BULLETIN ELEVEN

NATIONAL SPELEOLOGICAL SOCIETY

NSS

Member of the American Association for the Advancement of Science

IN THIS ISSUE . . .

Accurate and informative articles on caves including

ORIGIN

HYDROLOGY

SALTPETER

SICKNESSES

BREAKDOWN

SAFETY

MINERALOGY

ECOLOGY

NOVEMBER 1949

BULLETIN ELEVEN

Published by 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 - Nov., 1949

PREFACE 1

FRONTISPIECE 2

ORIGIN OF CAVES .... Ralph W. Stone 3

HYDROLOGIC INVESTIGATION OF CAVES ...... Dan K. Hamilton 8

SPELEOLOGY IN SOUTHEASTERN ALASKA, Robert J. Hackman 11

THE FORMATION OF SALTPETRE IN CAVES ...... Burton S. Faust 17

GEORGE A. WHITE 23

SALTPETER MINING IN AMERICAN CAVES, George F. Jackson 24

LIST OF GROTTOES 27

CAVE SICKNESSES .... W. R. Halliday 28

IF YOU FIND A BANDED BAT 30

SOME UNUSUAL FORMATIONS IN SKYLINE CAVERNS, VIRGINIA .... E. P. Henderson 31

FEATURES OF CAVE BREAKDOWN .... William E. Davies 34

A REPORT ON SOME FLUORESCEIN TESTS AT STARNES' CAVE .... Joe Lawrence 36

SAFETY PROCEDURES IN SPELEOLOGICAL EXPLORATION
John Dyas Parker 37

THE CAVE RESCUE ORGANISATION OF YORKSHIRE, ENGLAND .... Norman Thornber 42

THE ORIGIN OF THE MARKINGS IN PIG HOLE
John W. Murray 44

A PICTURE STORY OF SCHOOLHOUSE CAVE 45

MINERALOGICAL DATA IN SPELEOLOGICAL WORK
William J. Foster 51

A PRELIMINARY STUDY OF CAVE ECOLOGY
Thomas C. Barr, Jr. 55

CAVES IN EASTERN CANADA .... Harold B. Hitchcock 60

A STORMWATER CAVERN IN THE LOST RIVER REGION OF ORANGE COUNTY, INDIANA .... Clyde A. Malott 64

SPELEOLOGICAL ABSTRACTS
Edward F. Moore and E. L. Krinitzsky 68

WHO'S WHO 72

EDITOR: Jerome M. Ludlow; EDITORIAL COMMITTEE: William E. Davies, James A. Fowler, William S. Hill, John D. Parker.
PUBLISHED intermittently, at least once a year, by the National Speleological Society, 510 Star Building, Washington, D. C.

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

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

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

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

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

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

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

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

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

Preface to Bulletin Eleven

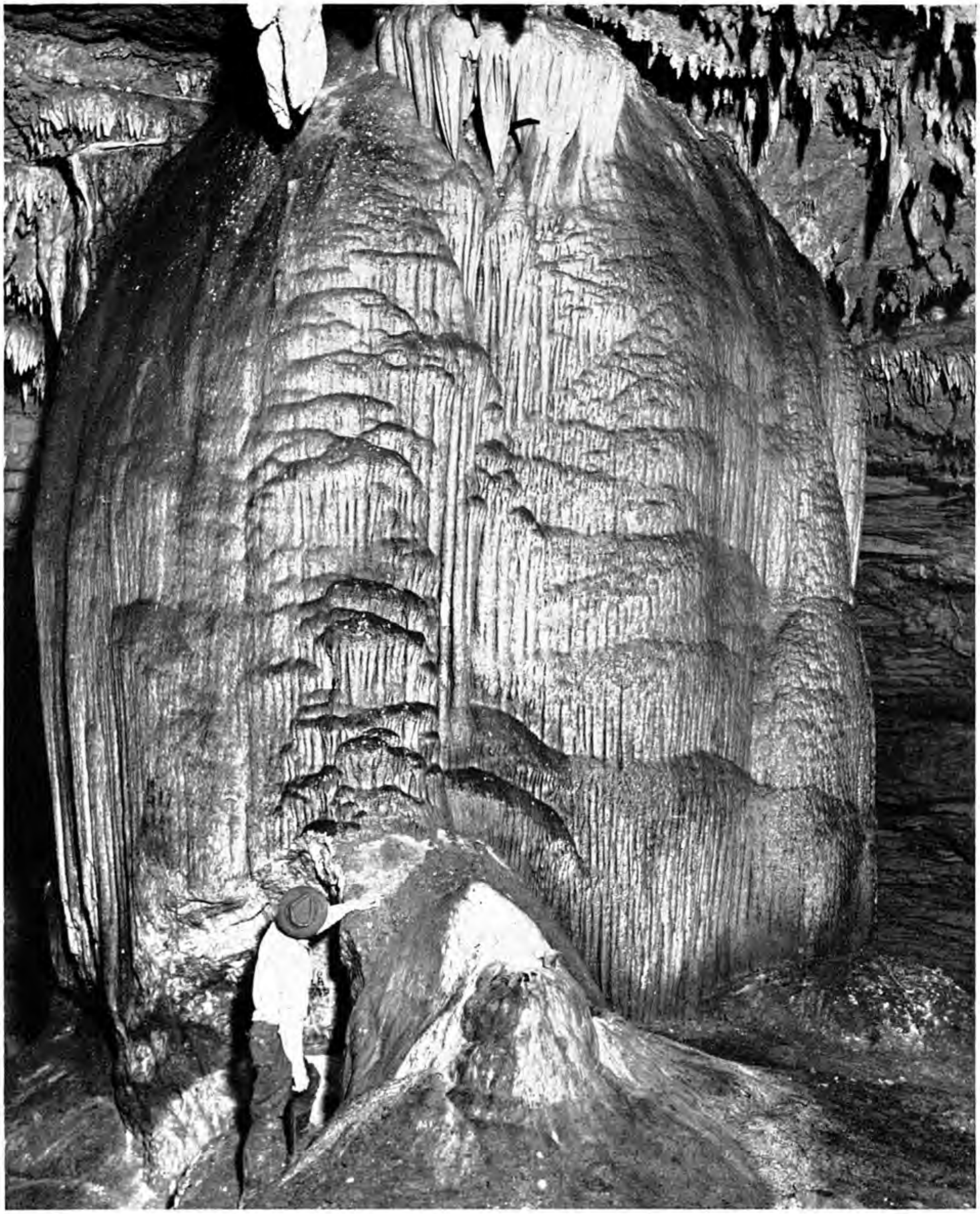
The *Bulletin* is one of the most effective forces which we have to increase the stature of our Society among the nation's scientists and scientific organizations. The Editorial Committee, to which responsibility for its preparation has been entrusted, believes that the *Bulletin*, as one of the two present publications of the National Speleological Society, should not become so highly technical that it loses its appeal to the layman as a source of interestingly written articles on caves. At the same time, however, it believes that it should emphasize the scientific aspect of the study of caves so as to be looked upon by the scientist and layman alike as a publication which is both of general interest and one which is thoroughly reliable as a source of information in regard to all phases of speleology.

Under present conditions the *Bulletin* is published intermittently (at least once a year) as a voluntary effort. It is the Society's goal, of course, that it will some day become a publication with a periodic publication date. It is obvious that the preparation of a single issue of the *Bulletin* entails countless hours of work on the part of many persons who contribute toward the final result. Its success or failure to achieve its goal is in direct proportion to the efforts of those who give their support when called upon to assume responsibility for any part of the necessary work. Each task, regardless of its size or the skill required to perform it, is important to the total result, whether it be writing manuscript for publication or attaching postage stamps for the final mailing to our members.

To give credit to each one of the many individuals who gave their time and talent in the preparation of *Bulletin 11* would run the risk of inadvertently leaving out the name of some person who would quite naturally be offended by such omission. Most of the credit for this issue, however, rightfully belongs to the Editorial Committee consisting of William E. Davies, James A. Fowler, William S. Hill, John D. Parker and, as *ex-officio* member, Philip A. Livingston, Publisher. Two other persons to whom especial credit should be given are Eva Keller of Trenton, N. J., who spent many hours typing manuscript so that the printer could have uniform copy, and May Ludlow, my wife, who contributed numerous evenings of her time in reading proof.

—J. M. L.

Trenton, N. J.
October 25, 1949



George F. Jackson

"THE PILLAR OF CONSTITUTION" in Wyandotte Cave, Indiana. This is one of the largest stalagmites in the world. The formation is 75 feet in circumference and 35 feet in height.

ORIGIN OF CAVES

By RALPH W. STONE

Guides in commercial caves commonly tell visitors that the cave was formed by a stream of water. In many instances evidence to the contrary is at hand. Most visitors might be puzzled if the guide said the cave was formed by differential solution of nonhomogeneous limestone below the water table in the zone of saturation. So the simpler but in many cases erroneous statement that a stream of water washed out the rock.

Members of the National Speleological Society have an opportunity to test the various theories of cave origin by observational studies underground. When many studies of many caverns have been made by many observers, we should have a successful theory of cave origin. My observations, almost exclusively in Pennsylvania caves, have resulted in the conclusions of this paper.

The author was spurred on in his study of caves by William Morris Davis, his professor at Harvard University in 1899-1901, whose essay[1] on The Origin of Limestone Caverns has been a guide.

Most caves are in limestone. All limestones are soluble, some more readily than others. In the same formation some beds yield more readily than others, and one part of a single bed may dissolve quicker than another. This fact is well illustrated where stripping the soil reveals a most irregular surface of channels and pits several feet deep where the limestone has been dissolved. This condition has been produced by differential solution without aid of corrasion by running water.

Limestones in general are dense and not permeable to water. However, along two principal surfaces, bedding planes and joint planes, water can penetrate and attack the rock.

It is commonly stated that the solution of limestone is accomplished by rain water, which picks up a little carbon dioxide in passing through the air and perhaps a little humic or other acid in passing through the soil. Where this slightly acid water seeps along the bedding and joint planes in the rock it slowly dissolves the calcium carbonate and enlarges the opening. Where a joint and bedding plane meet, more surface is exposed to attack and a larger opening is made. As these openings increase in size they give easier passage to the water and where the water flows freely it may further enlarge the opening by corrasion.

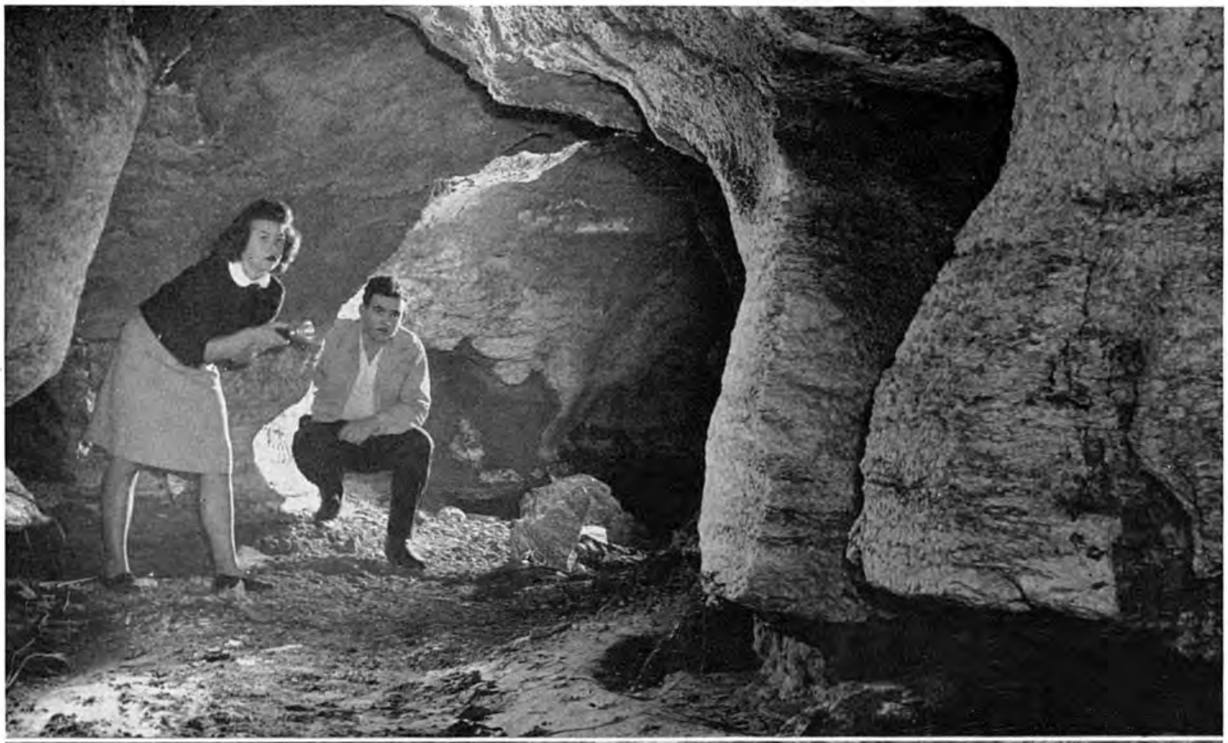
As a passage is enlarged, water is withdrawn from the roof and concentrated on the floor; consequently most solvent action on the roof ceases. A passage excavated by running water should have smooth, rounded walls, and must have certain relations to the direction of flow. It should in a general way increase in size down stream and also from top to bottom, except where constricted by less soluble or less easily corraded rock. The floor of such a passage should be graded; it may have abrupt descents but only minor depressions. The roof also should be fairly regular and, in a long passage, should descend less than the floor.

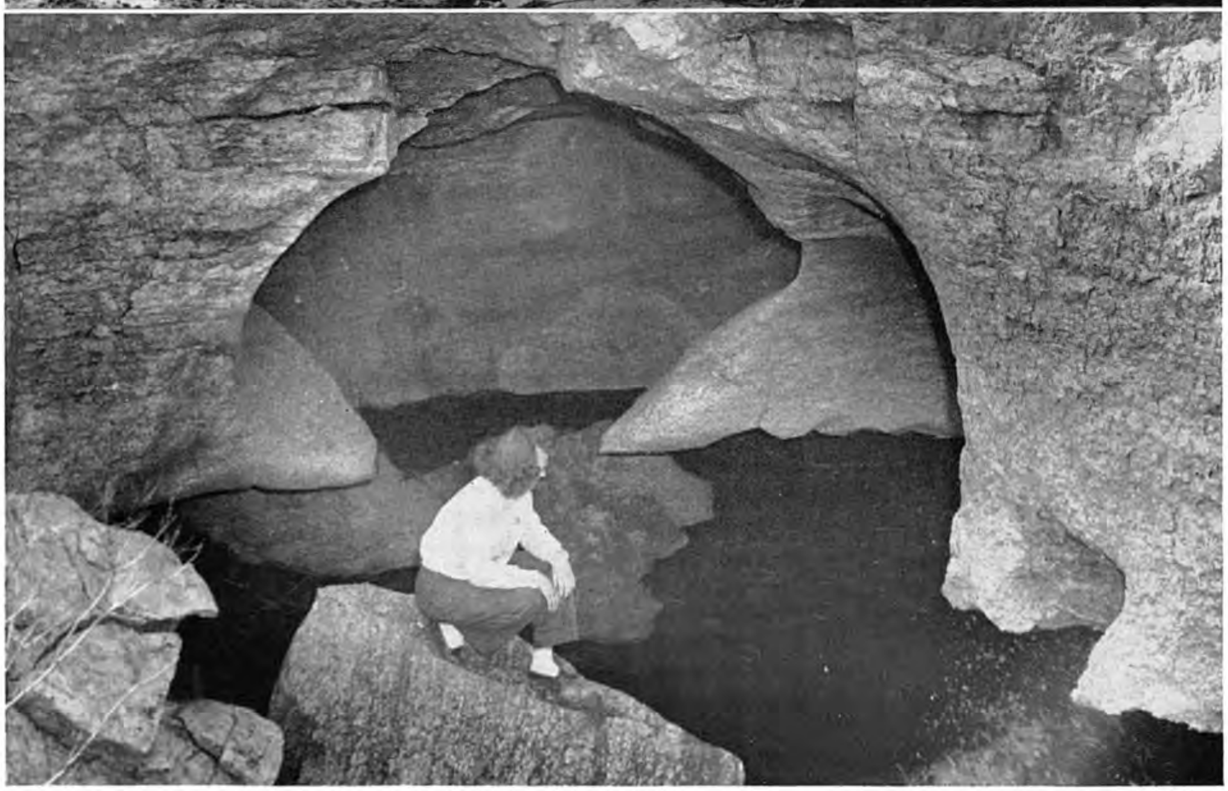
A cave produced by solution and corrasion in running water would be expected to have a somewhat branching, though angular, pattern developed on joints and bedding, but should not have loops and dead-end passages. Of course an opening produced by solution or corrasion may be further enlarged by blocks falling from the roof from lack of support.

