also several large sinks southeast of the spring.

The age of the sinks in relation to glacial cycles has given rise to diverse opinions. Bergquist[10] states the sinks are a result of preglacial collapse and the resultant depressions were not filled because of insufficient sediment in melt waters or subterranean drainage carried the sediment away. Poindexter, Warthin and Cooper[11] believe the sinks have resulted from post-glacial solution and collapse.

The large sinks, with the exception of those north of Long Rapids, are probably rejuvenation of pre-glacial sinks and solution channels. Their large size and wide-spread development demand extensive solution work—a condition that is difficult to vision in areas in which glacial deposits are impervious enough to support large lakes. On the other hand the sinks are not relics of a pre-glacial time as their funnel shape would have been erased by glacial deposits which would fill their floors. It is more probable that before glaciation the northern part of the Lower Peninsula was a vast karst area with a surface cut by sinks, caves and solution valleys. The glacier overrode the area and upon retreating left a mantle of drift filling the sinks. Subsequent solution reopened some of the solution channels and caused new collapse which finds expression in the rejuvenated sinks. The sinks north of Long Rapids, because of their clean-cut, vertical walls, and the accumulation of limestone blocks with little glacial debris on their floors, appear to be of recent origin.

Karst Features—Karren, bare bands of solution-grooved limestone, are apparently very rare in Michigan. The only karren observed was on Engadine limestine near the town of Engadine in the Upper Peninsula. The exposures, often

[9]Op. cit., pp. 440.

[10]Bergquist, Stanard G.: *Surface Geology of Montmorency County, Michigan:* Mich. Acad. Sci., Arts, and Letters, Papers, Vol. 25, 1939, p. 461.

[11]Poindexter, op. cit., p. 442.

Warthin, Alfred S., Jr. and Cooper, G. Arthur: *Traverse Rocks of Thunder Bay Region, Michigan:* Amer. Assoc. Petr. Geol., Bull. Vol. 27, No. 5, May, 1943, pp. 571-595.

Photo by Will B. Gregg, Onaway, Mich.

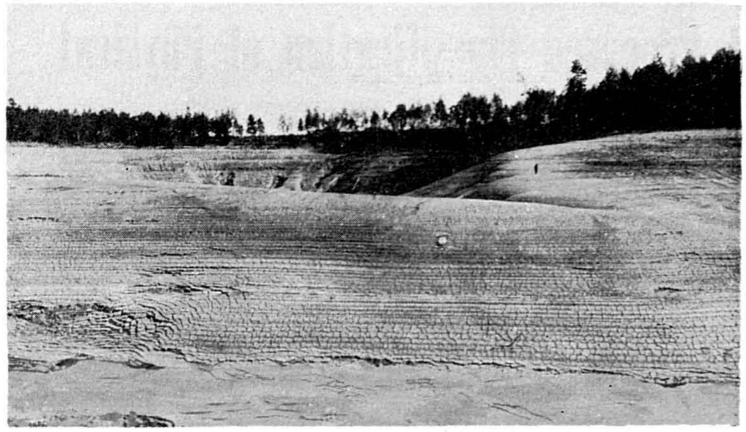

Fig. 11. Rainy Lake 1926.

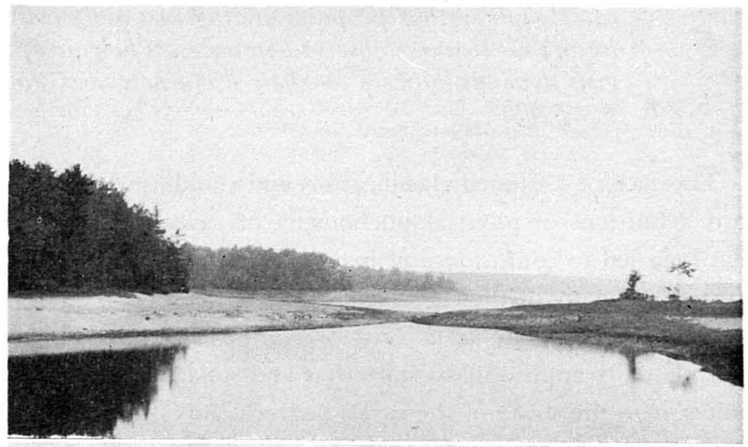

Fig. 12. Rainy Lake 1950.

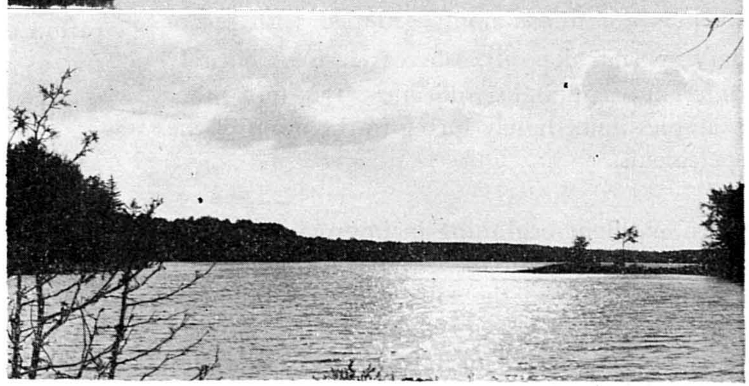

Fig. 13. Rainy Lake 1951.

referred to as "Pavement", are the work of solution although in some patches glacial action has modified the blocks by planing.

A unique karst feature is found on Mackinac Island. Three large solution cracks lie in the northern half of the island. Known as the "Northwest Crack", "Crack in the Island", and "Northeast Crack", they are a result of solution along joint or fracture planes. The cracks are up to five feet wide and range to 20 or more feet deep. The longest "Crack in the Island" is over 1000 feet long. Stanley[12] cites evidence that indicates the cracks are post-glacial in origin.

Similar solution features are developed on Manitoulin Island (Canada) to the east where the limestone in the upland is cut into large blocks 20 to40 feet square, separated by fissures two to five feet wide and up to 20 feet deep. Here the fissures are clearly of recent origin as they are free of glacial and lake deposits.

[12]Op. cit., p. 69.

A Proposed Classification of Physical Features Found in Caves

By WILLIAM R. HALLIDAY

Since speleology is a comparatively young science, it acquires a growing vocabulary of terms unique to it. Some of the terms carry over from the past, but are rendered inefficient for communicating exact ideas when they imply multiple meanings. The word SPELEOTHEM, *for example, is now generally accepted as a classification noun for all secondary mineral deposits formed in caves. The author proposes adding two more classification nouns (and adjective forms) for features observed in caves. Their acceptance or rejection by speleologists depends entirely on their usefulness over the course of time.*

The lack of a unified classification and standard definitions of physical phenomena of caves has long led to confusion and inaccuracy in discussion of many of their geological and mineralogical aspects. The term *cave formation* has been equally applicable to stalactites and stalagmites or to the strata of the cave's bedrock. Boxwork is not uncommonly grouped with secondary spelean deposits, whereas it is of entirely different origin and significance (1). Many other examples immediately spring to the mind of the speleologist.

An excellent beginning in improving this situation was made in 1952 by George W. Moore (2) who proposed the substitution of the term *speleothem* for *cave formation* in its sense of secondary mineral deposit. Today, this is widely accepted in speleological usage.

A second step was the introduction, in 1953, of the term *speleogen* (3) to describe phenomena caused by removal of material by solution or corrasion in limestone caves. While a notable concept, the initial definition of the term has apparently not proven satisfactorily oriented for general acceptance.