On the other hand, solution in standing water naturally produces irregular rounded forms because the limestone is not everywhere similar in composition and not equally soluble. All parts of a chamber being excavated below the water table are subject to solution and the roof as well as the floor is continually attacked. Therefore irregular depressions in the roof and floor alike are normal; the floor need not be graded with respect to any surface level; the roof may be exceedingly irregular in its relation to the floor of a long passage; returning lops, outgoing branches, and dead-end galleries are natural.

By these and other criteria the origin of caves is determined.

[1] Davis, W. M., Origin of limestone caverns: *Bull. Geol. Soc. Amer.*, vol. 41, pp. 475-628, 1930.





V. *A. Y. Owen*

UPPER PHOTO shows a scene in Bat Cave at Vinson, Oklahoma. Differential solution is indicated by irregular reentrants on both sides of main channel. **BELOW:** Entrance to Endless Cave near Weatherford, Oklahoma. Rounded outline appears to indicate erosion by running water. Large and small caves on one side may be the result of differential solution below the water table but not of erosion.

Unlike the caves in Indiana and Kentucky where the limestone beds are nearly flat, the caves in Pennsylvania and the Virginias are mostly in tilted beds, because most limestones in these States have been subjected to crustal folding and are inclined. Because of this folding it is probable that they have more joints and fissures than flat-lying beds.

All rocks are more or less fissured and more or less porous for considerable depths below the surface of the land. Rainwater, soaking into the ground, fills the fissures and pores up to a fluctuating height. The water there accumulated is called ground water; and the part of the underground rock mass thus water-filled is called the zone of saturation. The ground water forms a curiously tangled, skeleton-like body. An imagined surface marking its top is called the water table. Above the water table the spaces in the rock are filled with air. This part of the underground rock mass is called the zone of aeration.

Distinguished from ground water is that much smaller body called vadose water, which is in the zone of aeration and presumably on its way from the land surface to the zone of saturation. When vadose water reaches the water table it becomes ground water.

In the dense limestones with which this discussion is concerned, ground water is not contained in the rock but merely fills the more or less minute interstices along the bedding and joint planes. It is, then, merely a network.

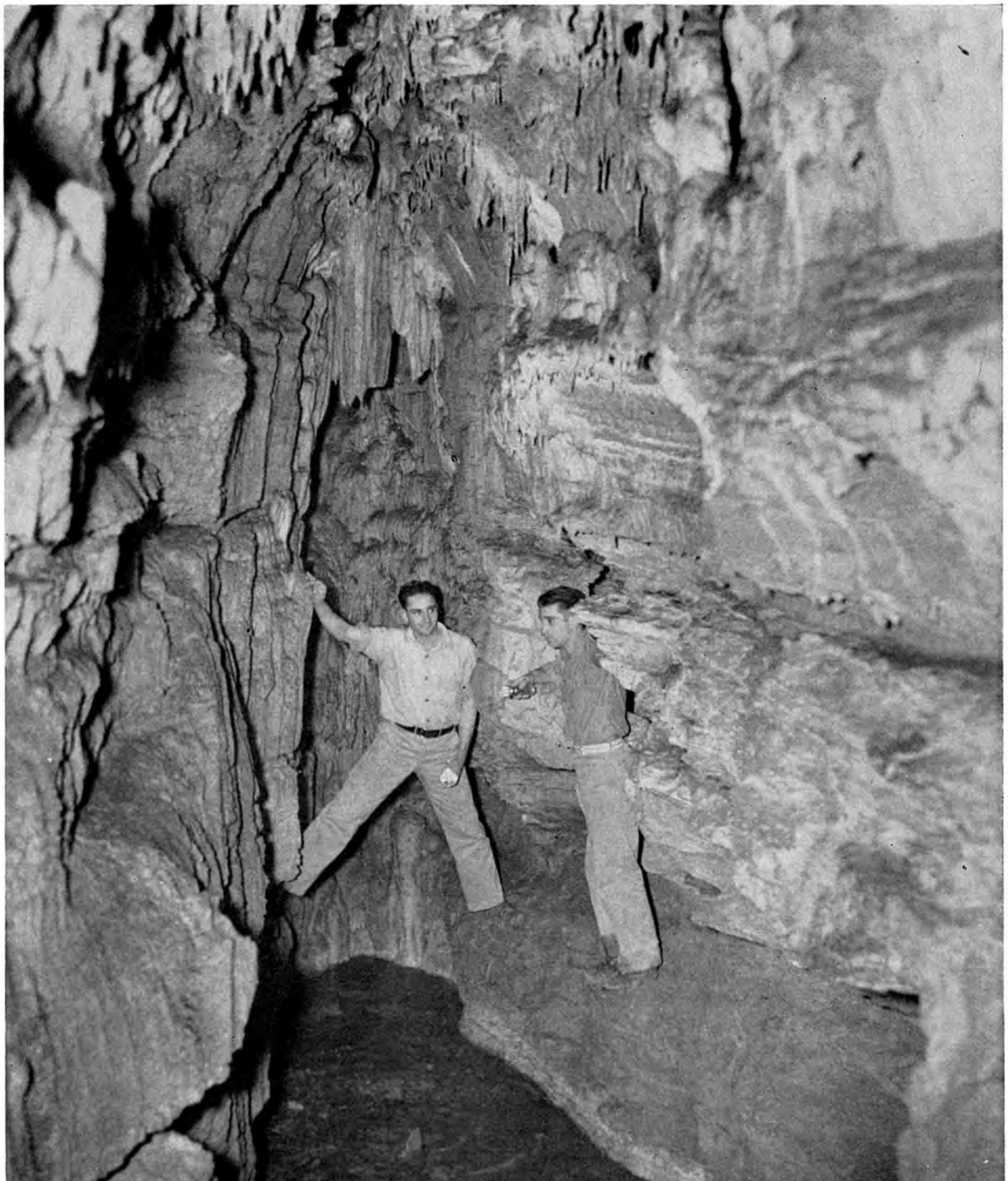
When one studies limestone caves it becomes apparent that many of them have galleries exhibiting forms and relations that seemingly cannot be explained as the result of corrasion by flowing water or by solution by descending water.

Rainwater descending through the zone of aeration slowly widens crevices by solution of the calcium carbonate. When an opening becomes so large that vadose water does not span it, further enlargement is reduced to solution on the side kept wet, and to corrasion when heavy precipitation fills the hole. For this reason the development of large openings in the zone of aeration is a very slow process.

As rainwater descending through the zone of aeration can dissolve limestone, so when it reaches the zone of saturation and becomes slow-moving ground water it has more time to exert its solvent action at a given spot and can do more work. That caverns are developed beneath the water table has been demonstrated repeatedly by drill holes. In exploratory drilling for dam sites caverns have been found deep below the channels of streams that are flowing on bedrock. Therefore they cannot have been excavated by running water. Deep-lying caverns in limestone have been found in mining operations when the water table was lowered by pumping. Corrasion played no part in their development. Ground water, however, is a competent and ever-present agent, and, given time and slow circulation to carry away the dissolved rock, will form caverns. Variations in the solubility of the rock result in irregularity in shape and distribution of the openings.

Knowing, then, that caverns are excavated in limestone beneath the water table, some of the distinctive features should be pointed out. What shall we say of a cave that has a generally level floor, perhaps now occupied by a small stream, but the roof in places is within reach and elsewhere 50 to 80 feet above the floor? What if the roof is a series of domes of unequal size, separated by partitions of solid rock that extend almost to the floor? What if the floor likewise is not graded? In many caves not only is there no general level but all sorts of holes, pits, shafts, and entrances to lower levels. These features are difficult to explain as the result of running water.

Likewise, how can an inverted pit the size and shape of a nail keg or barrel be excavated in a cave roof by running water? Or short discontinuous roof channels a foot or more deep? Or similar holes in the side walls? Long, narrow slabs of limestone bedrock projecting from walls and roof are familiar to cave explorers. In some caves the limestone bedrock has projecting edges of thin shaly layers so soft that they can be broken or rubbed off with the fingers. To my mind none of these features can be ascribed to the work of running water. These forms are easily comprehended, however, if it is assumed that they are the work of solution by ground



A. Y. Owen

A scene in Black Hollow Cave, Lake Spavinaw, Oklahoma, showing solution along joint in nearby horizontal limestone beds.

water of rock of unequal composition and so of unequal solubility.

The walls of a cave may not have conclusive evidence as to the mode of origin, for smoothly rounded curves are produced both by corrasion of running water and by solution in standing water. If the floor bears evidence of corrasion, the walls and roof may show incontrovertible evidence of origin by solution. In such a case the natural conclusion is that corrasion of the floor is subsequent to the excavation of the cave because the stream did not have access to the cave until the lowest level was above the water table. That a stream now flows through a cave is not conclusive evidence that the cave was eroded by running water. Running water should produce a graded channel, but suppose over the graded channel is a roof from 5 to 75 feet above the water, and the cavern several hundred feet long is not one but several great vaults separated by low-hanging walls, and the stream disappears at a "duck-under" or emerges to the surface through a low hole. To have excavated such a cavern the stream would have to flow uphill. It is much easier to believe that the great open spaces were formed by solution in ground water, and that subsequently the stream found its way into them.

Believing that caverns are formed below the water table, a possible difficulty is ended if it can be shown how the caves come to be in the zone of aeration, how it is that they are now filled with air instead of water. This changed condition would result from lowering of the ground-water table, either by general elevation of the land or by deepening of adjacent drainage channels. If earth movements raise a cavernous limestone above its former altitude, or if a stream cuts into the limestone or adjacent formation, the level of ground water is subsequently lowered and caverns near the surface will be drained.

There is abundant evidence that some of the Eastern States at least were subjected to regional elevation in Tertiary and post-Tertiary time. As such elevation gave increased grade to the streams and induced them to carve deeper into the underlying rocks, the conditions have been right for lowering the water table and admitting air to the caves. Thus brought above the level of ground water, the caves were drained and their enlargement by solution ceased. Since the elevation of the land that brought the caves above the level of ground water, surface streams have found their way into some of them and probably have lowered the floors by slow solution and corrasion.

The elevation of the land initiated a new cycle in the life history of the caves. In the first cycle they were being excavated and were filled with water. In the second or present cycle they are filled with air and some of them are slowly being closed by deposits of travertine. A complete change has taken place, a reversal of processes, from removal of limestone by dissolving the calcium carbonate, to the deposition of calcium carbonate in the form of travertine.

Prof. William Morris Davis concluded his exhaustive essay on the same subject:

> "Before it (the two-cycle theory of caves) is either accepted as true or rejected as untrue, much more observational study of caverns, especially in inclined strata, should be made by observers who shall bear in mind all proposed theories of cavern origin and all the consequences deductible from each theory. Care should be taken not to be distracted from the study of cave excavation by the fascinations of dripstone ornamentation. Whatever theory of excavation an observer may prefer, it will be his scientific duty to welcome all theories hospitably and to make himself equally responsible for the impartial discussion of every one of them. Only when he is thus mentally equipped for cave exploration, can he take best advantage from his opportunity underground. Whatever theory is under consideration, its relation to the general physiographic evolution of a cave district should be clearly defined, and a provisional place should be found under it for every item of observed cave form. Doubtless many items may be, for a time, incorrectly explained by false processes and erroneously assigned to false places; but in the end, after many studies of many caverns have been made by many observers, errors will be ruled out and a successful theory of cave origin will survive."

Hydrologic Investigation of Caves

By DAN K. HAMILTON
Prof. of Geology, University of Kentucky

Cave investigations supply the hydrologist with first hand information on the occurrence of underground water in limestone terrains. Frequently, the location of water supplies in such areas is a most uncertain and often unsatisfactory form of "educated guesswork". The hydrologist frequently refers to such terrains as areas of cavernous limestones. In this terminology, however, the largest "cavern" may be no more than a few inches in width or height. These potential water conduits represent an embryonic stage in cavern development. On the other hand, the term cavernous limestone may be applied in a more familiar manner to denote limestones characterized by labyrinthian passages sufficiently large to allow human exploration. In either case, the success of wells drilled for the purpose of water supply depends first, upon the drill entering some type of cavernous opening; and second, upon the characteristics of that opening as a water conduit. In most instances, the opening encountered in drilling is small—belonging either to an embryonic cavern system, or a minor connection to a fully developed cavern system. In either case, accurate prediction as to the whereabouts of such openings, the amount and character of water which is likely to be encountered, and other hydrologic considerations can be made more dependable only through a greater understanding of those cavern systems which in themselves are large enough to afford areas of first hand personal observation.

We know so little of the hydrology of caves that it is no exaggeration to say that any information which may be acquired by the speleologist would fill a definite need and be a real contribution to our present limited knowledge of the hydrology of limestone terrains. With a little effort and care the speleologist can materially contribute to the growing fund of hydrologic knowledge. For instance, no cave investigation will be of much value unless it establishes an exact description of the cave location and includes some description of the general floor plan.

The description of a cave location involves far more than the name of the state and county in which it occurs. It must be so precisely described that any interested party can find the cave from the description. It should indicate all known entrances to the cave as well as their location with regard to topography (top of hill, side of hill, foot of hill, bottom of sink hole, and other characteristics). Obviously, the best method of describing a cave location is by means of a map. On a location map the speleologist may perform great service to the hydrologist by adding to it a few more essential hydrologic facts. The stream or drainage pattern should be indicated. This frequently involves more than a brief sketch of stream courses and necessitates a generalized description of the topography in the cave vicinity. With a little extra effort or artistic skill the addition of these details to the location map may enormously increase its value to the hydrologist.

In describing the floor plan of a cave it must always be kept in mind that the cave system is a three dimensional feature. In order to properly describe the floor plan and its orientation in space a sketch may again seem to provide the most graphic description. Such a map, however, must indicate the third dimension of the cave by cross sections made at intervals through the cave system. The accuracies in cave mapping vary from guesswork to measurement by transit. Where no better information is available, even the roughest estimate is a valuable bit of information. Speculation, however, should not be allowed in the description except where clearly labelled as such.

A thorough investigation should show the accurate dimensions of the length and width of corridors and a detailed description of the vertical dimensions. Relationship of the different cave levels to one another should also be shown. Frequently the inclination of the various cave levels brings convergence of one or more of the corridors. To indicate such a feature it is often necessary to include longitudinal sections as well as cross sections on the map. In such sections the features of the land surface above the cave should be shown. The relationship between these external features of the land surface and the internal features of the cave are frequently most important. For this reason, if possible, the sketch map of the cave should show the location of the cave features with regard to sink holes, streams, hills and other surface features. Wherever possible the elevation of the cave with reference to nearby streams should be determined, and indications of flooding of the cave by such streams should be sought. If flood deposits or water lines are detectable their presence should be indicated on the map. To assemble all of this information accurately is the ideal contribution by the speleologist but with information so badly needed descriptions far from the ideal are priceless contributions. It is hardly possible to overemphasize the need for these maps in hydrologic investigations.

To the hydrologist, however, such information is just the beginning, and he must add information and evidence concerning the past and present behavior and distribution of water. Many features of the cave may give clues to its past history while direct observation provides the information on present conditions. In those caves which are so dry that no direct observation may be made on the behavior of water indirect information concerning the location of the areal water table is afforded by the very fact that the cave is dry. For those caves which contain water as much information as possible should be assembled.

The method by which water enters into a cave should be carefully noted. For instance, in some cases all of the water enters through the bottom of a sink hole and in effect comes down through the roof of the cave. It may enter the cave in one large stream, or several small streams, or simply seep in from numerous minute or large openings. It may enter the side of the cave, or rise up through the floor of the cave. It may enter by different means at different times of the year, month, or day. It may enter through round or angular openings. People long familiar with the cave may tell of changes in the method of entrance. In any event, whatever its form and time of entrance, careful studies should be made and the information duly recorded.

It is necessary also to consider the behavior of water inside the cave after it has entered. We find, for instance, that some cave streams flow the length of the cave with no appreciable addition or loss of water. This observation may be actual or only apparent. It is possible that loss and addition balance one another so that the volume remains constant. In such cases, temperature or chemical changes may give evidence of this loss and addition. Thus it may be possible for the volume to remain constant in passage through the cave while the water characteristics change. It may be that several streams enter the cave, join together in moving through the cave, only to issue to the surface again from several apparently discrete openings. The stream may appear and disappear several times in its course through the cave. There may even be some question as to whether or not this condition represents the same stream appearing and disappearing. To determine the accurate picture of water movement through a cave, extremely careful observation is necessary.