In this paper, it is proposed that the following basic classification of physical cave phenomena be considered for general use:

1. Speleothemic .... (Speleothems)
2. Speleogenic .... (Speleogens)
3. Petromorphic .... (Petromorphs)

To be excluded temporarily are mechanical cave fills, such as breakdown, clays, sand, gravel, and the like. These are currently under survey by William E. Davies and others, and a classification of these forms should be soon forthcoming.

The proposed definition of *speleothem* employed in this classification is essentially that proposed by Moore: *A secondary mineral deposit formed in caves.* In addition to stalactites, crystals, and other ordinary forms of calcite, aragonite, and ice, it also applies to "true" lava stalactites and to sublimates.

Speleogen is here defined as an *individual, specific modification of the surface of a cave's bedrock or a speleothem, other than a secondary mineral deposit.* While pertaining primarily to forms originating by solution or corrasion, this definition applies equally to limestone, lava tube, sea, gypsum pocket, and other types of caves. In limestone caverns, it includes such forms as joint cavities, ceiling pendants, and meander niches. In lava tubes, it includes contraction fissures and cupolas. In sea caves, it includes joint widenings and breakdown sites. In aeolian caves, it includes bedding plane cavities. Another distinction from the original descrip-

tion lies in its exclusion of overall cave patterns.

While speleothems, speleogens, and mechanical fills make up the vast majority of cave features, one small but important group yet remains. It includes boxwork, mineral veins, vugs, and perhaps shields (palettes). These are formed within the bedrock and are only accidentally exposed during speleogenesis. Nevertheless, they may assume great prominence, especially in the Black Hills and in some Utah caves. It is proposed that the term *petromorph* be applied to this group. Its members may be defined as *secondary mineral deposits formed within the bedrock and incidentally exposed within a cave.*

Modifications of this classification or its definitions may well be required by the test of time. Combined forms occur with some frequency, but should cause little or no confusion. Borderline forms occur, but this is basically due to our imperfect knowledge rather than to the classification itself. It is not proposed as any easy guide to the innumerable unsolved problems of cave features, but rather as an aid to discussion of these problems.

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2. Moore, G. W. *Speleothem—A New Cave Term.* Nat. Speleol. Soc. News, 10 (4) :2, June, 1952.

3. Mowat, G., Lange, A., and deSaussure, R. *Report of the California-Nevada Speleological Survey.* Tech. Report No. 2, West. Speleol. Inst., 1953.

Radio Transmission in Caves

By FIELDING McGEHEE

Radio communication between explorers working in caves and parties on the surface or in a different area of the cave will probably become standard procedure in years to come. Success in receiving a signal through rock depends on many factors—distance, the wetness of the rock, antenna loading—all are important. Here is the result of two experiments conducted by the author on the subject. He describes successes with the method, and points out areas in which there is much to learn. Radio, indeed, would be a useful tool for the speleologist to acquire, not only for communications, but for surveying and entrance finding.

Communications between explorers in caves and between exploration and surface parties has been a problem to speleologists for some time. There has been considerable speculation about the use of radio and some sporadic experimentation in this field, but the complexities of the subject have limited the usefulness of the results. The author has conducted some experiments on radio transmission through the earth; some of his results are of immediate applicability and others indicate areas open for further investigation.

The possibility of using radio as a prospecting tool for locating oil has interested geo-physicists since the early 1920's. This interest is evidenced by the fact that a good bibliography on the subject lists more than 300 titles, in German, French, Russian, and English. While it is not within the scope of this article to go into this material, a few comments on the general principles involved will perhaps allow a clearer understanding of the objectives of the experiments to be discussed.

To secure information concerning earth structure or the presence of oil, radio frequency energy must penetrate to a depth where the structure or oil manifests itself, and then must return. The distances involved here may be from hundreds of feet to several miles. (In addition, the structure or oil must reflect or re-radiate the radio frequency energy. We shall not comment on these matters here.) The radio wave suffers attenuation in passing through earth materials; that is, it becomes weaker as it progesses due to loss of energy to the material through which it moves. The more highly conductive the transmission medium (the wetter the rock), the higher this attenuation is. One may write the simple equation $E = ke^{-aR}/R$ as an approximation to the received signal from a transmitter, where

E is the radio field strength
k is a constant
R is the distance from transmitter to receiver
e is the natural logarithm base, 2.7128 . . .
a is the attenuation constant

This equation is sufficiently good for our purpose when R is much larger than a wave length of the radiation in the medium. In air "a" is negligible; in the earth its value depends on the type of rock and its wetness. One notes the effect on a car radio when going through a tunnel, or on a portable radio when one carries it into a metal building or a car.

It is easily shown on the basis of theoretical calculations that one cannot possibly explore the earth at depths greater than a thousand feet or so with radio frequencies in the broadcast range. There is some circumstantial evidence to the contrary, however, the existence of which has led to much interesting experimentation.

We shall now discuss briefly one of these experiments which yielded rather clear-cut results. The experiment was based on the proposition

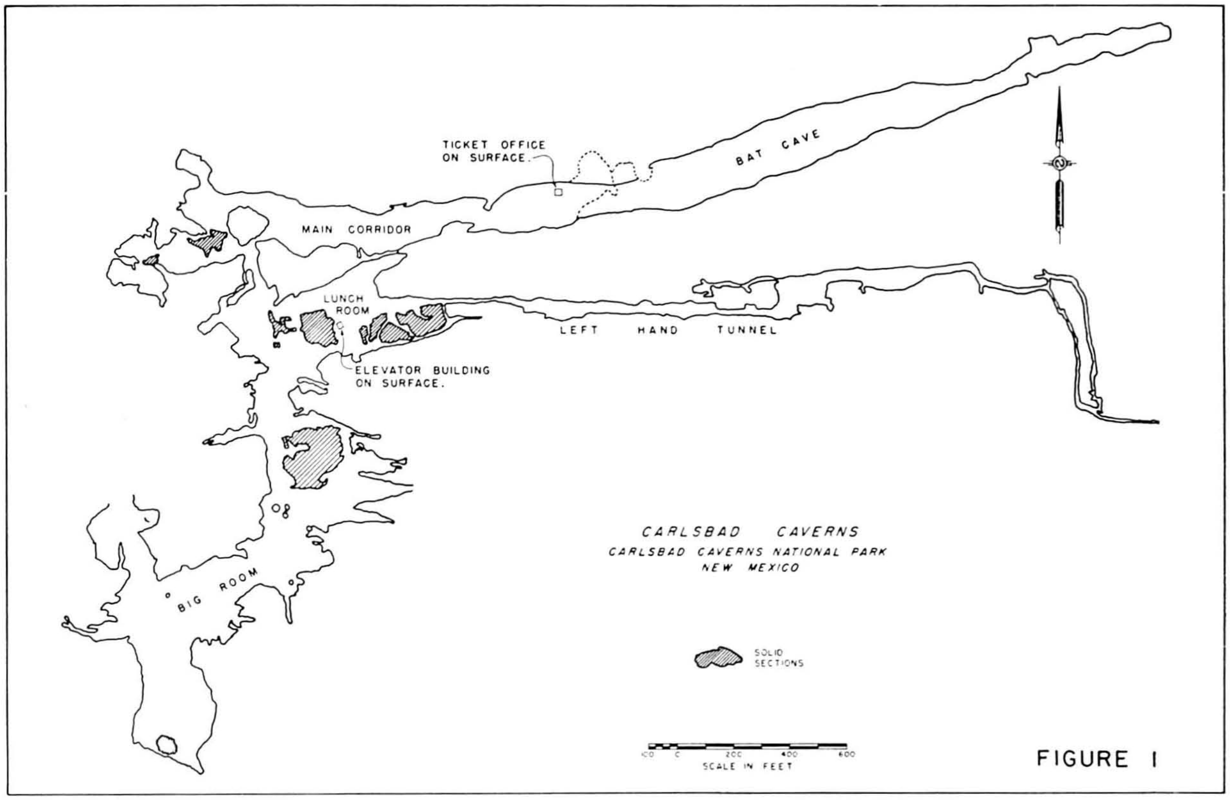


Fig. 1. Map of Carlsbad Caverns.

that, since it is very hard to tell whether what one observes on the surface of the earth is due to radio signals reflected from underground, one should go underground and see whether signals arrive from the surface. (It has been found to be rather difficult to answer this question by putting receivers down in a well.) Other workers have done roughly the same thing but with the emphasis on other phases of the question.

Experiments at Carlsbad Caverns

After many inquiries and much discussion, Carlsbad Caverns was selected as a promising site for work, a decision based on the results of some preliminary observations made in January, 1953. At that time it was found to be possible to receive programs from a station in Carlsbad, N. M., on a Hallicrafters portable communications receiver under conditions which required that the signals come through the earth. (The station was about 20 miles north of the Caverns. In an east-west passage, the Left Hand Tunnel, the receiver, which had directional receiving characteristics, pointed north-south; see Figure 1.) It is most improbable that this energy traveled all the way from the station to the receiver through the earth. It almost certainly traveled only the 750 feet from the surface to the receiver underground, but it most certainly did not come in through the tunnel opening. This station operated at about 700 kc., with a power of 1000 watts. At the same time an amateur radio operator in the Park area was transmitting at 7.2 mc. The signal was received at one point in the cave.

The Left Hand Tunnel, which is not normally open to visitors, was chosen as the work area. There was no wiring or piping which might interfere with the electronics equipment, it was easy to get into, and it had been well mapped by the National Geographic Society. The surface terrain permitted easy access.

Experimental Procedure

The objectives of the work were kept simple, to find out whether radio frequency energy (just above the broadcast band) would penetrate the earth deeply enough with sufficient strength to be useful for prospecting, and to secure any other information possible.

The knowledge that radio energy would penetrate to the Left Hand Tunnel aided the planning. The general plan was to set up transmitters on the surface and to measure the signal strength underground. No effort was made to get absolute values; that is, the primary concern was in the relative values of the signals at various points on each run. Anything done to a transmitter on the surface might change the signal at any point underground, but all the other signals would be expected to change proportionally.

Two transmitters were available: number 1, which had about 15 watts output, and number 2, which had less than ¼ watt output, operating at 1700 and 1614 kc. respectively. (An ordinary 2-cell flashlight uses about ¾ watt of electrical energy.) The antennas were insulated wires laid on the ground. These antennas were directional in the air; it was planned to change orientations of the antennas and to note the effects underground. The associated receivers had loop antennas, by use of which the transmitter direction could be determined. The receivers were equipped with meters for showing the numerical signal strength, and with headphones for the very weak signals which did not register on the meter.

Six surface and one underground transmitter locations were used, with one or both transmitters at each location, and with different antenna orientations, for a total of 18 runs. The locations are shown on Figure 2, a map of the Left Hand Tunnel. W was the underground location, of which more will be said later. The receivers were set up on tripods on the cave floor at locations

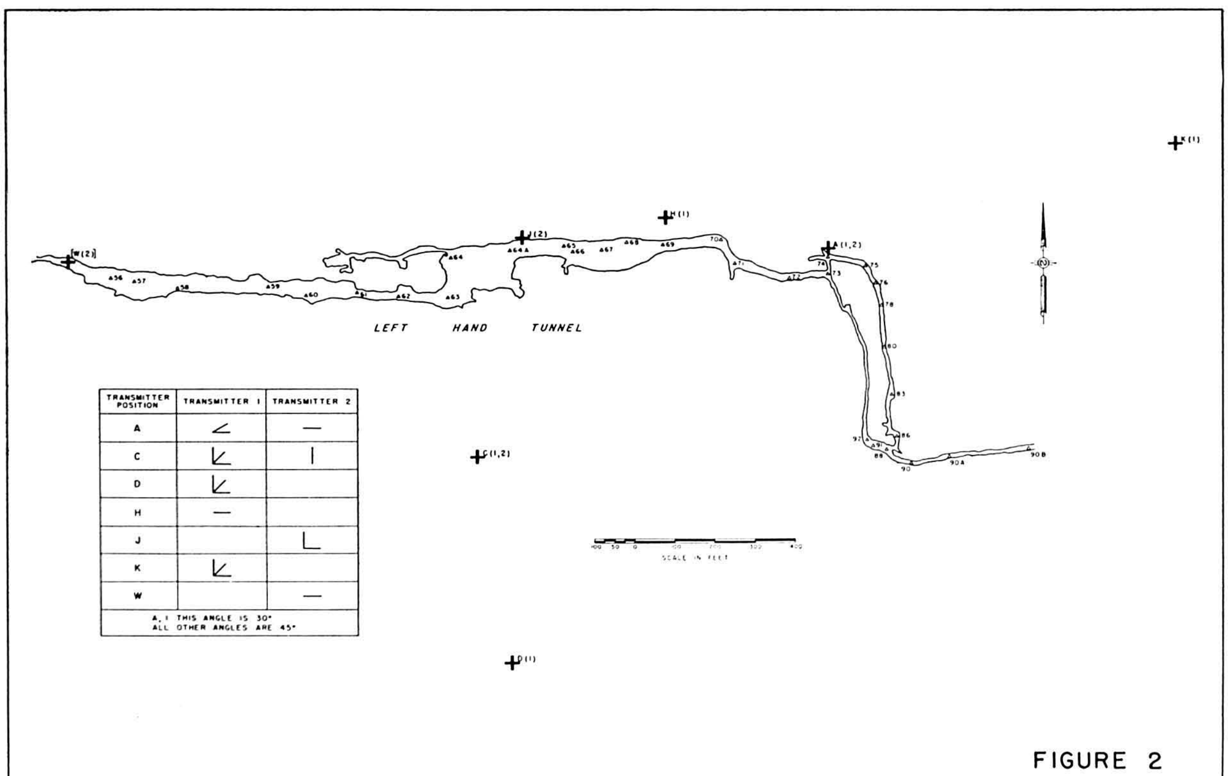


Fig. 2. Map of Left Hand Tunnel, showing surface and subterranean transmitter locations.