The gradient of cave streams should be examined and described. Some streams flow smoothly down gentle or steep, but regular inclines. Other streams move through caves in irregular profiles, pouring over waterfalls and moving sluggishly through pools. These waterfalls and pools sometimes afford excellent hydrologic evidence of past stages in cave formation and should be carefully noted and described. Wherever possible, the water table should be found and its altitude recorded. Its changes through the year should be carefully noted. The problems of water table in limestone terrains is still one of the most difficult fields of study in hydrology.

Under many conditions, muddy water pours into a cave and clear water flows out. This may be due to filter action, or more likely results from settling of sediments in areas of low velocity. Where this feature is apparent the correct explanation should be sought.

Many of the characteristics of the channel cross section have been produced by the water moving through the channel. Conversely, the water moving through the channel is greatly affected by the characteristics of the channel wall. Some attempt should be made to describe the nature of this channel and its composition. Frequently, this can best be shown on the cross sections of the floor plan. In other cases separate diagrams may be necessary.

As is the case with the entrance of water into a cave, the exit of water from a cave is likewise an important consideration. In some caves the water disappears into the floor, or through the walls of the cave, to issue at some point other than that entered by the exploring party. Effort should be made to find and describe these exits in a manner similar to the descriptions of water entering the cave. In the case of water entering and leaving a cave, fascinating cave studies may be extended beyond and outside a cave through the tracing of water courses by the use of dyes. The relationship of various cave systems to one another have been well defined by this method. By adding dyes to possible sources contributing water to a cave, valuable data may be gathered in regard to the speed of water movement, the path of movement, and the size and shape of the underground drainage area. In such studies, it should be remembered that negative results might have explanations other than the lack of connection.

Water temperatures in various parts of a cave and at various times of the year frequently give information on the behavior of underground water. Temperature observations are one of the simplest types of observations which can be made by the cave explorer. In addition to temperature studies the hydrologist frequently acquires much information from chemical analyses of the cavern waters. This type of study is beyond the means of most speleologists, but they might in some special cases render great service by collecting samples for analyses in those areas of particular interest to the hydrologist.

I have seen springs issuing from cavernous limestones which have definite cycles of flow corresponding closely with the daily barometric cycle. Such variations from the normal flow may suggest unusual reservoir conditions feeding the spring within the cave system. The explanation of such conditions frequently leads to much speculation and interesting theory. Perhaps theory and speculation can be replaced by fact through careful cave investigations of these puzzling springs and their associated cavern systems. In such investigations careful tabulation of the volume of water moving through the cave at different times of the day and year must be made. Fluctuations of this volume of flow should be assembled under various climatic conditions.

In addition to these direct observations of the behavior and characteristics of cave waters many observations of the features attributable to the action of water will afford needed information. Much attention has been focused on the dripstone deposits of a cave. This paper is far too short to go into details and problems of dripstone pattern and formation, but any cave exploration makes possible recorded information needed for the further understanding of these features. When the speleologist encounters features within a cave which are mysterious to him, sketches or photographs make it possible to bring such features before those who might explain them. In assembling information for the hydrologist there are many questions which should be answered concerning dripstone deposits. Are both stalactites and stalagmites present? Which is present in greater size? Greater quantity? What is the relationship between size and quantity? Are the dripstone features located in any discernible pattern? These are but a few leading questions which should be answered in the report of a cave investigation.

Blankets of travertine and their location should be recorded as well as their location with regard to the water source responsible for their deposition.

In most cases the cave itself is testimony to the solvent action of water. Other less conspicuous clues to this solvent action may be found in the development of scallops on the walls, ceilings and floors. Abandoned or active stream courses may show evidences of solution or deposition or both. Block falls from the walls and roof should be examined for traces of solution or deposition on the blocks since their fall.

Debris, such as logs and trash, should be noted for the indication they give of free connection to the surface. Similarly, great care should be taken in mapping stream deposits of mud, silt, sand or even gravel. The explanation of these deposits frequently furnishes excellent evidence of past stream behavior.

Although outside the scope of most cave investigation the hydrologist may find his most important data in the relationship of a cave to the enclosing rocks. In bedded formations the relation of the cave to the bedding is a most import-

(continued on page sixteen)

Speleology in Southeastern Alaska

By ROBERT J. HACKMAN

The Alexander Archipelago* of Southeastern Alaska offers considerable material for the speleologist, ranging from Indian burial caves to giant sea caves and caves with petroglyphic markings.

Although the location of only a few of these caves is known, there is every indication that a considerable number exist. Not only is a greater portion of these islands partly or completely of a limestone nature, but also in traveling through the many waterways between the islands one sees a great many sink holes and depressions on the islands themselves, while along the shore line an occasional sea cave is visible. This is especially true on the western fringe of the island group where the high rocky coast receives the full effect of the pounding Pacific waves.

There are three good reasons why the discovery and exploration of caves in this area is difficult. They are as follows: muskeg, dense underbrush and bears. In regard to the first mentioned, nearly all the sink holes are filled with muskeg, a sort of bottomless ooze overgrown here and there with patches of thick moss and gnarled shrubs with ponds of shallow water in between. This material would tend to fill up any caves or cave entrances that might exist in the sides or bottoms of the sink holes.

Next comes the underbrush, and a formidable obstacle it is. The greater portion of this area is covered with a dense forest of spruce and hemlock, intermingled with the smaller brush and thorny devil's club. Under all this are the rotted fallen logs of past generations of trees. As if this were not enough to make the finding of a cave entrance difficult, Mother Nature has gone a step further. A dense thick moss grows over everything,—fallen timber, stumps and even rocks. This verdant growth has a habit of arching across openings of any kind whether rotted stump holes, crevices or cave entrances. Under such circumstances, one would have to practically fall into a cave before being aware of its existence.

Picture of author after four months in the Alaskan brush.

The last reason, and although it is of a different nature from the two mentioned above, could well prove a menace to the cave explorer. The few caves that one does find in this area (and this is especially true of the higher drier ones) give every indication of present or recent habitation by bears. There are two general types of bear in this area, the black bear and the brown bear. The latter, although found only on the northernmost islands of the group, belongs to that species that is the largest in the world, sometimes weighing over a thousand pounds and standing upright to eight and nine feet. These bears would prove a formidable adversary to any speleologist. The black bear, on the other hand, exists in considerable numbers throughout the area and can usually be scared away by yelling, or waving one's arms, except when it is cornered

* See map, page 72.

or is with cubs. They are then fierce fighters. What their reactions would be when met in a cave is difficult to determine. The author attempted to find this out by crawling into a cave into which a black bear had been seen running only a few minutes before. After going in about sixty yards down a winding, twisting passageway with a thirty-0-six rifle in one hand and a flashlight in the other, the quarters became rather cramped, the smell of bear rather strong, and with speculation on what the effect of firing a rifle in such closed quarters would have on the ear drums, he decided to give up the experiment until another time.

Mummified Indians

There is considerable Indian lore tied up with many of the caves in this area, and my first clue to such a find came early in the summer while I was in Craig, Alaska. Here I heard of an Indian burial cave that was discovered by two trappers about ten years ago. The cave is located on the south side of a small inlet not far from the northern end, and on the west side, of Dall Island. The story goes that the two trappers found two mummified Indians in this cave. The remains were in a sitting position, wrapped in woven cedar mats and resting in hewn cedar boxes whose sides were held together by twisted bark rope of the same type of wood.

Although I was unable to visit the cave, the same story with little variation was heard many times during the summer from various people, giving it considerable authenticity. It seems that the bodies were removed, but here a certain amount of vagueness sets in. Some say they were sent to a museum in the States, while others claim they were kept in Alaska.

In regard to the possible age of these remains, the absence of nails or other implements that would show a contact with the white man would indicate the burials were at least a hundred years old, possibly much more.

Another Indian Burial Cave

The next clue to a burial cave came to me later in the summer. On one of our weekends in Craig, Alaska, I struck up a conversation with a local Indian, Joe Demrit, of Tlinket descent and a prominent citizen and fisherman of the town. During our conversation I asked the favorite question of a speleologist and one that I had asked and was to ask many times during the summer, "Are there any caves around this area?" Joe then told me of a ledge cave on a small island not far from Craig that contained the skeletal remains of about twenty Indians, and referred me to a person named Slim Wilder who lived on a small island nearby and who could show me the location of the cave. Here was one cave that was close to Craig, and plans were made to visit it as soon as extra time permitted.

Several days later, with Norman Dennis, one of the fellows with whom I was working, I took a small boat and motored over to Slim Wilder's place, and, after receiving directions from him, proceeded to the burial cave. The cave is on the middle of the three northernmost islands in the Alberto group. This very small cluster of islands is located off the southwest corner of Wadleigh Island, and is about three and one-half miles from Craig. The island is about half-a-mile long and almost as wide. There is a small beach on the southwest side of the island where a landing can be made, and about four hundred feet up a heavily wooded ravine is the cave. It is a horizontal ledge cave running into the face of the cliff in a wedge-shaped manner for about forty feet, the ceiling at the entrance being about five feet high.

It appeared that the bodies were originally placed in a jackknife position, wrapped in woven cedar mats and placed in cedar boxes. The majority of these boxes were joined together by a lacework of twisted cedar bark, running in and out of small holes drilled into the wood. A few of the boxes, however, were held together by small carved wooden pegs. The sides of the boxes themselves showed no carvings of any kind, but some of the lids, which were made to fit snugly on top of the boxes, had carved grooves and flutes on them indicating an attempt at artistic design. One top had a borderline of inlayed shell running around the edge.

Although the place was dry and protected from the weather, the boxes gave evidence of considerable decay. Several pieces of what appeared to be some kind of skin, dyed green, were mixed in with the scattered bones and were probably remains of the burial clothing.

In referring to the burial material as scattered around, that is exactly how it was when we came upon the sight: bones, boxes and other material in a disarticulate heap. When we again talked to Slim Wilder, who showed us

Robert J. Hackman

UPPER PHOTO shows Norman Dennis of the U. S. Geological Survey holding two skulls found in burial cave. **BELOW:** Group of four skulls in burial cave showing remains of broken boxes.

where the burial was located, he told us that he first came across this cave while hunting eagles some years ago at a time when there was a bounty on eagles in Alaska. Slim, by the way, is one of those hermit souls who lives alone and likes it; he is nevertheless an interesting person. When he found the cave, everything was in an orderly manner, appearing to be as yet in an untouched state, and since Slim is one of those persons who believes in letting the dead lie, he left the burial in the same condition in which it was found. He did, however, in the days to come, tell a few people about his find, and in a very short time some of the fishermen got around to investigating the place. It wasn't long before these "pot hunters" had really messed things up —breaking open the boxes and stirring up the place. Whether they ever found anything of value or interest, I am not aware.

In estimating the age of this burial there is again an absence of articles that would indicate contact with the white man or early trader. Sometime previous to this discovery the author had examined a surface burial on a small point of land overlooking a whirlpool and about ten miles north of this burial cave. This surface burial consisted of a wooden shed, in a very rundown condition, surmounted by two very weathered totems. The interesting point regarding the burial, which by the way was that of a Tlinket witch doctor, was that the wood used in the construction was joined together by square nails. These nails, the local people told me, were of the type that were first used in trade with the Indians and they date the burial as being at least seventy-five to eighty-five years old. Since no nails were used in connection with the burial cave, it would be logical to assume that the remains are at least ninety years old. Now to some further evidence that gives an even greater age to the remains.

About half-a-mile from this small island on which the cave is located is the site of an old Tlinket Indian village of considerable age. Unless the spot were pointed out, one would have difficulty in finding it, since a thick growth of trees has covered the place. But there again our friend Slim Wilder, who appeared to be well-informed on the Indian lore of the area, pointed out the old lodge holes, some of them ten feet deep and some almost completely unrecognizable totem poles that at one time must have been two-and-one-half feet in diameter. In regard to the lodge holes, they all had trees growing in them. In the center of one was a hemlock tree which had a diameter of twenty inches and was estimated by Slim to be about one hundred years old. If this is true and the burial did come from this old village site, which is the closest one to the burial cave, and since the village has been deserted these hundred and possibly more years, it would appear that the burials date back to a time when the village was occupied.

Folklore Cave

The folklore of the Tlinket Indians gives the raven as the principal deity and ancestor of their race. The story goes that 'way back in the days of creation, and before he started his line of descendants, the raven wished to make the seas safe for his people. Therefore, selecting as a meeting place a cave on the island which later was named Coronation Island, he invited all the terrible monsters of the deep and when they had all assembled in this cave, he cast a spell on them that they might never be free to molest his people. And today when one visits this cave the monsters are all there to be seen.

This story was told to me by Joe Demrit, the local Indian who told me of the burial cave. Joe is part Tlinket and has visited the cave. He states that there are considerable formations in the cave and that it was probably the shape of some of these that inspired the imagination of the early Indians to associate them with terrible monsters of the deep. The author did not have an opportunity to visit this cave since it was a considerable distance from where we were working at the time.

Petroglyphs In Cave

Biting far inland and on the northwest side of the rugged Kosciusko Island is Shipply Bay. Located on the southside of the bay is a cave and upon its walls are petroglyphic markings. This was told to me by the forest ranger of the area. He had never seen the cave himself, but another man in the forestry service had visited it some years back and informed him of its existence. Likewise in the bay itself and just offshore is a large rock which is covered with petroglyphic markings. Many such markings have been found in Southeastern Alaska, and are believed to be of great age, since the present day Indians have no knowledge as to what these markings mean.

The majority of them are found along the shoreline and face seaward. By some they are believed to have been used as informative landmarks. This is a field that is open for further study. This again was a cave that the author was unable to visit because of its distance and lack of available spare time.

Other Caves On Other Islands

Although the author was able to visit only a few islands other than the ones on which we worked, considerable information concerning caves on other islands in the near locality was obtained through conversation with the fishermen who trolled for salmon up and down the waterways, and trappers who ran traplines on the various islands during the wintertime. Below are listed some of the islands and their speleological possibilities:

Large elevated sea cave on the western shore of Noyes Island.

BAKER ISLAND. This island has a large blow-hole cave on a point to the northwest and shoots spray high into the air. The island is almost completely of limestone and a mining engineer that made a study of the deposits on the island stated that traveling on it was dangerous because of the many sinks, caves and pits.

NOYES ISLAND. Along the rocky Cape Addington that juts out into the Pacific are several caves. One consisted of two caves which have a talus slope in between them and when viewed from out at sea gives the appearance of a large wolf head. Another cave nearby is at the base of a high cliff and has a picturesque lake in it. Farther to the north and up the coast is a cave that runs through the cape, which at this point is about a quarter of a mile across and high and rocky. One can look in one end and see light at the other end. There are other sea caves along the western shore of the island proper.

WHITE CLIFF ISLAND. Running into the face of a vertical limestone cliff and about ten feet above the water's edge is a small cave that runs about fifty yards into the face of the cliff and ends up in a series of small chimneys.

ORR ISLAND. On the central eastern side of this island and behind a small offshore island is a cave that runs into the face of the cliff and has a small stream in it.

KOSCIUSKO ISLAND. Near Cape Pole and on the homestead of one "Pike Pole Slim" is a small cave which runs about seventy-five yards into a low bluff. The cave has a small stream in it and the owner has dammed up the entrance and uses the cave as a reservoir for his water supply.

This island gives every indication of a great number of caves. The author visited about six while camped in the vicinity of Edna Bay. The location of one of these six was described to me by the superintendent of the now temporarily closed Juneau Spruce Mill Logging Camp. Upon looking for this cave I found five more in the same general locality. All are along the east face of a ravine and appear to belong to a chainwork of caves and underground channels that catch the overflow from a lake about a mile up the ravine. The ravine itself is dry at present but at one time must have been the main drainage of the lake before the caverns were hollowed out. Although the underground channel meanders some, it does run roughly parallel to the ravine but at a slightly lower level.

At the time I visited the cave, which was during an unusually dry spell, there was no visible running water. There were, however, some deep pools in the cave, some over ten feet deep, and in one of them I chanced to see a twelve-inch fish swimming around. Whether high water had carried this fish into the pool, or whether it was a blind cave fish was not determined since upon a return trip with a net the fish was nowhere visible. The back part of the pool was a duck-under and the fish was either back there or had moved on to another part of the cave through some nonvisible channels.

CORONATION ISLAND. This island belongs to the extreme westerly group, and has considerable limestone on it. It is high and rocky with sheer cliffs dropping off into the sea and, besides the folklore cave already mentioned, has many giant sea caves along the coast. One fisherman told me that on a calm day he ran his fishing boat into one of the larger caves. These trolling boats are usually about fifty to sixty feet long and about as high.

A very interesting fact about these large sea caves is the abundance of bird life in them. Thousands of wild ducks and other types of sea fowl use them for nesting places. One can fire a gun near the entrance of one of these caves, and thousands of birds will fly out. In fact, so great is the number that by the time the first portion of the flight has completed a half-mile circle over the water and begins flying back into the cave, some of the rear section of the flight are still coming out of the cave.