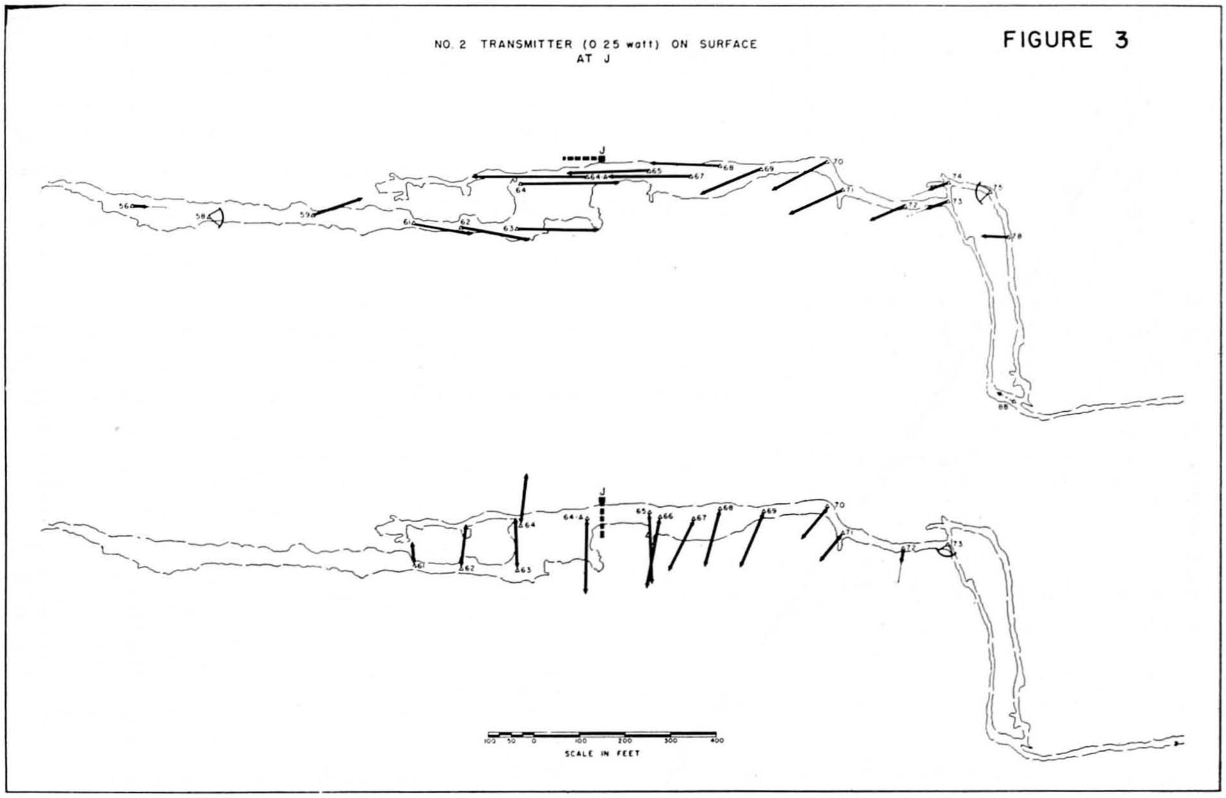


Fig. 3. Vector plot of data for number 2 transmitter at J.

identified by the National Geographic Society map. The antennas were rotated to the point of maximum signal strength; both the antenna orientations and the signal strength were then recorded.

*Results and Analysis**

The data may be presented in a number of ways. Tabulated numbers are not adequate for a proper visualization of the results. Two graphical plots are more suitable for the major part of the analysis.

One of these graphical presentations is shown in Figure 3. The symbolism indicates that the smaller transmitter was set up at station J on the surface with the antenna oriented east-west for one run, north-south for the second run. The arrows indicate the magnitude of the signal received underground at an indicated location and the apparent direction from which they came.

A detailed analysis of these and other data leads to certain conclusions vital to the event under investigation. The radiation is polarized in the sense of the antenna, and the transmitter appears to radiate equally well in all directions investigated; neither of these statements is true for the radiation on the surface of the earth. Other data not shown here indicates that beyond a distance of about 1200 feet, the character of the radiation changed, as is discussed below. None of these effects were predicted.

Another method of presentation is based on the equation $E = \underline{ke^{-aR}}/R$. If one writes this expression as $E \times R = ke^{-aR}$ and plots $E \times R$ as a function of R on semi-logarithmic paper, a straight line results, with a slope of $-a$. All of the data were computed in this fashion, normalized, and plotted together on one sheet, as shown

*Since the specific details of the data are not of interest to the general reader, they are omitted here. For further information the reader is referred to an article which appears in the July, 1954 issue of *Geophysics,* pp. 459-477, "Propagation of Radio Frequency Energy Through the Earth."

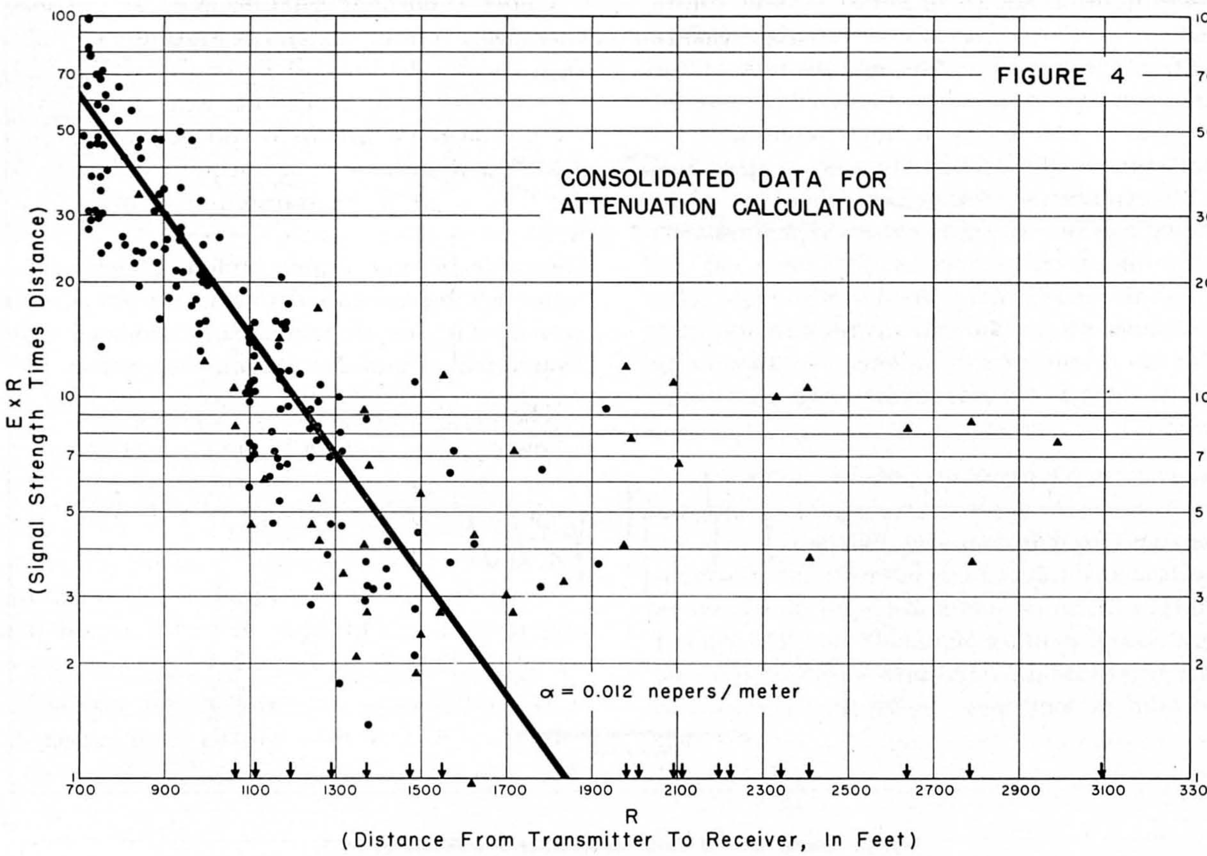


Fig. 4. Signal strength times distance as a function of distance.

in Figure 4. Three symbols are used. A circular dot indicates a high-confidence value; a square dot indicates a value which fell in or near the range at which the receiver response became non-linear; an arrow indicates a non-readable but audible signal, or the first no-signal point, in a run. It is at once apparent that the line drawn represents the major portion of the data fairly well.

There has been much discussion concerning the points which lie between 1100 and 3000 feet. It may be demonstrated qualitatively with a high degree of certainty that these signals arrived in the Left Hand Tunnel from almost directly overhead, that is, the radio signal moving over the surface of the earth lost energy downward to give these effects. It is this which permits one to receive a distant radio station in a cave.

These more technical aspects of the work have been treated at length elsewhere. For the present article it is of more interest to comment on other features of the work.

The question has been asked, why not use a more powerful transmitter and hence get greater range? It is easily shown from the working equation that to obtain the same signal at 2000 feet as was received at 1000 feet would require 6000 times as much power as was used. This was not feasible.

It was anticipated that the objection might be raised that the radio signals which were received had "leaked in" through the cave mouth or by way of wiring. To forestall such criticism, traverses were made through the Natural Entrance and in the Lunch Room, and the wiring was carefully checked, with the result that no signal leakage was found. To make doubly sure, the number 2 transmitter was set up at W, underground, and a regular traverse was made down the Left Hand Tunnel. The signal went from saturation value at station 58 to essentially zero

at station 68, as shown in Figure 5. This constituted proof that there was not enough leakage to affect the results in the middle part of the Left Hand Tunnel, since its presence would have been evidenced by the high values near W. This point is of particular interest to speleologists. It demonstrates that communications might be established between explorers separated 1500 feet or more in a cave. At the same time it should be stressed that more distance might have been obtained had the antenna been rotated 90°. (The properties of this antenna are apparently not the same underground that they are on the surface of the earth.)

It was found to be possible to maintain surface-cave two-way code communications at horizontal distances in excess of 1500 feet, using the low powered transmitter in the cave. The best transmission point tried was station 64, where there was a pool of water. The underground transmitter was operated into various antennas; the simplest but most inefficient arrangement was connection to two ground stakes five feet apart.

Under conditions such as exist at Carlsbad Caverns, a transmitter and receiver the size of a cigar box could be used by exploration parties to maintain comumnications with the surface. No special radio circuits would be required, except that there should be adequate provision in the final stage of the transmitter to match into whatever antenna system is used. An antenna laid on the ground is quite different, electrically, from the same antenna in the air. A good ground is a primary requirement. Either long-wire or loop antennas may be used on the receiver.

The progress of exploration parties could be followed on the surface by simple triangulation means. As a guess, it is estimated that positions might be plotted with an accuracy of 10% of the depth.

It was found that the signals received in the cave increased in strength markedly toward the end of the Left Hand Tunnel. With the number 1 transmitter at K, the signal at 90B (Straddle Alley) was 5 to 10 times greater than expected. This region was wet, which should have weak-

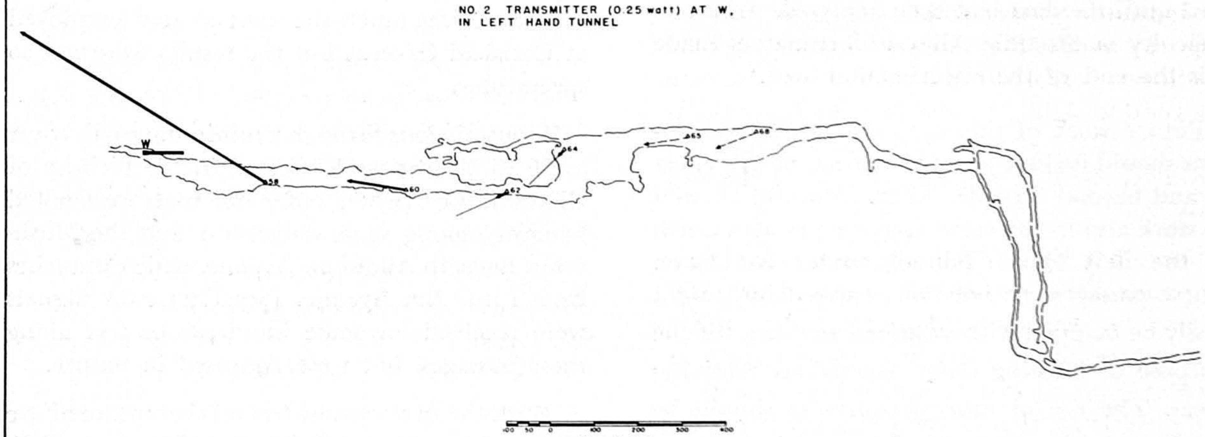


FIGURE 5

Fig. 5. Vector plot of data for number 2 transmitter at W.

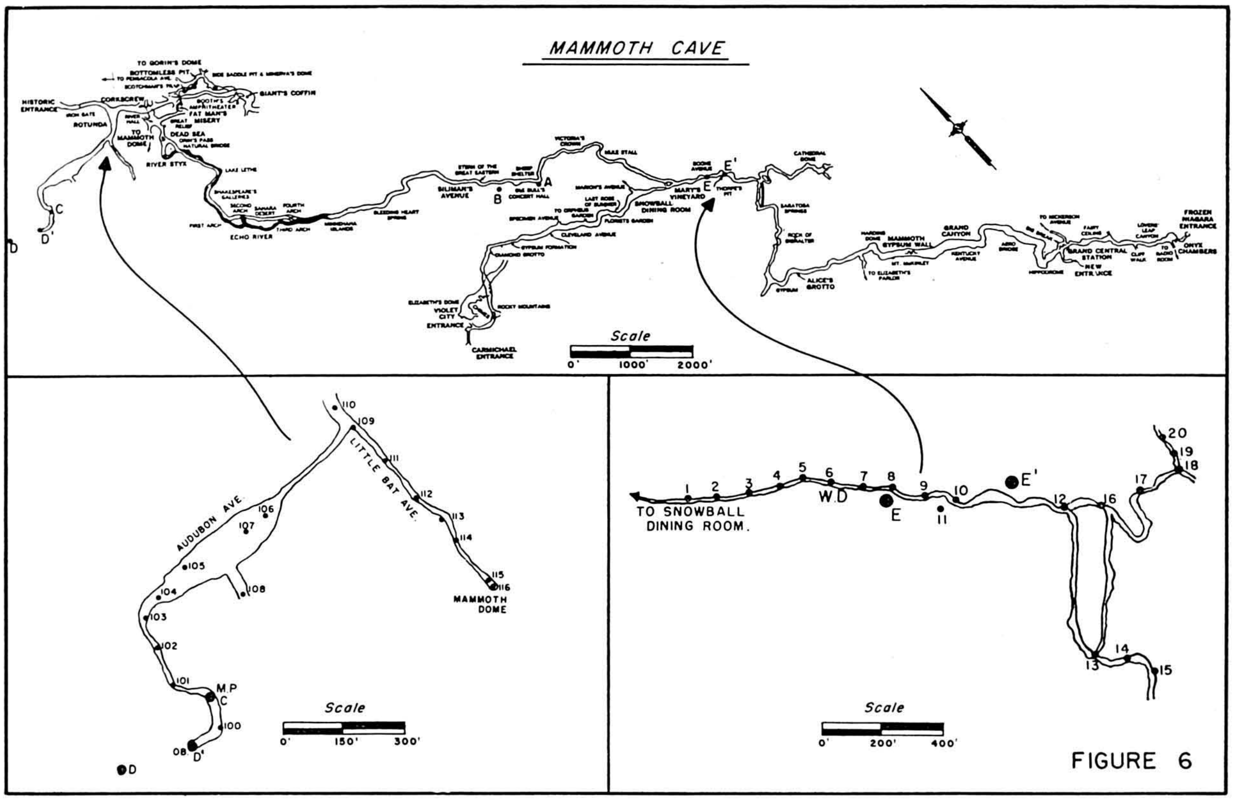


Fig. 6. Map of Mammoth Cave.