HECETA ISLAND. This island is mostly of limestone and has a considerable number of sink holes on it, some of them filled with water and forming picturesque lakes. There is a large cave entrance in a sink hole about half-a-mile inland from the east side of Port Alice. The cave has an underground stream in it and is believed to drain a sink hole lake farther up the way. And just offshore, seen at low tide a large spring gushes out of the ground and is about eighteen inches across. It is believed to be a part of the same drainage system. The author talked with some geologists who were working on the island and they said they had seen some cave entrances but had not investigated them any further.

Conclusion

The information for preparing the preceding paragraphs was obtained through sparetime exploration and conversation with some of the local inhabitants while spending four months in this area doing map work. On the whole, the area is uninhabited except for a few isolated settlements. The few caves I have attempted to describe are probably but a fraction of the ones that exist, and I am sure that future investigation in these parts will turn up some rich cave material.

•

Hydrologic Investigation of Caves

(continued from page ten)

ant consideration. The inclination of the bedding and stratigraphic section must be determined. Evidences of diastrophic activity and the presence of faults and joints should initiate a careful study of their relationship to the cave. The lithology, porosity, permeability and chemical composition of the rocks must be studied in detail. Careful hydrologic investigations must include painstaking geologic mapping of the area involved on large scale maps, with the cave features well located on such maps.

Speleology is a qualitative type of hydrology. By applying some care and observation much quantitative information may be assembled on the hydrologic characteristics of limestone terrains.

The Formation of Saltpetre in Caves

By BURTON FAUST

From a vast fund of material it appears possible to draw some conclusions concerning the physics, chemistry and bacteriology involved in the formation of saltpetre in caves. There seem to be great differences of opinion between geologists, bacteriologists, agricultural chemists and others who, by profession or avocation, have a degree of interest in the problem. The statements and conclusions which follow comprise a partial discussion of the facts and opinions upon which those conclusions are based.

The instant problem is to investigate some of the methods and processes whereby cave nitrates are formed and deposited. The present interest is in the chemical or non-symbiotic bacteriological processes by which nitrogen is fixed in the form of nitrates.

Only some of the theories and ideas that have been advanced will be discussed to a limited degree. The author will indicate points of weakness, and will promulgate a theory to explain the presence of nitrates in caves. It is recognized that this is a controversial subject and any one who attempts to interpret such facts as are known sometimes finds himself in a position similar to that of the astronomer who theorizes about the apparent canals on Mars. The mere fact that different ideas have been advanced to explain the same or similar deposits must be accepted as evidence that the subject is controversial.

Saltpetre is found in very widely distributed natural deposits. Among the earliest known deposits and those from which usable and commercial quantities were obtained are as follows: plains in Spain; chalk deposits near Eureux in France; the nitre caves of Ceylon; grottoes of Mont Hamberg, in Germany. The calcareous soil of Molfetta, Italy, Turkestan, Hungary, the Ukraine, and Podolia furnished Europe large amounts of the salt. It was obtained from the valley between Mount Sinai and Suez in Arabia. Persia and India both contributed this important material.

It appears self-evident from the above that the recovery and refining of saltpetre, the incident trading in and transportation of the product, as well as its utilization and consumption resulted in a large amount of activity in the commercial, military, and industrial world during the middle ages.

Our present concern is not with these phases of the problem or with the world wide distribution of saltpetre, but is directed to such deposits in caves, particularly those found in the Appalachian Region of this country.

Of the nitrate minerals only nitrocalcite is of present interest. This nitrocalcite, nitrate of lime, or calcium nitrate is often found in the form of white or grayish tufts, or masses, or as crystals interspersed with cave soil. In many instances calcite, aragonite, gypsum and certain other mineral crystals are found mixed with the nitre crystals in the cave earth.

Some authors have stated that the accumulation of saltpetre in caverns is the result of the action of putrifying bacteria in the decomposition and oxidation of excreta and other animal by-products and remains.

It is not necessary or desirable to consider the chemistry or bacteriology involved in this process as it has been discussed at great length by many writers, but there is another phase of this problem that has a slightly different aspect to which attention is now directed. From about 1300 to about 1700 a great share of the world's supply of saltpetre was obtained from rotting compost heaps. These artificial nitrate beds were made by a mixture of any and all kinds of organic waste material kept moistened with urine or water and maintained in an alkaline state by adding available limestone, plaster, or any other material of similar basic nature. An excellent discussion of this method of obtaining saltpetre has been prepared by Leather.[1] A further consideration of this topic will be found in a resolution[2] passed by the Continental Congress July 28, 1775.

Certain writers go so far as to make the more or less broad and sweeping statements as follows:

"There is no doubt that the nitrates in the caves originate in an exactly similar way. Caves or cavernous ledges are the natural refuge of all sorts of animal life, including insects, birds, reptiles, and many of the larger animals. In these recesses they leave not only excrementa but bits of their food, hair, bones, flesh, and even grains, mixed in a soil that is often light and porus, and may be filled with twigs and dried leaves. This is probably stirred by the coming and going of the cave denizens. Parts of these recesses are often damp with ground moisture or with wind blown storm water, or mist, and when damp, and at the same time warm, they are in an ideal condition to promote the activity of the nitrate-forming bacteria. Thus it is easy to account for the accumulation of saltpetre or nitrate salts in caves and in cavernous recesses of rock ledges."[3]

The superficial way many persons have of dismissing any serious discussion and taking for granted a preconceived idea of the manner in which the saltpetre deposits get into caves is illustrated by the following remarks which apparently are based on casual observation:

"It is generally known that the earth in these caves contain the nitrates of lime, potash, and other salts. The numerous caves which have been found in the Cumberland Mountains and other parts of Tennessee, have been very productive of the nitrate of potash. In the investigation of the causes which have given origin to these salts, it may be recollected, that wild animals burrow in these caves; that when pursued by the hunter, they make them places of their retreat, and probably die there; that the aborigines have made them a place of burial; and that streams of water which flow through them in wet weather, carry with them not only great quantities of leaves but many other vegetable productions."[4]

No evidence of the presence of any potash salts in any cave has come to the attention of the author. As is well known, calcium nitrates, calcium sulphates, magnesium sulphates, and calcium carbonates comprise the greater bulk of common cave minerals.

While wild or predatory animals do use caves to a very limited extent, no amount of evidence has been found to substantiate the contention of wide use. It is believed the presence of animals in caves may be attributed to fear of enemies rather than seeking shelter. Animals, in general prefer the burrow or small grotto type of shelter. Furthermore, no appreciable amount of evidence of the past or present peregrinations of animals in the vicinity of saltpetre bed deposits has been found.

In the Appalachian region practically no evidence has been found that the aborigines used any saltpetre cave as a burial place. Numerous cave burial places have been studied but there appears to be no correlation between such and the presence of saltpetre.

No instance is known to the author in which any cave stream, whether it had an underground or surface source, has or does flow through or immediately close to a saltpetre bed. There are several reasons for this fact. First there very probably would be no soil in which the saltpetre might lodge since a flowing stream would have washed such dirt, or, as some writers call it, the caput mortum, out of the cave or piled it in compact layers in some lower section of the cave. Second, the nitrate mineral compounds are so soluble that they would be carried, from any clay beds, completely out of the cave; this was the manner employed, under control, of extracting the calcium nitrate from the petre-dirt. Third, all saltpetre deposits that have been observed, inspected, and studied by the author have been deep underground, a considerable distance from the surface and free of any evidence of running or percolating water for many years. Thus running water seems to have had a negligible part to play in the production or deposit of the saltpetre.[5]

From the above brief analysis it may be seen how superficial observation and lack of consideration of all the factors involved will often lead one to erroneous conclusions.

As may be seen from the above quotations it would appear that the decomposition and oxidation of organic remains has been given great weight in attempting to account for the formation of nitrates. However, it is believed a brief resume of other processes whereby nitrates are formed would be in order.

Another known natural process of nitrogen fixation occurs when the nitrogen oxide base of nitric acid is formed in the air as a result of lightning discharges. Generally there is sufficient ammonia in the air or dissolved in rain to combine with all the nitric acid so formed. The ammonium nitrate which results eventually reaches the earth.

Another phase of this lightning discharge theory has been advanced by some authorities. It has been suggested that the nitrogen oxides formed by lightning discharges that are changed to nitric or nitrous acids and not neutralized by atmospheric-borne or rain-dissolved ammonia will act directly with limestone and thus form the calcium salts.

Another natural source of nitrates is the great quantities of ammonium salts in the immediate vicinity of an active volcano. For example, nearly all reports of the eruption of Paricutin in Mexico mention the great deposits of ammonium chloride found close to active fumeroles.

Unquestionably the organic processes are important in the fixation of nitrogen and the production of nitrates insofar as the well-being of the world is concerned.

What appears to be one of the most plausible theories and one which is somewhat generally accepted by authorities is based on combined bacteriological and chemical processes. It has been discovered that certain kinds of bacteria not associated with plants have the property of being able to fix nitrogen.

An abstract from one of the earliest statements advancing this bacteriological theory is given below:[6]

> "Professor William B. Rogers remarked that from his observations in the caves of the Middle and Southern States, he was satisfied that the earthly deposit containing the nitrates, known in some places as Petre dirt, was chiefly derived from the overhanging and adjacent rocks, and not from sediment brought into the cave by existing or former streams. . . . As to the production of the nitrates with which the Petre dirt is more or less impregnated, Professor Rogers thought it could not, in any large degree, be referred to the excretions and other remains of animals occasionally found in these caves since the quantity of nitrogen required for this purpose far exceed such a means of supply. Besides this, the nitrates are found in the earthly mass while it is still adhering to the roof or walls and far removed from the organic matter supposed to be buried in the floor. Nor can we regard the nitrogen as chiefly derived from organic substances in the decomposing rocks. For in the case of some caves producing Petre dirt, the surrounding limestone contains only a trace of such ingredients. We must, therefore, refer the formation of the nitric acid, and ultimately the nitrates, to mutual chemical reactions between the porus calcareous earth and the contiguous atmosphere."

Mr. John A. Myers[7] in speaking of the work Mr. S. Winogradsky has done states in part:

> "Winogradsky has devoted a large amount of time and attention to the study of the nitrifying organisms which convert ammonia salts into nitrates. . . . He has succeeded in isolating and preparing a pure culture of a group of organisms, called by him 'Nitromonas' which he is disposed to consider rather as a group of bacteria than as a single species whose special function is the oxidation of ammonia. . . . He also found that the 'nitromonas' developed normally either in the light or in the darkness, and that they can assimilate the carbon from carbon dioxide in entire darkness. They are able, in entire darkness, to appropriate this carbon from carbonates or from carbon dioxide and cause it to combine with the nitrogen to form organic matter, without the aid of sun's rays. He believes that some sort of an amido compound is produced at the expense of the carbon dioxide and the ammonia. These chemical changes developed by the nitromonas, differ materially from those which occur with chlorophyl. In the action of chlorophyl, carbon dioxide is decomposed by the sun's rays, the oxygen liberated, and the carbon united with the hydrogen and the oxygen to form carbohydrates, but the investigations of Winogradsky indicate that the nitro-bacteria, instead of decomposing the carbon dioxide and setting oxygen free, effects its union with ammonia and makes use of the oxygen of the air to oxidize the nitrogen to nitrous and nitric acids, the energy for this change being supplied to them from the oxidation which they bring about."

Another phase of this problem is discussed in a summary of additional studies by Winogradsky and Omeliansky and is reported as follows: [8]

> "The activity of the nitrifying organism is retarded or even entirely stopped by the presence of small quantities of organic matter; the nitrous bacillis is more sensitive in this respect than the nitric. No doubt this retardation plays an important part in the transformations of the nitrogen in the soil. The denitrifying organisms convert nitrates into ammonia and then into free nitrogen, but they can act only in the presence of

sufficient organic matter. So long as organic matter is present, the organic nitrogen is converted into ammonia, and nitrification cannot take place; but when the organic matter has disappeared, nitrification begins, and the denitrifying bacteria cannot destroy the nitrates produced. The nitric organism does not come into play until all the ammonia has been converted into nitrite; ammonia is fatal to the activity of the nitric bacillis."

In some of the studies[9] conducted by Mr. Wm. P. Headden some very startling conclusions are offered. The study will not be reviewed since it is easily obtainable.

An interesting sidelight on this bacteriological theory and more than a hint that early men of science suspected that some strange phenomenon was transpiring is evident for Dr. Samuel Mitchell[10] reports in a discussion of saltpetre caves the following conclusions:

"When the earth (from the caves) has been letched with the vegetable alkali (potash) and deprived of its acid, it is common for the men to replace it. For experience has taught them that if put back again into its former situation, it renews its salt-petrous quality in about three years. Being impregnated after lying that duration of time with another supply of acid, it is fit to be treated once more with wood ashes, for the purpose of forming a second portion of salt-petre. There seems to be no end to the possible repetition of these processes, of extracting and regenerating the acid ingredient of the salt."

"Men of science may theorize and speculate on these remarkable facts. It seems difficult, in the present state of our knowledge, to explain how either the acid or the alkali should be spontaneously formed by synthesis, in those dark and rocky caverns. But before this can be done, we must acquire a knowledge both of the acid and alkali which constitute salt-petre, much more intimate and profound than the modern chemists possess."

The present day chemist, bacteriologist, physicist, engineer or other scientists are oftentimes prone to regard some of the early men of science as freaks, alchemists, astrologists or just plain charlatans. They seem to disregard the fact that many of those early scholars had just as high a degree of intelligence as the man of today. The only difference was in extent of background and a much lesser fund of knowledge and information from which to draw. Those men as illustrated in the above extract from Dr. Mitchell's writings must be given credit for keen powers of observation and the ability to so govern their procedures and conduct as to utilize the observed facts. While they might not have known why the saltpetre dirt would revive itself, they did utilize that property to their own advantage. The studies of Heddon and others seem to indicate the early saltpetre men might not have been too far mistaken in speaking of the saltpetre dirt renewing itself as spontaneous synthesis.

While the above is not meant to include all the natural processes whereby nitrates are formed, the most important, insofar as the instant problem is concerned, have been mentioned. It is thus self-evident that here are several possible sources from which cave nitre deposits might have been derived.

At one time the attempt was made to explain the production of nitrates in the soil on the basis of oxidation of organic matter. The theory was held that the nascent nitrogen, released by the action of putrifying bacteria, was oxidized by the oxygen of the air and which in turn by interaction with the nitrogen of the organic matter formed nitrates. This theory was soon discarded for the more plausible idea that the action was more complex than implied. The theory of the interactionary relations, almost communal in nature, of putrifying, denitrifying, and nitrogen-fixing bacteria was accepted and appears to have withstood the tests of time. On the basis of these reactions every compost heap, every artificial nitrate bed is a home for these reactions. This process has been utilized for many centuries to produce the nitrates necessary to meet the demands of trade and war. Whether the nitrates are thus produced; or produced by the action of nitrogen fixing bacteria in legumes as host plants; or by the tiny amounts resulting from the discharge of lightning, or by volcanic, or mineral sources, there is a tendency for them to accumulate in the soil unless they are washed away by rain water. The accumulation of the nitrates in a cave thus became a mechanical problem. The mechanics of accumulation have been discussed in considerable extent by Ross,[11] Nichols,[12] and Hess[13] and will not be considered at present.

Since all nitrates are water soluble such accumulated material is bound to be found in percolating water. This property is well known and certain authorities[13] have advanced theories based on this fact to explain the occurrence of nitrates in caves. Now, if as advanced, the water as it percolates through the soil is intercepted by an open cavern, and the air movements within the cavern are such that the water transported minerals will be left behind, deposits will be accumulated on the cave floors and walls. On this basis it appears reasonable that nitrates should occur in all caves in which the proper balance of humidity and air movement are maintained. Analysis, observation, and past history have shown a wide distribution of such deposits but the presence of saltpetre is not universal.

The above sounds very simple, plausible and workable. However, there are a number of arguments that may be presented against such a theory. Some of the questions that must be answered satisfactorily before such an explanation can be accepted are as follows:

1. If the same water that dissolves the nitrates will concurrently dissolve limestone, why are there not nitrate-bearing stalactites, and why is there not nitrate-bearing flowstone found in saltpetre caves?
2. If the nitrates are brought into caves by percolating water how can one explain the fact that the distribution of saltpetre in the "petre dirt" appears substantially uniform in both areal extent and vertical depth?
3. If percolating water serves as a vehicle for nitrates how can one explain the fact that petre dirt was mined from passages and grottoes so filled as to prevent air circulation which is necessary for continued evaporation?
4. If ground water serves as a means of transport for surface produced nitrates how can one explain the fact that the author has never discovered or observed a petre-dirt bed that shows any evidence of water percolation through the cavern roof above the deposits? Such evidence of past water action as has been observed apparently took place before the petre-dirt beds were deposited.