ened the signal. No wholly satisfactory explanation has yet been advanced to clarify this phenomenon. This anomaly was not fully appreciated until the data had been analyzed. An access difficulty at Straddle Alley unfortunately made this the end of the experimental area.

Future work of this nature at Carlsbad Caverns should include an investigation of this effect at and beyond Straddle Alley. It would be well to work also in the very extensive passages north of the Left Hand Tunnel, under Bat Cave. These passages are not now mapped but might easily be mapped with sufficient accuracy for the purpose of locating other anomalous receiving areas. The use of other frequencies should be considered. The effect, if any, of various antennas has yet to be investigated. Finally, it would be of considerable interest to work in Bat Cave, which lies at a depth of 130 feet, to extend the data obtained to date into the 130 to 750 foot region.

Experiments at Mammoth Cave

The investigation was continued by a similar experiment at Mammoth Cave, Kentucky. The procedure was much the same as that employed at Carlsbad Caverns but the results were not so spectacular.

Transmissions through a minimum earth cover of 30 to 50 feet were effected in the vicinity of Olives' Bower (where cedar tree roots were noted hanging among some stalactites) and the Mushroom Beds, in Audubon Avenue, which branches from Little Bat Avenue. (See Figure 6.) Signals were received for some hundreds of feet along these passages, but were confused in nature.

With the two transmitters on the surface above Silliman's Avenue and Ole Bull's Concert Hall, traverses were made through Carmichael Entrance to the Dining Room and as far as the Stern of the Great Eastern. No signals were received except leakage into the cave on the electrical wiring. The number one transmitter was

then set up over Thorpe's Pit, tuned very carefully, and a traverse was made under it, 270 feet below the surface. Sufficient signal was obtained to justify a rough calculation as to the attenuation in this location. The result was what theory predicted, considerably higher than the value obtained at Carlsbad Caverns, due to the general wetter character of the rock over the cave.

General Considerations

The work which has been reported was directed towards obtaining an answer to a specific technical question. It was originally intended that the Carlsbad Caverns experiment would be only a preliminary trip, and that a second experiment would be conducted after the first data had been digested. The unexpected results described led to calculations sufficiently good for general purposes. (As an example of the good fortune attending the work, a transmission was received the first time a receiver was turned on in Carlsbad. The receiver was then moved three feet, to get it out of the way, and the signal disappeared. The trouble was finally traced to a wire which broke on the move; days of work could easily have been lost here had the initial signal not been received.)

Recent Explorations in Floyd Collins Crystal Cave

By ROGER W. BRUCKER

When The National Speleological Society's expedition left Crystal Cave in February, 1954, there were many unanswered questions. The Caves Beyond *sets down the findings of that eventful week, but nothing has been written in detail about work that has continued there for nearly two years. Here is the story of a trip made into the system almost a year ago. For the most part it is a tale of adventure in an area expedition members never saw.*

We sat in Bill Austin's snug living room and glanced out through the window now and then to see clouds scudding over a gray Kentucky sky. It was cold this February 18th, almost one year after the Society's expedition to Crystal Cave, and to the small group gathered there excitement was at the same high pitch. Besides Bill and his wife, Jacque, Dave Jones was there, having driven all night from Ohio to join us. Only a few months before he had been initiated into cave exploring and had liked it.

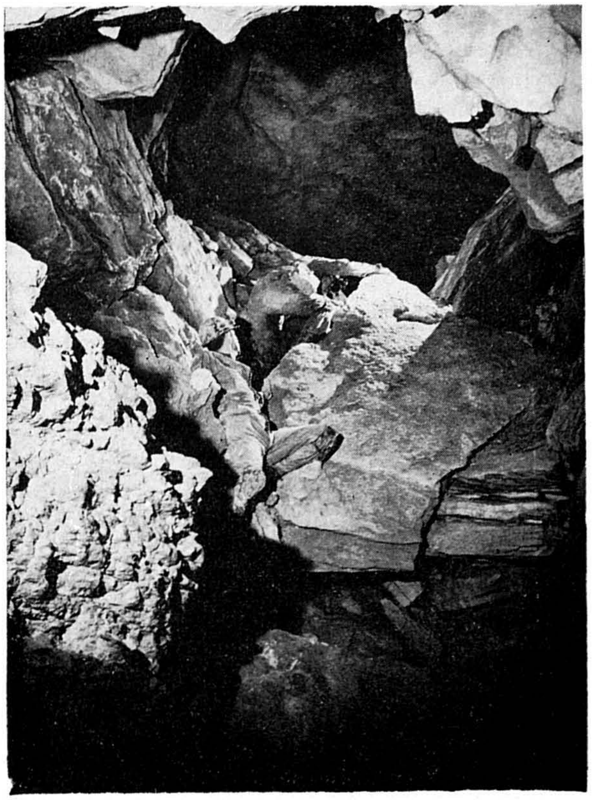
Coles Phinizy was there, a staff writer with *Sports Illustrated*. He and Bob Halmi had come from New York to go on a trip with us into Crystal, to a point beyond the expedition's farthest penetration. Halmi had no illusions about the trip—he knew Crystal was a rough cave from the week he had spent inside it a year ago, and the fact that he had streamlined his photographic gear was proof that he had finally learned the lesson about "traveling light". "Phin" had never explored caves, but in his calm way he spoke of his aqua lung work and a ride in a free balloon when the rip panel let loose; he seemed thoroughly capable of standing the worst Crystal could offer.

We laid out the maps, covering a floor area about the size of a ping-pong table, and carefully traced with our fingers the route we would take to reach Eyeless Fish Trail, a newly discovered stream passage deep within the system. Phin had some background; he had read the manuscript of *The Caves Beyond* and had talked with Halmi. Our aim was to survey downstream in Eyeless Fish Trail and, hopefully, find another entrance there. We also wanted to dye the stream and have some of our party check Pike Spring for green water; seeing it would be proof that an entrance was close by.

We had planned the trip several months ago, when a party led by Phil Smith had surveyed from the Overlook Pit complex to Eyeless Fish Trail through Storm Sewer, a half-mile long semi-walking passage. On plotting their survey, they discovered that its end was not far from Pike Spring, and the downstream end of Eyeless Fish Trail should be closer yet! We had planned a diving attempt with aqua lungs for this weekend, but a six foot rise in the water level of Green River had dimmed any hope of success. Working at it from the other end seemed the next best thing.

Around noon we moved down the steps and into the cave, following the trail to Scotchman's Trap. Phinizy was carrying more than he should have, but we learned long ago that no one listens to such lectures. Halmi was his old self, swearing outrageously at every turn and keeping up a light-hearted banter. He could handle himself in any cave, but not his camera gear; we bore most of the burden.

We traveled the Crawlway in an hour and reached the Lost Passage in two. At the site of Camp One the sleeping bags still dangled on wires from the ceiling, but they were fat with dripping moisture. An assortment of mold



Sports Illustrated

Fast moving exploration and survey parties have replaced the mass approach of the 1954 expedition.

covered them. Oleomargerine left behind showed no signs of deterioration, but everything else was crumbling under the onslaught of moisture, rats, and time. I thought back to the days of the expedition when this place was the cave's center of warmth and companionship; now it was a litter of unattractive mementos.

Without eating, we moved out B Trail, past the hole in the floor leading to the Bogardus Waterfall Trail. Along our route was a new plastic-covered telephone wire, laid there Thanksgiving weekend, 1954 on our first major assault after the expedition. We stooped, squatted, crawled, crouched, and occasionally walked, to survey station B-53, where we ate. Phin was tired. Sweat rolled down his angular face, and wet patches marked his clothing. We had told him that it would take six or eight hours to reach the place where our survey would start, but he had counted on a more leisurely pace. He said he didn't know whether he could make it at the pace we had been setting.

Up we went through the Lehrberger Link to the top of the Bogardus Formation, where we chimneyed down into a low room filled with formations. We were now at the farthest point of penetration by the expedition. "Beyond Bogardus there's not enough room to spread a sleeping bag," someone had said, but that was a year ago. The following July we discovered that no one on the expedition had reached Bogardus' Waterfall, which actually lies on out the Lehrberger Link beyond the Bogardus Formation. The water we could hear now came from another waterfall, subsequently named Bogus Bogardus.

A draft of air blew from under a ledge in our faces. I led in, crawling beside the telephone wire through a grape-studded passage, then the crawling became easier as the passage became higher and wider. About 50 feet past a room big enough to stand in, we started into Fishhook Crawl, a muddy, Keyhole-size passage with nodules of calcite jutting out of walls, floors and ceiling. To those of us who were familiar with Crystal Cave, it was the most unpleasant passage in the system, and it extended only 200 feet. Phinizy's face was beet-red when he emerged through the hole in the wall of Black Onyx Pit and slithered down the eight-foot flowstone wall to the bottom. We had been moving for almost five hours.

While Halmi made a few pictures, Phin discarded his wool sweater on a ledge. He announced that this dubious activity could hardly be called "sport", and we agreed. Bill Austin pointed out that we explored Crystal Cave primarily as a data gathering project, but that we enjoyed doing it also. Dave Jones added that the enjoyment part of cave exploring might be considered sport, but that the work was pure science. Halmi ended the debate by announcing that cave exploring was the sport of slow suicide, pursued only by fanatics.

Crossing 60 foot high Black Onyx Pit involves squeezing through a small tube, skirting a pit, then climbing 16 feet down a precipitous mud bank. The price for a slip is a fast ride to jagged rocks 20 feet below the base of the mud bank. Austin and Phinizy led the way, with Phin taking nearly 10 minutes to make the descent. "This," he proclaimed, "is the most dangerous place in the cave." As I started

over the route, Phin yelled that he could see light through a small hole and that I ought to investigate it. The hole proved to eliminate handily the 16 foot climb, so we named it Phinizy's Relief in honor of its discoverer.

We traveled in the top of a muddy canyon and arrived at Camp Pit, our advance base for explorations in this new area. The telephone wire terminated here, and a stockpile of food lay against the wall. The pit itself was about 60 feet high and 30 feet in diameter, with a pool of drinking water in one corner. Although Phil Smith had left his Primus stove there on one trip, we used disposable propane blowtorches for cooking; fuel for the Primus was too dangerous to carry.

Sports Illustrated

Austin enters Black Onyx Pit from Fishhook Crawl. Note new phone line under Austin's left arm.

Austin, Jones, Halmi, and I joked back and forth as our coffee heated. Phinizy, sprawled full length on a mud bank, said *he* didn't see anything so funny about cave exploring in general nor about Camp Pit in particular. The man who would explain "cave humor" to a novice has no chance of being understood, as we soon discovered.

We didn't tell Phin what was around the next bend; Bill told Halmi to bring flash powder for "something big", but Bob had scorned the idea. Now we stood at the Overlook, a balcony opening into an enormous pit. The balcony is about 70 feet from the bottom and probably 100 feet from the top. The pit is a perfect cylinder, about 40 feet in diameter, with smooth gray walls marred only by prominent bedding planes. A waterfall cascaded invisibly from its gloomy top, and splashed below still unseen. Rocks thrown into the abyss plunged into a deep body of water below, and sounds of waves lapping a rocky beach continued for a few seconds afterward. Phinizy whistled in awe. Halmi muttered an epithet, admitting the pit was too big to be photographed with his electronic flash equipment. Austin and Phil Smith had discovered it and the wonders that lay beyond on Thanksgiving, 1954.

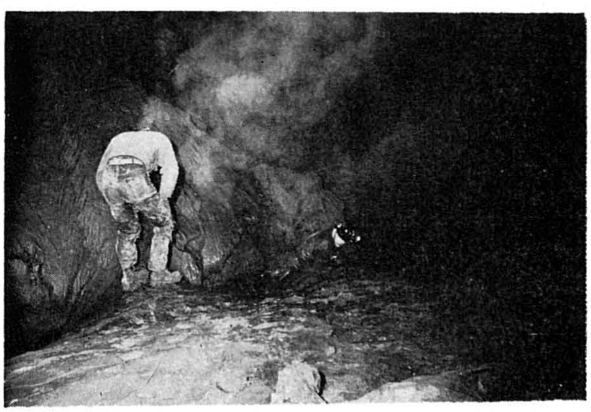
The route lay through a muddy passage on the opposite side of the balcony. One by one we climbed down into Storm Sewer, a canyon passage that led onward. The floor was firm mud for the most part, but while we could walk most of the time, we had to drop on hands and knees near the end of the passage where it entered Eyeless Fish Trail in much the same manner as B Trail enters the Lost Passage. It had taken us seven hours to reach this point, and now work could begin.

Bill suggested that we dye the stream first, so we moved down a mud slope and turned a corner. Pools of deep, green water bracketed the route, and slick mud underfoot made travel treacherous. I hoisted the surplus 30 caliber ammunition box to the other shoulder. Bill had given it to me at the head of Storm Sewer; it contained our survey equipment and his camera. The others moved down a steep slope, over a mud bridge a foot wide between the pools, and up a mud slope on the other side. It didn't look difficult, but it did look dangerous, and with the heavy ammunition box on my shoulder I thought it would be safer to cross the bridge on hands and knees rather than risk standing up. I moved out, eyeing the bridge and the two pools; the one to my left was about four feet in diameter, the one on my right was a kidney-shaped pool about

three feet long and 18 inches wide. I must have moved two feet, and then . . .

My hands were slipping! I was sliding head-first into the kidney-shaped pool, and I couldn't stop myself. These are the moments in which one's life is supposed to flash through one's mind. As I plunged into the pool I had visions of it being only a few feet deep, and that it would be too small to turn around in. But no. Blackness first, then the coolness of water penetrating my clothing, and the terrible feeling of sinking down without touching bottom. I rolled over underwater and struggled to reach the surface. How long can I hold my breath? My hard hat struck something, the chin strap wrenched . . . I was trapped by an underwater ledge. Already I knew that the pool exposed to the passage belled out underwater, but how could I find that small hole? I struggled and kicked, and then it was over . . . I sucked in air to ease the pounding of my heart, then held on to the bank for a few seconds. "Help!" I yelled.