Certain authorities have stuck to the theory of the decomposition of animal excreta and remains as a source of nitrates in the cave soil. In this instance also there are certain questions that must be answered satisfactorily before this theory can be accepted. For example:

1. If bat droppings have furnished the nitrogenous matter why is it that bat rookeries generally are highly localized in the caves and the "beasties" do not appear to roost in large numbers in all parts of the cave? It does not seem reasonable to assume bats have changed their roosting habits through the years.
2. If the bat-roosts are local arrangements, as appears to be the case, why are the saltpetre deposits spread so uniformly as analysis and past collecting experiences seem to indicate?
3. If bats and/or other animals were the source of cave nitrates how is the presence of nitrates in substantially closed passages and tightly packed grottoes, niches, cracks and crevices to be explained?
4. If animal by-products provide the source of the saltpetre how is the great paucity of animal remains such as bones, hair and skin in or about the beds to be explained?

Since the theory of the formation of cave nitrates from bat guano, the decomposition of animal remains, oxidation and neutralization, has been given wide circulation and is accepted so unquestionably by many writers it is proposed to briefly examine some of the arguments that have been advanced in its favor.

Some cave deposits have been worked for saltpetre at great distances from the surface entrances. For example, the tremendous deposits in The Hall of the Mountain King, in Sinnit Cave are over 1,200 feet from the entrance. While there probably is a shorter route as the bat flies, the author has never been able to see any evidence that bats had at any time roosted in the immediate vicinity of the petre deposits. Reports indicate that Mammoth Cave was worked at a distance of over five miles from the mouth of the cave. Other instances might be cited of great distances from cave entrances to nitre deposits but the above are considered sufficient to make the point. Analysis and reports seem to substantiate the statements that the concentration of the nitrates is substantially uniform over the whole of the beds. The numbers of bats that have been observed at any great distance from the entrances of saltpetre caves have been comparatively small. However, that in itself does not necessarily imply anything of particular significance since the bats could have migrated or changed their roosting places. Furthermore, it does not appear reasonable to assume that all the hair, toenails, bones and other stable remains would have become so completely disintegrated that much smaller amounts of organic remains are found than would reasonably be expected. Nichols[12] has an excellent discussion of this phase of the problem.

The nitrates are found in some instances in the earthy masses still clinging to the ceilings and walls of passageways that were originally, from all appearances, completely filled to the ceiling with the petre dirt. For example, certain passages in Breathing Cave and Clark's Cave and almost the entire intermediate level of passages below The Hall of the Mountain King in Sinnit Cave are instances the author has particularly studied and observed. The material clinging to the ceiling is far removed from any organic substance that might be in the soil underfoot. The author has seen many instances in old saltpetre diggings in which pockets, small grottoes, cracks, crevices, crannies, shelves and filled passage-ways have been scraped clean to recover petre dirt. It is considered safe to assume the early miners were not going to carry non-producing dirt from the caves. It is not believed possible to explain such deposits by the bat-guano theory.

Another minor angle of this problem seems to be involved in the matter of the capacity of the bats to do the job with which they have been credited. The task of providing the vast amount of raw material from which the thousands of tons of saltpetre obtained has been recovered would have been a tremendous job for the bats. This seems to approach too closely to harboring the belief and expectation that the family pet dog could have built the Panama Canal by scratching for squirrels.

There is no question, in the mind of the author, that all the above outlined processes whereby nitrates are formed might have entered into the picture. The magnitude is impossible to determine and no intention to belittle or disparage any theory is intended.

The author is of the opinion, however, that there is another method, to which too little attention has been given, that might account for a much greater volume of nitrate deposition than all the popular theories combined. This method is discussed below to a very limited extent.

As one reads the older literature, in which the procedures in mining, recovery, refining, and utilizing saltpetre are described, statements repeatedly appear describing the return of a leached soil to the caves where after a period of about three years it could again be treated and additional saltpetre recovered from the same soil. Craig[14] reports that such procedure was not unknown and suggests that dirt be carried into caves, spread, and left to become charged with nitrates.

As stated above Winogradsky discovered that certain nitrifying organisms are capable of producing organic matter from the carbon dioxide, ammonia and water vapor in the air without the necessity of having sunlight present. It was further discovered very early (circa 1860) that it was necessary to actually have soil present in order to produce the fixed nitrogen. Such reactions appear not to have been possible without the mysterious catalytic action of the soil.

The possibility that nitrogen fixing bacteria exist which have the ability to produce fixed nitrogen in the form of nitrates directly from inorganic elements and compounds is a question to which it appears very little attention has been given. Based on the observations and reports of early scientists, such as Dr. Mitchell, Wm. Barton Rogers[15] and studies such as those conducted at the Colorado Agricultural Experiment Station, to which reference is made above, it would appear that this method of fixing nitrogen must be considered very important. Of course, the main reason so little attention has been given to the deposits of cave saltpetre during recent years is probably due to the fact that the economic need of the product has not warranted the necessary expense involved. The fact that the action of these non-symbiotic nitrogen fixing bacteria are fairly well understood and that the circumstances under which they will live and function approximate very closely the ambient conditions in a cave make it necessary to consider this very pertinent source of nitre. The necessary conditions which seem to promote the growth and activity of these bacteria are found in every saltpetre cave the author has visited. These are: a uniform temperature, good air circulation, relatively low humidity, heavily alkalized loose and porous or semi-porous soil, and freedom from running, dripping or flowing water.

There is no intention to disregard any of the theories advanced to explain the occurrence of saltpetre deposits in the limestone cave areas of the country. It does not appear that the presence of saltpetre in any cave is explainable by any one theory. Rather it seems that each method may have played a greater or lesser role in this natural phenomenon. There are many things about caves that have not been fully explained. This problem is one of those which has been incompletely solved. However, this last theory is presented to the reader in a sketchy and incomplete manner only as another facet in the whole picture.

REFERENCES

[1] LEATHER et al. "The Indian Saltpetre Industry".
[2] "Several methods of making saltpetre recommended to the inhabitants of the United Colonies by their representatives in Congress."
[3] H. S. GALE, "Origin of Nitrates in Cliffs and Ledges", *Min. and Sci. Press*, Vol. 115, pages 676-678, Nov. 10, 1917.
[4] KAIN, *Am. J. of Sci.*, 1:65, 1819.
[5] Since the above was written information has come to the author that certain saltpetre caves such as Julian's and McFerrin's do have at the present time running water closely adjacent to the old workings. Wm. E. Davies has reported that he has inspected certain caves in which the saltpetre deposits are relatively close to the entrances. However, it appears safe to assume such deposits were not affected to any extent by outside rains, snow, or wind-blown water.
[6] *Proceedings of Boston Society of Natural History*, Vol. 5, page 334, 1856.
[7] *Proc. Am. Chem. Soc.*, 21: 464 plus, 1899.
[8] *Journal Soc. Chem. Ind.*, Sept. 20, 1900: 835.
[9] *Colorado Agri. Exp. Stat. Bull.*, 155, February 1910.
[10] *Med. Rep.* 9:86, 1806.
[11] "Origin of Nitrate Deposits", *Pop. Sci. Mo.* 85: 134-145, Aug. 1914.
[12] "Nitrates in Cave Earths", *Proc. Soc. Nat. Hist.*, Boston 5: 334, 1856.
[13] "Origin of Nitrates in Cavern Earths", *Min. & Sci. Press*, 115: 19, 1917.
[14] "Report on Nitrification", *Smithsonian Institute Reports*, 1861.
[15] ROGERS, "A reprint on the Geology of the Virginias", 1884.

GEORGE A. WHITE

George A. White, a Toledo member of the National Speleological Society since 1942, died suddenly at his home on July 24, 1949. He was 58 years of age at the time of his death.

A lifelong resident of Toledo, Mr. White was employed by the City of Toledo as an Engineering Estimator in the Division of Engineering and Construction.

Mr. White was a member of several field parties from Toledo, exploring various caves in the Mammoth Cave region of Kentucky. One of these trips was described in Bulletins No. 6 and 7, as reported by L. E. Ward. The following year Mr. White was a member of a similar group, which was joined by J. S. Petrie, Wm. J. Stephenson and three other Washington speleologists, when additional Kentucky caves were explored, including the treacherous "jug" in the old Doyle Cave near Diamond Caverns.

Mr. White was greatly interested in the work of the Society and his death will be a distinct loss to many of the Society's members and to his many friends in Toledo and throughout the State of Ohio. He was President of Local 7, City Employees Union, AFL., Chairman of the Public Employees Legislative Committee of the State Retirement System, a member of Euclid Avenue Methodist Church, an Odd Fellow and a member of various civic groups in Toledo.

Surviving are his wife, Eva Belle; daughters, Mrs. Theone Meyers and Mrs. Virginia DuFour; sister, Mrs. Bertha Casey, Adrian, Michigan, and three grandchildren.

Saltpeter Mining in American Caves

By GEORGE F. JACKSON

NOTE: A shorter version of the following article appeared in the Field Artillery Journal for September-October 1948, under the title "Caves and the War of 1812".

Recent speculation regarding the possibility of using the caves of the United States as underground workshops, factories and places of refuge in case of an Atomic War brings to mind the little-known fact that some of our caves contributed greatly towards our winning an earlier conflict—the War of 1812.

This war might have ended in disaster for the United States had it not been for the abundance of saltpeter, one of the principal ingredients of gunpowder, furnished by some American caverns.

At the start of hostilities we were completely cut off from foreign sources of supply by England's embargo, and for a number of years after the start of war enormous quantities of the then precious mineral were "mined" in various sections of Kentucky and Indiana.

The fact that saltpeter, or potassium nitrate, could be made from the nitrous dirt in some of the caves was among the many enterprising discoveries of the pioneers who followed in the footsteps of Daniel Boone during the early part of the nineteenth century. Since gunpowder was one of the absolute necessities of life and its importation through wilderness trails and over lofty mountain passes was a long, hazardous and complicated operation, this was an important milestone.

As early as 1806 the American Philosophical Society of Philadelphia had in its possession a report of the resources of certain Kentucky and Virginia caves which said that they would be quite valuable in time of war. This report was prepared by a Dr. Samuel Brown of Lexington, Kentucky, and described in detail a "great cave" where, in one spot, workmen dug for fifteen feet through solid niter on the floor of the cavern.

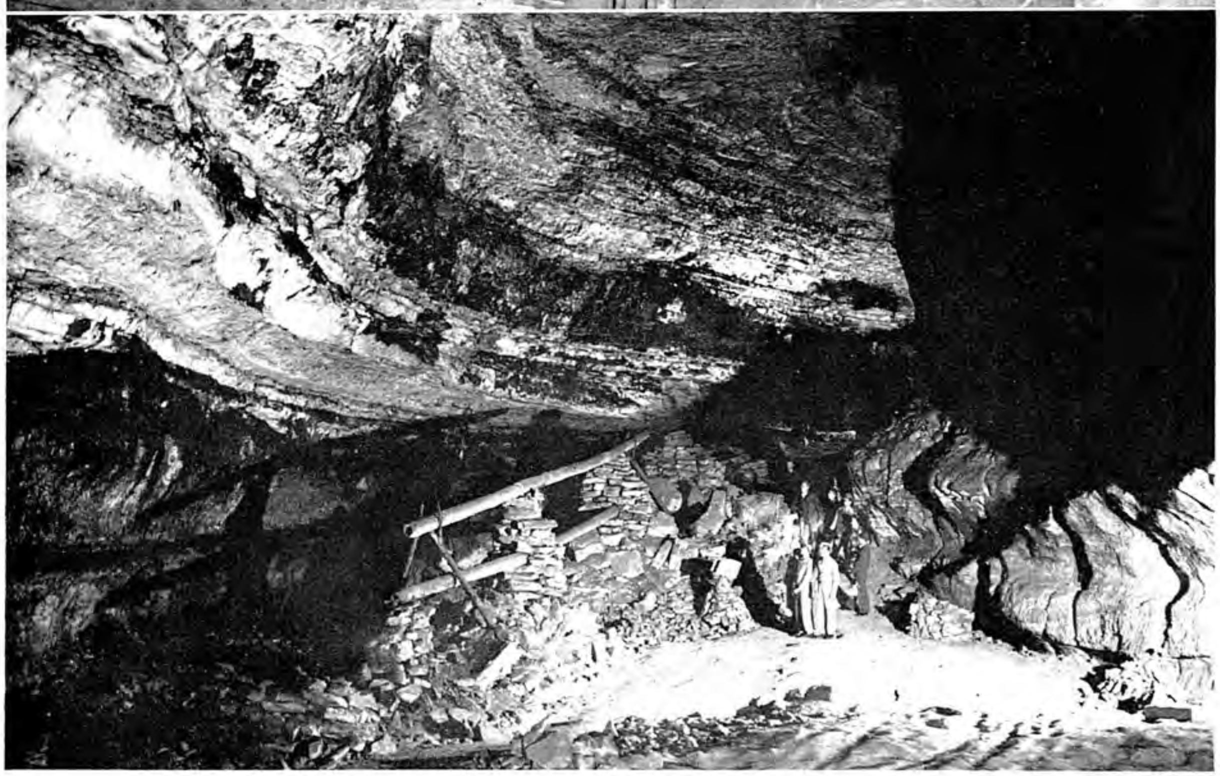
Dr. Brown's report continued with an appeal to all patriotic Americans to make themselves independent of foreign sources of supply, stating that the domestic saltpeter was far superior to that imported from India and Spain.

Prompted by this report the owner of the largest gunpowder plant in the country prepared, in 1807, to make arrangements for a trip through the same region to investigate the saltpeter deposits. It is not now a matter of record that he ever found the time to make the trip, but history shows that his itinerary was mapped out and that he realized the importance of securing nitrates from a home source.

Today, in both Mammoth Cave, Kentucky, now part of Mammoth Cave National Park, and in Wyandotte Cave, Indiana—two of the largest known caves in the world—may be seen the remains of the old saltpeter "mines". In Mammoth the relics are perfectly preserved and may be seen in almost their entirety just as left by the old miners, more than 136 years ago. The ancient wooden pipes, leaching vats, wooden hoppers, and their supports, the actual tracks of the ox-carts and the hub marks worn on the sides of the narrow tunnels by the creaking wagons are still in a remarkable state of preservation. These are all that are left to tell the story of hard labors in dim subterranean workshops—labor that cannot be applauded too highly because it contributed greatly toward our successes in the second conflict with England.

At Wyandotte Cave, in southern Indiana, the remains of the saltpeter mines are not so well preserved, since they were abandoned nearer the outer air, and temperature and moisture changes have caused the wooden equipment to disappear almost entirely. Had they been left back in the cavern the dry even temperature would have kept them in perfect shape for ages.

Probably the first published account of the saltpeter deposits in the United States—and also the first printed account of any cave in the country—appeared in 1819 in William McMurtrie's "Sketches of Louisville and its Environs" and



Photos courtesy National Park Service, U. S. Department of the Interior

UPPER: Salt Petre Leaching Vats in Mammoth Cave, Ky., used in extracting Salt Petre for the manufacture of gunpowder during the War of 1812.

LOWER: Old wooden pipes used in leaching Salt Petre solution from the nitrous earth in Mammoth Cave, Ky.

described Wyandotte Cave. Referring to it as the "Mammoth Cave of Indiana" McMurtrie quotes General William Henry Harrison as saying at the time he visited the cave (1806) ". . . there were . . . enormous lumps of some saline matter scattered over the floor, individual pieces of which . . . would have weighed from one to two hundred pounds." This is undoubtedly an exaggeration and what Harrison probably had reference to were the huge piles of fallen rock that still dot the passageway here and there.

Continuing, McMurtrie says that the earth in the cave ". . . contains about five pounds of the nitrate of lime or magnesia, to the bushel, and is composed of decaying animal and vegetable matter."

At the time of McMurtrie's report Wyandotte was in the possession of a Dr. Samuel Adams who had secured the cave and the land surrounding its mouth from the government for the purpose of making saltpeter. The only portion of the cavern then known was the part now called the "Old Cave Route" and to it Dr. Adams gave the name "Indiana Saltpeter Cave" although he later referred to it as his "Epsom Salts Cave."

The next account of American saltpeter deposits appeared in Volume I, "Transactions and Collections of the American Antiquarian Society", which was printed in 1820. The report appeared in an appendix entitled "Account of a Great and Very Extraordinary Cave in Indiana, in a letter from the Owner to a Gentleman in Frankfort, Kentucky." The letter was written by Dr. Adams on February 27, 1818, but was not published until 1820.

He referred to the cave as his "Epsom Salts Cave" and mentioned the amount of that mineral abounding in the cavern and also stated that "The next production is the nitrate of lime or saltpeter earth. There are vast quantities of this earth and equal in strength to any that I have ever seen."

Dr. Adams carried on the business of making saltpeter on a very extensive scale. However, with the war over the business became less profitable and he gave up his claim on the cave for more lucrative fields.

Meanwhile, down in central Kentucky, reports by early explorers of Mammoth Cave of its nitrous dirt, led to its purchase by a Mr. McLean in 1811. He kept it just about long enough to sell it to a Mr. Gatewood, that gentleman selling it almost immediately to Messrs. Gratz and Wilkins at about the time the War of 1812 started. Most of the old accounts are quite vague, but all seem to agree that Mr. Archibald Miller, acting as agent for Gratz and Wilkins, made a "fortune for them from the saltpeter business" during the War of 1812.

Undoubtedly, slave labor was used for mining within the cave and all heavy work outside. The nitrous dirt was probably gathered up in sacks in the smaller and more remote channels and carried to the large passageways where it was dumped in great piles. From these supply dumps ox-carts again transported the dirt to the leaching vats, or hoppers. Marks of the huge hubs of the unwieldly carts are plainly seen today on some of the limestone walls.

The vats were from eight to ten feet wide, four or five feet long, and about the same depth, with bottoms of small logs, split in halves. These were roughly grooved and placed in two layers, the first resting on wooden supports with curved surfaces down, the second with convex surface up, and fitting into grooves in those beneath. The water needed for the leaching process was piped, also in wooden pipes, from the outside and after passing through the fine dirt in the hoppers was made to flow into the small pits near the vats, from where it was conducted to a larger reservoir to be pumped to the surface. The leached and discarded dirt was thrown into large piles to one side, well out of the way of operations.

Upon reaching the entrance the concentrated water, or "beer" as the workers called it, was run through hoppers filled with wood ashes, then boiled and cooled in the wooden troughs. About 24 hours later the crystals of potassium nitrate which formed were removed, packed and shipped to the East—probably Philadelphia—by pack mules and other primitive methods of transportation. Miller is quoted as having told his employers that they "could supply the whole population of the globe with saltpeter from Mammoth Cave alone."

One old writer says that the average daily yield was from three to five hundred pounds of saltpeter, "worth from sixteen to twenty-five cents a pound" and that the cost of making was about four cents a pound.

Although a number of other caves were mined for saltpeter during the early part of the nineteenth century, apparently at none of them were the workings as extensive as at Mammoth and Wyandotte caves, or if so, the caves not having become famous as have the two cited, they have been forgotten, in most cases, even by local history. Scattered throughout the cave section of the country there are many caves known today as "Saltpeter Cave" or "Salt Cave" because of this early industry, but all of them were worked on a comparatively small scale.

Dixon's Cave, said by some speleologist to have been the original mouth of Mammoth, was well worked by the peter miners and its floors completely overturned by them. The rocky piles of discarded material within it give some idea of the amount of labor involved for many are from thirty to forty feet in height and forty feet through the base.

Saltpeter Cave, located one-quarter mile from Wyandotte, was also mined during the War of 1812, but since the cave is fairly short it could have furnished only a small amount of the nitrates mined in these parts.

Donaldson's Cave, in what is now Spring Mill State Park, may have been worked during the peter-mining era for Professor John Collett —in the Indiana Geological Report for 1873— says that "about the year 1800, gunpowder was here made from the great supply of nitrous earth in the upper chambers of the cave, remains of the powdermill still being visible." What he may have referred to, however, is the grist mill that stands near the cave entrance and which was erected by the first pioneer settlers of the region.

Thus it may be seen that the caves of America had their day of glory in helping us to win in a war and it is quite possible that some of our greater caves, with their thick protective layers of rock and soil, may again do their share in serving as shelter and factory sites if there is a future one in store for us.

LIST OF GROTTOES

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

1. *Adirondack*
William E. Barnes,
38 Church Street,
Little Falls, N. Y.
2. *Charleston*
Sarah McFarland,
506 Nancy Street,
Charleston, W. Va.
3. *Charlottesville*
Louis Herrink,
Law School,
University of Virginia,
Charlottesville, Va.
4. *Cleveland*
Betty Yoe,
28923 Westwood Road,
Bay Village, Ohio
5. *District of Columbia*
Nancy Rogers,
1841 R Street, N.W.,
Washington, D. C.
6. *Elkins*
Robert L. Lutz,
302 Center Street,
Elkins, W. Va.
7. *Emory University*
George M. Goza,
2230 Stephen Long Drive, N.E.,
Atlanta, Georgia
8. *Helderberg*
Kenneth O. Straney,
44 Vley Road,
Scotia, N. Y.
9. *Indiana*
George F. Jackson,
Box 170, R.D. 5,
Evansville, Ind.
10. *Iowa City*
William L. Petrie,
411 North Dubuque St.,
Iowa City, Iowa
11. *Lexington*
Richard R. McDonald,
521 Jackson Ave.,
Lexington, Va.
12. *Metropolitan N. Y.*
Ronnie Moorse,
214 Merrick Road,
Bellmore, L. I., N. Y.
13. *New England*
Kenyon L. Sweitzer
26 So. Mountain Road,
Pittsfield, Mass.
14. *Nittany*
Morris Jarrett,
Sigma Phi Alpha,
State College, Pa.
15. *Philadelphia*
Margaret Loye,
625 Fordham Road,
Bala-Cynwyd, Pa.
16. *Pittsburgh*
J. R. Fisher,
1700 Crafton Blvd., Apt. 7,
Pittsburgh 5, Pa.
17. *Rensselaer*
Arthur H. Fieser,
634 Magenta Street,
New York 67, N. Y.
18. *Richmond*
Betty V. Loyd,
R.D. 2,
Waynesboro, Va.
19. *Southern California*
Dr. W. R. Halliday,
Naval Shipyard Dispensary,
Long Beach, Calif.
20. *Southwest Missouri*
Shirley Bridgeforth,
Box 520, Route 3,
Springfield, Mo.
21. *Stanford*
John Funkhouser,
Beaverdam, Va.
22. *Tri-County*
Charles J. Hanor,
84 Elm Street,
Oneonta, N. Y.
23. *V.P.I.*
J. D. Lawrence,
Box 5453 Va. Tech. Sta.,
Blacksburg, Va.

CAVE SICKNESSES

By W. R. HALLIDAY, B.A., M.D.

In recent months there has been marked interest and more than a little apprehension among cavers who have heard of the recently published report entitled "CAVE SICKNESS—A NEW DISEASE ENTITY?".[1,2] There has been considerable confusion from hearsay on the subject, and an evaluation of the topic in terms of its application to speleology would seem in order. We will in this paper discuss this disease of unknown cause, and a few diseases to which cavers are known to be exposed.

At Foreman, Ark., on a bluff overlooking the Red River, there is a small limestone cave which is locally said to contain treasure buried by Jesse James, DeSoto, or someone else, depending on the source of the story.[3] About 50 years ago the outermost room was enlarged in an unsuccessful attempt to develop commercial limestone production. It is described by Dr. Tuohy, who conducted the studies alluded to, as being: "composed of many small cells connected in sequence by apertures low to the ground through which one must wriggle from room to room . . . The opening . . . is roughly 5′ x 10′ and as far as we could ascertain, furnished the only source of ventilation for all the subsequent chambers. These rooms varied in size from 5′ x 8′ x 20′ (c) to 20′ x 10′ x 40′ (c). We explored eight in sequence and had not followed the cave to its end."[1]

On Sept. 12, 1947, a party of 25 local persons ranging in age from 11 to 55, the average being 19.5, began to excavate the cave in search of the fabled treasure. Flashlights served as illumination, and extremely crude equipment and techniques were used throughout, apparently thoroughly disturbing the cave floor. Four days later sickness began to appear among the workers and by the thirteenth day after even a brief exposure, all who had entered the cave became ill. No one with whom they were otherwise in contact developed this unusual syndrome, indicating that the condition was one resulting from exposure in the cave and not transmitted from one person to another.

The symptoms of this previously unrecognized condition somewhat resemble those of virus pneumonia, with chills and fever beginning suddenly after a head cold, followed by chest pain, headache, vomiting, marked nervous irritability and weight loss. Cough is only mild. Prostration was usually marked, and one patient lapsed into coma for 48 hours. Severity of the condition varied markedly, but was roughly proportional to the length of the exposure. All recovered within a week or two, but were left with shortness of breath and easy fatigueability for a period of several months. X-ray showed far wider infectious spread than was expected from examination of the chest, with a pattern indicating uniform diffuse involvement of both lungs, but cleared paralleling the clinical course, and reverting to normal within two months.[1]

A great multitude of laboratory tests were carried out in an attempt to determine the cause of this illness. The air and dust of the cave were also carefully examined. No definite conclusions were reached, but the researchers strongly suspect Histoplasma, a little-known fungus-like organism.[4] Attempts to rule out of consideration Monilia, a yeast-like fungus, were unsuccessful. This last organism is the known cause of several reported cases showing similarity to those described above, and is suspected as being the etiological agent in two somewhat similar epidemics, one of which centered around a storm cellar.[5]

There are a number of conditions prevalent in caves which predispose to illness of one kind or another. These include agents of trauma, inhalation, exposure, and the micro-organisms, not to mention disturbances of psychogenic origin like claustrophobia, the discussion of which has no place in this paper. In any event, it may be seen at the onset that the problem is a complicated one.

The questions of trauma, as from falling rocks or wildcat bite, and of physical exposure can be dispensed with quickly. Most cavers are well aware of the dangers of thorough wetting and cold over a period of time, and no one has ever demonstrated a higher incidence of pneumonia among members of the NSS, suggesting that normal precautions in this regard are routinely followed. Ice-containing lava caves are in general not sufficiently large enough to make frostbite a major cave problem.

The sources of potential danger, it may then be seen, lie in the fields of bacteriology and the mechanical inhalents, and it is not possible to fully separate these factors.

There are many chemical substances which may be considered as toxic occurring in caves. Silicosis, fortunately, is not the problem in caves that it is in mining, due to their primary occurrance in limestone, the dust from which is relatively chemically inert in regard to reaction with body tissues compared with that of similar silica dust. Nevertheless there have been reports of transient moderately severe lung disorders following inhalation of any type of concentrated dust, limestone included.[6,7]

Cave dust also contains particles of bat guano and rat droppings in most instances, along with other organic matter. While no studies of the effect of inhalation of these agents have been made, it seems unlikely that it would prove beneficial. These particles can cause direct irritation and allergic responses, and carry bacteria and fungi even more than do those of ordinary dust. From personal experience in Bodfish Cave, California, the author can state that inhalation for a period of two minutes of a high concentration of cave dust with a little powdered bat guano will produce a noticeable shortness of breath and, on deep respiration, pain for a couple of days. Students of archeology routinely wear dust masks when stratigraphing cave sites, and we would do well to emulate them in dusty caves.

In a discussion of this nature, the question of gases always arises. In the 1948 Bulletin there was a reference to phosgene forming in cave mud.[8] This would be a major problem if confirmed. Until chemical analysis is available, judging from the symptoms, it would seem better to assume these particular bubbles to consist of carbon dioxide, which, in contradistinction from phosgene, is readily formed under the circumstances described. Dangerous concentrations of CO_2 are known in some limestone fissures in Wyoming and California, but are not common in limestone caverns, due to the excellent cross-ventilation typical of their geology.

Other gases are not common in caves. Methane, or coal damp, has never to our knowledge been reported in a limestone cave. Ammonia, however, occurs in irritating quantities in wet guano caves and is not filtered out by all gas masks. Hydrogen sulfide is encountered in many volcanic regions, in some localities in deadly amounts, but the typical odor of rotten eggs, if not masked by that of carbide, serves as warning. It is also produced as a byproduct of impure carbide[9], and from this can conceivably build up to a dangerous concentration in a location with poor ventilation. Long-continued inhalation of even a low concentration of this gas can produce chemical bronchitis and pneumonitis, as well as eye, mouth and other symptoms[10].

So much for the so-called nonspecific maladies. There are a number of animal vectors of micro-organisms that have predilections for caves and should be avoided as at least potential sources of disease. Bats are well known carriers of ticks, fleas and mites,[11] and at least the former two are vectors of such conditions as relapsing fever, Q fever, tularemia and Rocky Mountain spotted fever. Birds also are hosts for these parasites, and also serve as a theoretical source of ornithosis. Cave rats, like those outside, can transmit rat bite fever directly, Weil's disease (a type of jaundice) through the urine, and all the flea-borne diseases including plague. Actually, however, the occurrance of potential rattlesnake bite in some Texas caves[12] is probably more important. Not to be neglected are the diseases transmitted by mosquitoes, which apparently hibernate extensively in caves.[13]

It is useless for one who has never seen a case of "cave sickness" to speculate on its cause when well trained researchers with all the resources of modern science available on the scene were unable to reach any conclusion. Regardless of the ultimate etiology, however, some definite conclusions can be reached. Assuming that the three similar epidemics mentioned actually represent the same entity, disturbed dust was markedly present in two, and probably inhalable in the third. The incubation period of the malady and its general nature suggest that it is more likely some low grade infectious agent carried in the dust rather than a direct chemical pneumonitis, which usually develops promptly and disappears within a few days.

Whether "cave sickness" represents an infection, an allergic response to some organic factor inhaled, or an acute direct chemical inflammation, it would seem that speleologists can remain reassured. In only one cave has this condition been reported, and there under quite unnatural circumstances. Repeated exposure of men and test animals in these localities at other times under more normal circumstances has resulted in no illness whatsoever. Concerning the other diseases discussed, although from this article it might seem difficult to emerge from a cave in reasonable health, cavers can from their own experience realize that the dangers are more potential than actual.

Despite all this, the subject remains of marked interest to all cavers, and is deserving of close study in an attempt to determine the causative agent of the "sickness." All cases resembling those described should be reported to the Society as soon as possible in hopes that a study can be made under the conditions producing the illness, if another outbreak is found to occur. Only thus can it be decided if "cave sickness" is actually a sickness of caves.

REFERENCES

[1] Washburn, A. M., Tuohy, J. H., and Davis, E. L. Cave Sickness, a New Disease Entity? *Am. J. Pub. Health*, 38 (11): 1521-1526, (Nov.) 1948.

[2] Rogers, N. Cave sickness. *D. C. Speleograph*, II: 12, pp. 2-3, (Dec.) 1948.

[3] Anon. Cave sickness, a new disease. *Arkansas Health Bull.* (Nov.) 1947, p. 3.

[4] Tuohy, J. H. Personal communication.

[5] Cain, J. C., Bevins, E. J., and Downing, J. E. An Unusual Pulmonary Disease. *Arch Int. Med.*, 79 (6): 626-641, (June) 1947.

[6] Blue, J. A. Dust, Its Effect on Man. *So. M. J.*, 31 (10): 1101-1106, 1938.

[7] Knuckey, C. T. Respiratory Conditions in the Dust Bowl. *Rocky Mtn. M. J.*, 35: 466-468, 1938.

[8] White, P. J. Phosgene in the Dark. *NSS Bulletin*, 10: 118, 1948.

[9] Kohls, G. M., and Jellison, W. G. Ectoparasites and other Arthropods Occurring in Texas Bat Caves. *NSS Bulletin*, 10: 116-117, 1948.

[10] Sollman, W. *A Manual of Pharmacology*, (6th Ed.) Saunders, Philadelphia, 1944. p. 766.

[11] *Ibid*, pp. 140-141.

[12] Fowler, J. A. A Texas Snake Den. *NSS Bulletin*, 10: 118, 1948.

[13] Cunningham, J. W. and Burrill, A. C. Mosquitoes Overwintering in Caves. *NSS Bulletin*, 9: 51-56, 1947.

Clamping metal band on wing of bat.

IF YOU FIND A BANDED BAT

Many hundreds of bats have been banded within the past few years. Some of them have been banded in caves, during hibernation, and others elsewhere during the summer months. The banding has been done to enable the bander to discover various things about these animals. How long do they live? Do they always go to the same cave? Do they migrate? How far do they travel from their summer home to reach the cave? These are some of the questions the bat bander hopes to get answered by banding.

Speleologists can render a great service to science by reporting all banded bats encountered. Examine the band carefully, and record the full number. There is always a series number and specific number on each band, for example 48-87652. Note also the date and place where found. Report your finds to

Fish and Wildlife Service
U. S. Department of Interior
Washington, D. C.

The Fish and Wildlife Service will notify the bander of your discovery, and will also inform you as to when and where and by whom the bat was banded.

Never remove the band unless the bat is found dead, and disturb the bats as little as necessary during your explorations. Bats are beneficial animals, destroying great quantities of objectionable insects every summer. They can be handled without danger with gloved hands. Your reports of banded bats may be of especially great value if they happen to be made where the original bander is unable to visit himself.

Some Unusual Formations in Skyline Caverns, Va.