Someone far away said, "What was that?" but instantly I heard the thud of Bill Austin's boots as he ran towards me. His lamp appeared over the lip of the mud slope, and in an instant he had leaped down beside me. When he saw I was out of danger he grinned, "Swimming?"



Sports Illustrated

Austin comes to Brucker's rescue.

"I should have spikes on my gloves," I said. The relief of tension was welcome. Phinizy blinked incredulously as I told the group what had happened. Austin wondered where the ammunition box had gone. I said it must be at the bottom, wherever that might be. We moved closer to the pool and looked in. The contents of the box were worth about $200, and Austin said he'd volunteer to dive for it; it wasn't the principle of the thing, he said, it was the money involved. Just as I suggested going after it since I already knew the layout of the pool, we were amazed to see the box floating bottom up. The camera and equipment inside were dry, thanks to a tight-fitting lid with rubber gasket.

The next surprise occurred when my lamp failed to operate, even after a fresh change of carbide. Strangely enough, it was out of water!

It was ridiculous to consider surveying; the trip in is enough to exhaust most people, let alone surveying and trying to leave the cave in soaked clothing. I apologized to Phinizy for ruining his story, but he said he was ready to leave anytime—the sooner the better. In fact, he said, he had been ready to call it a day back at the Lost Passage.

David Jones and I made a non-stop dash to Camp Pit, where Dave held a blowtorch against me. Great clouds of steam boiled off, and when he kept the flame moving, the heat felt comfortable. We ate a great quantity of meat, and started for the entrance six hours away, just as Austin and Phinizy came in. Phinizy looked exhausted; mud caked his face. Halmi was still swearing; we knew he would survive.

Jones and I reached the surface at six in the morning, with the others two hours behind. I was staggering from fatigue caused, probably, by the increased weight of wet coveralls. A warm sleeping bag felt good.

That afternoon Phinizy, looking like an old man with red eyes, announced that hereafter he would cover the "outside phase" of any cave exploring story to which he was assigned.

NOTE:

Since that trip, in which little was accomplished but much learned, Eyeless Fish Trail has been explored both downstream and upstream. Downstream it ends about 600 feet from Pike Spring in a sand fill. Upstream, it has proved to be the key to the Flint Ridge Cave System, with its 32 known miles of passages (23 of them mapped). It appears to be the largest known cave system about which reliable data is available.

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WHO'S WHO IN BULLETIN SEVENTEEN . . .

ROGER W. BRUCKER, born in Shelby, Ohio in 1929, received his A.B. in fine arts from Oberlin College in 1951. Until June, 1955, he was a member of the United States Air Force, serving as a documentary and technical film writer, stationed in Alexandria, Virginia; New York City, and Wright-Patterson Air Force Base in Ohio. He joined the NSS in December, 1952 and explored caves with the Met Grotto, EDS Grotto, and the Central Ohio Grotto. He served as an explorer and surveyor with the Society's 1954 Crystal Cave expedition, and subsequently co-authored, with Joe D. Lawrence, Jr., *The Caves Beyond*. Brucker is serving his second term on the Board of Governors and also directing the Society's Flint Ridge Project to continue the work started at Crystal Cave. His family consists of his wife, Joan, and two children, Tom and Ellen.

WILLIAM E. DAVIES, President of the National Speleological Society, is a geologist for the United States Geological Survey. He became interested in caves in 1939-40 when he explored many caves while engaged in field work for the Pennsylvania Geologic and Topographic Survey. At the present time his basement laboratory is filled with bottles and boxes containnig cave earth fills, one of his present speleological interests. He has authored two important contributions to speleological literature; *Caverns of West Virginia*, published by the W. Va. Geological Survey, and *The Caves of Maryland*, published by the Maryland Department of Geology, Mines, and Water Resources. A project of current interest is to increase the financial resources of the Society, to find a building to house the national headquarters, and to increase the efficiency of NSS operation and government.

BURTON S. FAUST, Vice-president for administration of the NSS, is a Patent Examiner in the United States Patent Office in Washington, D. C. His special speleological interest is the historical, procedural, chemical, and archaeological aspects of salt petre mining in caves from the earliest recorded instance up to 1865. His past writings on the subject have appeared in *Bulletin Eleven* and in the *D. C. Speleograph*. As founder of the Society's annual International Salon, he maintains a keen interest in color photography. In 1955 he was instrumental in obtaining for the NSS Library a collection of photographs and documents from the estate of Russell T. Neville, a pioneer cave explorer active in the 1920s and 30s. Faust began exploring caves in 1922.

WILLIAM R. HALLIDAY received his B.A. at Swarthmore College and his M.D. at George Washington University. He has explored many caves in Virginia and West Virginia, as well as all the western states. He was founder and former chairman of the Southern California, Cascade, Colorado, and Salt Lake Grottoes of the NSS. He is a member of the Society's Board of Governors and has served on many committees. On completion of his training in chest surgery he entered the United States Navy for the second time, and when last heard from, his ship was in the Japan area. His favorite caving areas are northeastern Nevada and Sequoia National Park in California.

ANTONIO NUÑEZ JIMÉNEZ was born in Cuba in 1923, received his Bachelor of Letters and Sciences from the Institute of Havana, and his Ph.D. from the University of Havana. His studies in geology and archeology took him to half a dozen foreign countries. Currently he teaches historical geography and geomorphology in his native country. Founder of the Speleological Society of Cuba, he has written extensively on Cuban speleological subjects, and has studied caves elsewhere in South America and France as well. Aside from cave exploring, he is an accomplished photographer as the pictures in his article indicate. He is a member of the NSS and four other scientific societies. Among his more important writings is a book, *The Bellamar Cave*.

FIELDING MCGEHEE was born and reared on a plantation near Natchez, Mississippi. He attended Mississippi State College one semester, spent nearly four years in the Army, then returned. He transferred to the University of Alabama, where he received B.S. and M.S. degrees in physics. At the University of Virginia he completed his Ph.D., specializing in electrical discharges in rarified gases. He is married and has three children. For a while he worked in the research laboratory of the United Gas Corporation, and currently is the Deputy Chief of the Operations Analysis section for the 2nd Air Force at Barksdale Air Force Base, Louisiana. He is a member of four professional societies, and does woodworking, teaching, and consulting in his spare time. His interest in caves has an indirect conneciton with his work in the use of radio to prospect for oil.

KENNETH A. SYMINGTON resides in Havana, Cuba, where he was born in 1932. After receiving his early education in Havana, he attended Michigan State College and Rensselaer Polytechnic Institute where he received his B.S. in chemical engineering in 1953. At present he is associated with the Proctor and Gamble Company of Cuba. He joined the Society in 1949 and at R.P.I. served variously as chairman and vice-chairman of that Grotto while exploring the area's caves. He is now recording secretary of the Cuban Speleological Society and took part in explorations of caves in eastern Cuba. He has explored caves in Mexico, France and Italy, and is a member of the Italian Alpine Club, the AAAS, and several other scientific societies. He is the Assisting Training Commissioner for the Cuban Boy Scout organization.