By E. P. HENDERSON

Associate Curator, Minerology and Petrology, United States National Museum

Early in 1948 the author experienced the pleasure of a visit to Skyline Caverns near Front Royal, Va. The excursion was especially interesting as it was made during the season when the Caverns were closed to the public and because W. S. Amos of Skyline Caverns personally conducted the tour and provided ample time to enjoy it.

At the time of this visit to the Caverns some new rooms were explored. Finding a chamber is a slow and difficult task and requires cleaning mud from long narrow channels until a room is found. In order for us to gain entrance to one room it was necessary to crawl or wriggle in a prone position for about 50 feet and then to squeeze through a small porthole-like opening into the chamber. Once inside we could easily move about because there the roof was about 3 feet above the level of the mud.

The upper surface of the mud was firm and where the entrance had been cut through, stratified layers were seen. As we crawled over the mud numerous wide shrinkage cracks were noticed indicating that there had been considerable volume reduction. These shrinkage cracks may have been formed since the room was opened because the author was not present when the actual opening was made but the evidence of layers in the clay and the firmness of the clay clearly indicated it had been consolidated to a considerable degree. Probably these wide shrinkage cracks represented enlargements of some smaller ones that had developed prior to the opening of this room.

They informed me that this chamber is about 25 feet in diameter and that the thickness of the mud on the floor has not been determined. A few broken fragments of fallen stalactites were found on the surface of the mud. On the roof and higher parts of the side walls there were numerous clusters of slender branching tubular formations. None were seen that were longer than about 18 inches and most of them averaged about 6 inches.

Fig. 1. A cluster of small tubular stalactites on the ceiling of a room. These formations are described by the officials at Skyline Caverns as "anthodites".

The cavern officials have given these complexly branching tubular formations (Fig. 1) a new name, "anthodites" from the Greek word "anthos" meaning flowers. With a little imagination some resemblence to a flower can be recognized. It appears that cavern guides are always alert to their duty of stimulating the imaginations of their visitors.

Thus they make a distinction between anthodites and helectites. They limit helectites to the distorted twig like lateral projections of calcium carbonate which are found on a stalactite and anthodites to the small cluster of complexly branching tubular stalactites of about equal length. This newly coined name may or may not have been needed, however, as it is not the purpose of this paper to discuss problems of nomenclature or define the characteristics which each name implies.

The formations are confined to the ceiling and upper side-walls of this room and the majority of them seem to be clusters of small tubes originating near a common point, radiating outward and downward. A number of peculiar ones were seen which are worthy of special mention. Some were seen which had grown downward for several inches and then developed a growth near the lower end of the tube which extended outward and diagonally downward. A few were found where the long tube extended downward for several inches, branched and grew back up towards the roof. (Fig. 2)

Fig. 2. An unusual stalactite at Skyline Caverns, Va. One delicate tube extends downward about 5½ inches, branches and has extended itself almost to the ceiling.

As we moved about examining these delicate formations one of the workmen said that these seemed to have grown in a vacuum. On questioning him he said that his hat was sucked off his head when the opening was made into this chamber, which to him indicated that the room had been sealed shut.

Explanation for the Reduced Air Pressure

These rooms and narrow passage ways between them originated from the solution of the country rock, limestone, in the ground water. The impurities in the limestone, such as ferrous iron will oxidize and a brown hydrous iron oxide will form which will be mixed with the clay like material from the limestone. This material is mechanically transported by the moving water through these channel ways until the velocity of the water is checked and the sediments precipitated.

After a large chamber has been formed along a channel way its outlet may become partly dammed and a lake formed. The sediments carried by the water will then be deposited in this lake. There may come a time when the outlet of the chamber is completely stopped up by sediments and the level of the mud which has been carried into the lake could close off the entrance to the room.

Assuming this to be the case there then exists a room which has mud on the floor, covered over with water and since the ceiling is domed, air is trapped above the water. A room blocked off in such a manner may later be reopened if the mud consolidates and shrinks below the level of the opening. Evidence that this has happened exists because some of the longer tubes suspended from the roof had several inches of mud on their lower ends indicating that the water level had raised subsequent to their growth.

When a pendant extending downward, contacted the water on the floor of the cave, growth would stop. If the water level is raised above the tip of the stalactite a water mark will occur on it. The distance the discoloration extends up from the bottom may not be the exact level of the water because there is a chance that some of the muddy water will be pulled up on the tube. The cavern officials say that when a colorless tube is dipped into muddy water it discolors some distance above the level of the water. This may be due to the fact that the tube they are testing has an empty channel in it through which water can rise by capillary action, but the tubular formations still attached to the roof more than likely contain water inside of them, hence these are not likely to be discolored very far above the level of the water outside the tube.

Fig. 3. The largest stalactite in this room in Skyline Caverns, Va. This is about 18 inches long and about ¾ of an inch in diameter at the lower end. A symmetrical tube has grown out from a complex cluster of spines and a thicker tube. This cluster of stalactites are located near a fracture in the ceiling where the rate of flow of the water must have been greater than from the small pores in the roof around which the small "anthodites" formed.

When a room is sealed shut the pressure on the trapped air might even be increased to slightly above the normal air pressure if the water table in the surrounding rocks is raised above the entrance of the room. But this is not likely to be the case for more than a brief interval of time.

Once the entrance and exit of a room is sealed off by sediments there remains two ways in which the air pressure can be reduced to less than normal. One is for the mud on the floor to become consolidated thus taking up less volume. The other way is for the water above the mud to diffuse through the pores in the wall rock when the water table in the surrounding rocks is lowered. The loss of water and the consolidation of the mud will give the air a chance to expand, hence its pressure may be lower.

Explanation for the Formation of Some Tubes with Unusual Habits

When the air pressure within a sealed room is reduced there may be a tendancy for the water to be sucked from the pores of the exposed rock within the room. The water that exudes from these pores may start to deposit its dissolved calcium carbonate and make a stalactite. These grow by a process known to all speleologists, e.g., through water being carried down through the central opening in the tube and depositing its salts around the open end of the tube. Thus more or less normal growth will continue as long as the water flows rather rapidly through the tube. But once the flow is retarded the tube grows under a different set of conditions.

When the solution flows rather fast through the tube, drops form at the opening, the salts deposit around the drop, and the crystals tend to form a radiating crystalline pattern outward from the center of the tube. Since the composition of the solution remains rather constant and as long as the rate of flow continues at a fixed rate, a tube with a rather constant diameter will form. These formations occuring within this room in Skyline Caverns usually have a more or less symmetrical cylindrical tube near the place of attachment but as the tube increases in length there is a tendency for its diameter to increase to several times its former diameter.

The reason the tubes tend to increase in diameter after they have grown for some distance is explained by the increased friction the sides offer to the movement of water. A very sluggish flow of water permits random crystallization to take place across the opening at the end of the tube. Growth of a single crystal across the opening, but not completely obstructing it, will make two new openings which in turn will have crystallization across them. This growth of crystals develops a sort of a porous crystalline screen which further retards the flow of solution as well as diffuses the solution through a larger area. Hence the diameter of the tubular stalactite is increased.

Several broken formations were collected from the floor of the cavern. When these were again broken and the cross section of the structure (found on the thicker end) was compared with that of the narrow tube, near the point of attachment, a difference was observed. A rather symmetrical arrangement of crystalline structure surrounds the open channel in the tube at the narrow portion of the stalactite and the crystals radiate out from the central cavity. A cross section of the thicker portion of the stalactite usually shows several small and poorly defined channels and an open mesh work of delicate crystals.

If for some reason the pressure on the water in these stalactites is increased, which is the same thing as saying the flow of water becomes more rapid, then each of these delicate openings which exist in the mesh of open crystals becomes a point where a new tubular growth can develop.

The long tubular formations usually show considerable variation in their diameter and become increasingly more and more delicate as their length is increased. Their weight may then exert a greater pull than the bond which binds the particles in the sidewalls together; hence they may break off and fall or minor ruptures will occur through which some solution may seep. A new lateral arm may form or the crystalline deposit may seal the fracture shut.

The secondary growth on a suspended stalactite which extends out in a more or less horizontal direction will exert leverage and failure of a horizontal arm is more likely to occur on the upper side of the tube than on the lower because leverage places the upper side walls under tension.

Only a few of the tubes attached to the ceiling in this room were longer than the general average and only a limited number of these longer ones had a complex habit. Since there is a tendency for the shorter formations to branch and form very complex habits, the absence of the longer complex tubes is explained by the fact that their weight may cause them to break off.

The unusual stalactite shown in Fig. 2 first grew downward as a long tube with a small diameter. There are several places where the sidewalls are thicker like nodes of a plant stem. The downward portion of this formation must have grown faster than the arm which reaches towards the ceiling because the solution could in all probability, move faster when it descended in the tube. When the tube turned and growth started up the rate of flow of the solution through the tube would decrease as the upturned arm would contain water and this acts as a check on the rate of flow down the other arm. The diameter of the walls of the upward arm is considerably larger than the downward arm. This would indicate that as the movement of the solution through the tube is slowed down the thickness of the walls tend to increase.

L. C. Huff [1] in some cleverly devised experiments in which he made artificial helectites found that when the flow of solution was sufficient a stalactite like tube formed but when the valve controlling the supply of the solution was closed the growth rate was not only slower but the habit of the formation became more complex. Huff produced a branching complex formation which in some respects resembles that shown in Fig. 2 by decreasing the rate of flow of the feeding solution.

Some of the largest and best formations in this room have grown along fractures in the ceiling through which the ground water could move more rapidly. Some of the shorter and highly complex formations cover large areas of the roof and even occur on the upper sides of some shelf like ledges which extend into the room from the sides of this chamber. Some of these formations appear to have grown upwards as easily as others have grown downwards from the ceiling.

The officials of Skyline Caverns have kindly offered to present to the U. S. National Museum some of these unusual formations when the problems related to both their removal from the cave and their display in the Museum have been more carefully studied.

[1] Lyman C. Huff, Artificial Helictites and Gypsum Flowers, Journal of Geology, V 48, p.641, 1940

Features of Cave Breakdown*

By WILLIAM E. DAVIES

Of all the features in caverns, the most awe inspiring and fearful are the huge masses of fallen, broken rock known as breakdown. Such rockfalls are found in most caves and are an interesting phase of their development.

Breakdown can be classed into several groups according to the mode of origin. The simplest type is that resulting from solution work along joints. Most rock when subjected to forces causing uplift or folding develops microscopic fissures known as joints. These joints are most abundantly developed along vertical planes with subordinate ones along horizontal planes. Water, in utilizing the small joint openings in its subterranean movement, removes material and increases the size of the joints. The removal of material continues until such a time that the block surrounded by the joints is so weakened that it falls from its position in the ceiling of the cavern. However, joints seldom confine a single block but extend in such a manner that they cut a number of blocks. In such cases the weakened rock extends for considerable distance both horizontally and vertically and the resultant collapse is of enormous size. The fallen rock is uniform in size and tends to be cubical in shape. Breakdown of this type may well be designated as *Ceiling Blocks*.

A similar type of collapse that is designated *Ceiling Slabs* has a somewhat different origin. In limestones that are horizontal in structure water travels along the bedding planes in such a manner that it removes soluble materials from the upper surface and deposits a thin film of insoluble residues along the lower surface thus confining the solution work to the bedding plane. Water in such cases will travel along the bedding plane for considerable distances. Joints by which water could migrate vertically are sealed off by the insoluble coating on the bedding plane. When the solution work has re-

*Reprinted from *D.C. Speleograph*, Vol. III, No. 3, March 1949.

moved the cementing bonds along the bedding plane, breakdown occurs in the form of flat, large slabs. In some cases, as in Poorfarm Cave, West Virginia, the slabs measure up to 25 feet by 25 feet in area and 2 feet thick, extending along the passages for over 100 yards. Unlike the Ceiling Blocks, the Ceiling Slabs are limited vertically to one or two beds although they extend over greater areas.

Although not as common as breakdown resulting from ceiling collapse, that resulting from the collapse of passage walls accounts for a large amount of rock debris in caves. In horizontally bedded rock it takes the form of blocks similar in shape and origin to ceiling block breakdown. The extent, however, is limited to a depth of a few blocks from the face of the wall. In general, it is in the form of huge blocks that tilt and rotate in their fall thus locking together and forming various levels in a passage. After such a fall the blocks are stable even though they are wedged above the passage floor. In vertical beds the breakdown is in the form of large slabs that peel from the wall and collapse in a form similar to ceiling slabs.

Limestones often develop closely spaced joints. The joints may be normal, closely spaced, structural types or may be polygonal in nature. These conditions are found most commonly in thin bedded, impure limestones or in sandstones. Solution work opens the joints surrounding the blocks and the rock fall consists of isolated plates of rock measuring up to a foot in length and width and several inches in thickness. This type of breakdown is designated as *Scaling Plates.*

Scaling Chips are the smallest fragments of rock fall. The chips are thin, flat pieces of rock, generally of a crumbly nature. They result from the fall of clayey material that remains when the more soluble parts of the limestone have been removed or from minute layers of rock that scale off because of the release of compression at the ceiling face. Scaling Chips are seldom noticed in caves because of their insignificant size.

The methods of recognizing potential areas of breakdown are of vital interest to the speleologist. To provide positive information will require considerable study. However, the following conclusions can be drawn now:

(continued on page seventy-two)

Photos courtesy West Virginia Geological Survey

UPPER: Block breakdown, Laurel Creek Cave, W. Va.
MIDDLE: Slab breakdown, Poorfarm Cave, W. Va.
LOWER: Polygonal joints which produce breakdown of scaling plates, Rapps Cave, W. Va.

A Report on Some Fluorescein Tests at Starnes' Cave

By JOE LAWRENCE

Starnes' Cave, which has been visited frequently by the V.P.I. Grotto, has held stubbornly to its secrets. In two visits this summer some of the cave's secrets were revealed.

The first of these two trips was made on July 30, 1948 when Earl Thierry and Joe Lawrence spent ten hours in the cave surveying and checking the results of a fluorescein test. The surveying was done in the portion of the cave known as "The Left Hand Passage". In order to complete the survey in this portion of the cave it was necessary to descend a forty foot drop on a rope ladder.

The second summer trip was made on August 22 by James McClary, Marvin Parks, Brooks Gilmer, Joe Lawrence, Joe Jefferson, Bill Briggs, Don Lemon, Bill Miller and Hayden Hannabass. This trip was also devoted to surveying and stream study. A part of the most difficult portion of the cave was surveyed. The survey party worked below a fifty foot waterfall. The gorge at the waterfall was descended on a rope ladder that had been set up the day before. Once below the falls the survey party had to rig ladders at three other short drops before they could reach the lowest level. The survey party worked all day below the falls, but surveyed less than half of the passage in that portion of the cave.

The most interesting aspects of these two trips were the fluorescein tests. There are two streams in Starnes' Cave. In addition there are four or five trickles too small to call streams. The fluorescein was used to determine the source and destination of some of this water.

The first test was started at 7:00 A.M. July 31 when 100 grams of fluorescein was placed in a surface stream. This stream flowed underground near the cave entrance. An hour and a half later green water showed up in the first stream encountered when one walks through the main passage. This stream has since been named Vanishing Stream. After flowing through the main passage for several hundred feet, Vanishing Stream runs into a small crack in the floor. The fall stream flows through the main passage in the opposite direction. There is no visible connection between the fall stream and any other stream in the cave. When the fall stream was checked it was also green. This indicated that even though the fall stream and Vanishing Stream ran in opposite directions they both get at least part of their water from the same surface stream. None of the water in the left hand passage was affected by this test. The party was too small to check water below the falls.

The second fluorescein test was started at 7:30 P.M., August 21 when 100 grams of dye were put in Vanishing Stream at the point where it enters the main passage. About eighteen hours later, when the survey party reached the lowest level below the falls, they found that the stream here (which is independent of the fall stream) was green. This proved that this stream was part of Vanishing Stream. Between the point where Vanishing Stream disappears in the main passage and reappears at the lower level additional water joins it. The stream is noticeably larger when it reappears. All of the rest of the water in the cave was checked on August 22 for traces of fluorescein. As was expected, neither the water in the left hand passage nor the fall stream (which was checked at its lowest point where it flows into a deep pool) showed signs of coloring.

These two fluorescein tests have revealed a great deal about the streams in Starnes' Cave. They have shown that both streams in the main passage (the fall stream and Vanishing Stream) get at least some of their water from the same surface stream. They have also shown that what appears to be two separate streams are really two parts of the same stream (Vanishing Stream). They have shown further that the water in the left hand passage is independent of the streams in other parts of the cave. While these tests have been quite revealing, there are still mysteries concerning the Starnes' Cave streams which it is hoped additional tests and additional exploration will at least partially clear up.

Safety Procedures in Speleological Exploration

By JOHN DYAS PARKER

"With the Speleological Society yet in its first year and with interest in caves growing apace, it seems appropriate that one of the first problems that should be dealt with is safety"—so stated William J. Stephenson in the first issue of the N.S.S. Bulletin.[1]

Since that article was written the Society has come a long way, but thanks to the ceaseless war against accidents we have established an excellent safety record, in fact a record that would cause any insurance company to revise its opinion of explorers. This has not been a haphazard thing but rather the result of constant study and practice in the fields of rigging, mountaineering, psychology, and first aid on the part of those responsible for the trips sponsored by the National Speleological Society and its affiliated Grottoes. However, though we have trained many members in safety engineering we need more safety men and a more expanded safety program than ever before, if we are to maintain our fine record, for our membership is growing by leaps and bounds.

Although safety articles have appeared in this journal several times before,[2] we feel that these articles are not available at this time to at least half our membership. We will, therefore, once again delineate our safety program.

Safety work, as in all pursuits, can be divided into two phases. The first phase, or accident-prevention campaign, is the common type of safety program in which rules of behavior are set forth in an effort to prevent accidents. The second phase, or disaster campaign, is the plan that is put into operation after an accident strikes. Naturally, we must be *prepared* for any type of accident *before* it does strike.

Most gratifying results have been achieved from our accident prevention campaign through the years. It is guarding and will continue to save our lives even though we may not realize it. Almost every country where spelunking is a recognized sport reported at least one fatality last year and we have already been notified of two deaths occuring in foreign countries this year. Several countries maintain rescue groups, such as the Cave Rescue Organisation of England, and these find plenty of work to do. However, in our entire existence, we have yet to record a fatality of an N.S.S. member. This is due primarily to a very comprehensive safety campaign as follows:

The National Speleological Society has a Safety Chairman and under him each organized grotto has a chairman who is in charge of all accident prevention in his group. Besides enforcing safety rules such as having three sources of light, never going into a cave alone, and other common sense rules he must set up an adequate accident prevention program.

Accidents are studied for their causes and then a sincere attempt is made to eliminate the conditions which might cause them. A list of some basic causes of accidents follows:[3]

- A: Smoke, gas, or lack of oxygen resulting in unconsciousness.
- B: Falls from ropes, improvised ladders, loss of footing, etc.
- C: Immersion.
- D: Injury from falling stones, debris, formations, equipment.
- E: Physical ill health or limitation.
- F: Failure of illumination.
- G: Burns and explosions.
- H: Claustrophobia.

Not long ago the Philadelphia Grotto took a visiting spelunker from another group along on a cave trip. He looked amazed when he saw ropes, winches, crow bars, blocks, blankets and other safety paraphernalia being unloaded. Inside the cave he said, "Why, this isn't difficult. My bunch would swarm all over this place with no trouble at all." We replied that we could do the same thing but an experience of the Grotto's best climber at this same "easy" cave had given us reason to always proceed with caution. The climber was hit by a falling rock, but due to proper training he swung his body when he

[1] Stephenson, William J., (1)
[2] Stephenson, Wm. J. (1). (2) and Chamberlin, Jo. (3)

[3] Mohr, Charles E. (4)

Correct treatment in an underground emergency. 1. Examination of injured person for broken back or ribs. This is done prior to moving the victim. 2. The rescuer removes his outer clothing and places it under the victim and if necessary, he lies on top of the body to keep it warm. 3. As soon as possible the injured person is wrapped in blankets and warmed with heat blocks. To prevent burning the body, place the blocks in gloves. It is important to keep the injured person warm as shock will set in and so lower the body temperature that Pneumonia may set in. 4. After the patient is warmed he is moved to a comfortable position and treated for shock. 5. The extent of injury is then ascertained. 6. First aid is rendered. 7. The patient is evacuated to the surface in a blanket stretcher or other conveyance and given more formal treatment. He remains warmly wrapped all the way to the surface. Pictures posed by Philadelphia Grotto First Aid Squad and taken by William Hertl.

heard the rock falling and received only a glancing blow on the head. His helmet was pierced and a small scalp wound necessitated one stitch. However, had he not been wearing a hard hat and a safety line he could easily have been killed.[4]

Then we told this spelunker about some other actual incidents. For instance about the case of one owner of a cave property who decided to enlarge a fissure-like entrance by building a fire on the limestone to expand the entry. He raked the fire into the cave where its continued burning used up the scant oxygen supply. When he finally entered the cave he fell to his death when he lost consciousness from lack of oxygen.[5] Thus when we say watch out for smoke, gas or lack of oxygen it is because we know it can result in unconsciousness and death.

"Four boys between the ages of ten and fourteen went to an abandoned quarry . . . for the first swim of the summer. . . Two of the boys who undressed more quickly dived in but failed to come up. The other two boys waited several minutes then became frightened and ran scream-

[4] Parker, John D. (5)

[5] Chamberlin, Jo. (3)

ing for help. Men arrived who entered the water, found and recovered the bodies; both boys had gashes in their scalps. Artificial respiration failed to revive them." [6] Investigation revealed that during the winter boulders had rolled across the lake bottom and reduced the depth from ten to four feet.

Profiting by this lesson one safety man refused to let his party dive into a quarry hole near Williamson, Pa., until he inspected it. When he had climbed a high overhanging cliff he spotted a large pipe about eight feet under the surface right where the party would dive. The group went swimming but everyone stayed clear of the pipe.

A young engineer prospecting in the Mojave Desert region was descending a shaft. About 30 feet down he was told to "freeze" and after he did so his helper shot a rattlesnake just above the engineer's head.[7]

We have never seen a rattlesnake in a cave entrance (they are not too common near the author's home) but common sense made him invest in a snake bite kit and causes him to carefully inspect each cave entrance.

A group of students at a mining college were having a "keg" party in an old quarry. A large bonfire was built against the toe of one of the walls as the temperature was well below freezing. The fire thawed and split the rock permitting a large section of the bank above to cave suddenly. Fortunately no one was hurt.[8] Safety chairmen will do well to remember this lesson when they pitch camp or build fires.

The examples given above illustrate the desirability of a continual accident prevention campaign and the necessity of advance planning to preclude a possible repetition of the same type of accident. For this reason all accidents, no matter how slight, should be reported to the Safety Chairman of the National Speleological Society, 510 Star Bldg., Washington 25, D. C., so that we can take precautions against them in the future.

Each group of spelunkers has its own problems, and it is impossible for us to formulate a set of rules that will hold good everywhere. However, each safety man should formulate his own *NEW PROGRAM*, then pass it on to his District Governor as well as to the National Safety Chairman. Each spelunker should help prevent accidents by obeying his safety rules whether he likes them or not.

Last summer we sent out fifty letters, to each grotto then in existence as well as to many individual cavers within the N.S.S. Each was asked to give his own safety regulations and to tell why they were selected. The replies were many and varied, the stories of accidents were appalling, and the suggestions were excellent. These have been weighed pro and con by three safety experts and finally condensed into the following rules:

A. EQUIPMENT:

1. Hard hats are mandatory.
2. Gloves will be worn inside caves except while engaged in certain rope work.
3. Minimum personal equipment to be carried by each individual:
   a. At least three sources of light other than matches.
   b. Waterproof matches.
   c. Spare parts for light sources.
   d. Spare supplies for light sources (water, carbide, batteries, etc.).
4. Optional personal equipment:
   a. Light nylon line of fairly short length.
   b. Extra change of socks.
   c. Personal first aid kit.
   d. Concentrated foodstuffs.
   e. Halazone tablets for water purification.
   f. Spoon.
5. Minimum equipment for the party:
   a. First aid equipment.
      (1) Mine Safety Appliances Company waterproof first aid kit or equivalent.
      (2) Two or more MSA Rediheat blocks with charges.
      (3) Two or more chemical heat pads.
      (4) Two blankets and a waterproof cover.
      (5) Snake-bite kit.
      (6) L. L. Bean canvas stretcher or equivalent.
   b. Rope and tackle (latter with snap eye, not a hook).
   c. Safety line.
   d. Pitons and carabiners.
   e. Rock tools:
      (1) Heavy hammer.
      (2) Star drill.
      (3) Pinch bar.
   f. Entrenching shovel and pick.
   g. At least one timepiece in the party.
   h. Shatterproof containers for carbide, gasolene, alcohol, etc.

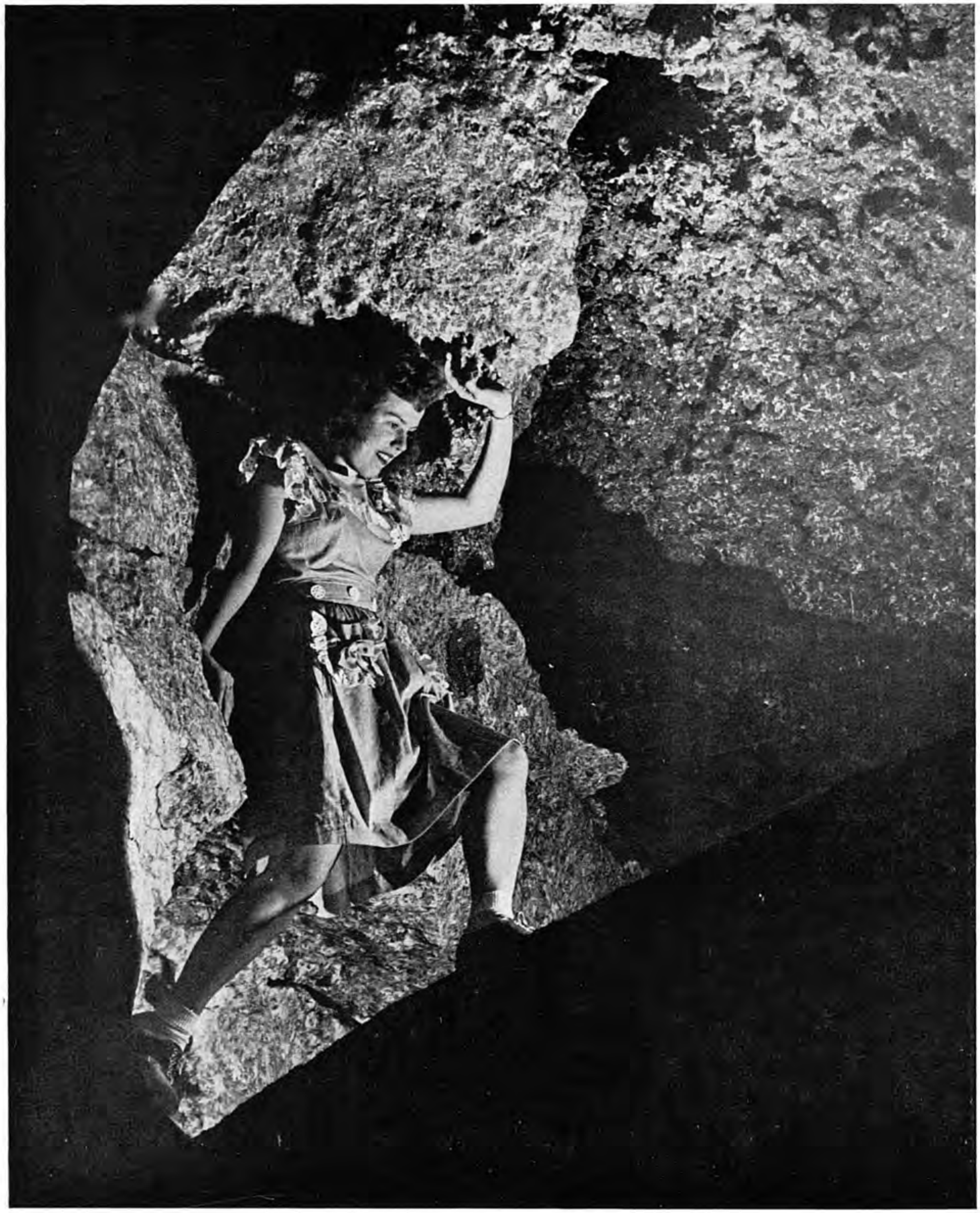
B. BEHAVIOR:

1. Everyone should be physically capable.
   a. Epilepsy, drunkenness and other physical incapabilities are not to be tolerated in a caving party.

[6] Reprinted from Bureau of Mines Information Circular 7479, p. 2, 1948

[7] Look, Van Fleet, and Walker (7)

[8] ibid.



A. Y. Owen

Exploring caves like this in Alabaster Cave, Freedom, Oklahoma, is lots of fun but ill equipped cavers are asking for trouble. The sensible caver wears his gear whether he thinks he will need it or not.

b. No one shall exert himself beyond his limit of endurance.
c. Those suffering from heart trouble or other incapacitating ailments shall not place a burden on others by overtaxing themselves.
d. Never explore alone.
e. If light source fails *WAIT IN PLACE.*
f. Avoid jumping.
g. Don't camp under or climb on unscaled cliffs (unscaled means ones which have not been cleared of loose rock within at least two days prior to the climb).
h. Follow the advice of authorized leaders.
i. Don't build a fire at the base of a cliff.
j. Don't build a fire or use a flare in a cave where the oxygen supply is not sufficient to keep the air pure.
k. Firearms will not be used indiscriminately.
l. When exploring in a commercial cave avoid all wires and electrical outlets.

C. PROCEDURE

1. Use a cave map and compass if available.
2. Mark all passages clearly.
3. Look back frequently, especially at each turn and side passage.
4. If possible follow or consult someone who is familiar with the cave.
5. Check all persons in and out of each cave.
6. Use modified buddy system below ground.
7. Notify someone above ground when the party expects to enter the cave and when it expects to return, and let them know when last man is out. In lieu of this, post notice at the cars.
8. All rigging is to be done by an experienced and capable person.
9. Use standard mountaineering techniques.
10. Never leave a novice alone.
11. Test all equipment, including rope, before each trip.
12. Inspect all equipment before each use.
13. Each caver should experience at least one safety fall in which he is belayed by an expert. In this way he learns to trust a rope.
14. Each caver should practice a belay with a falling weight.

Disaster units should take over after an accident and carry through till a doctor relieves them. This unit should be a section of each party and it should be trained before the accident. The Philadelphia Grotto trained a unit in the summer of 1948. A few weeks later a slight accident occurred,[9] and the injured person was treated for shock, evacuated to the surface and was in a hammock sipping a hot stimulant in less than ten minutes.

The first time this unit tried to make a suspended traveling stretcher to swing a spelunker across a chasm it took about six hours to accomplish the passage. On their last try they did it in about as many minutes. Instead of carrying the injured spelunker over rough terrain they hoisted him, stretcher and all right up into the air and made a horizontal passage of several hundred feet about thirty feet above ground. Evacuations of this kind are the only ones feasible in caves such as Schoolhouse, and they are not spur of the moment projects.

Duane Featherstonhaugh

Ernest Ackerly and Bradford VanDiver III, manning the safety rope for another member to descend the rope ladder into the sinkhole entrance of Hanor's Cave, Schoharie County, New York.

All disaster unit members should have first aid training as well as experience in mountaineering, rigging and knot tying. The first may be obtained from the American Red Cross but the other skills will have to be self taught with each person contributing whatever he can. Standard manuals on the subject should be consulted.

With the cooperation of everyone we can prevent most accidents and minimize the rest, but we can do little to keep up our excellent record if spelunkers regard safety regulations as a joke.

BIBLIOGRAPHY

1 STEPHENSON, WILLIAM J., 1940, Bull. Speleol. Soc. of D. C., vol. 1, p. 25.
2 STEPHENSON, WILLIAM J., 1941, Bull. Nat. Speleol. Soc. vol. 2, p. 1.
3 CHAMBERLIN, JO., 1944, Bull. Nat. Speleol. Soc., vol. 6, p. 11.
4 MOHR, CHARLES E., 1948, Personal Correspondence with the Author.
5 PARKER, JOHN DYAS, 1948, N.S.S. News, June. p. 3.
6 PARKER, JOHN DYAS, 1948, N.S.S. News, Sept. P. p. 3.
7 LOOK, VAN FLEET & WALKER, Bureau of Mines Information Circular 7479.

[9] Parker, John Dyas (6)

The Cave Rescue Organisation of Yorkshire, England

By NORMAN THORNBER, Hon. Sec.

The North of England, a region of varied caverns and potholes, has its own cavers first aid scheme. It was formed fourteen years ago and is based on Settle, a small Yorkshire market town. Its formation was the result of an accident in Gingling Hole, when twenty-two hours were spent bringing out a man with a broken leg.

The Cave Rescue Organisation is not merely a team of voluntary rescuers. It is a plan by which speleologists who are fit enough to undertake long spells of hard work underground are available in an emergency. In short it is the means of getting a club or caver who is trapped in touch with those who will release the injured. There have been many minor accidents in the Yorkshire caves, and three fatalities, which have needed the attention of the Cave Rescue Organisation. In addition a concise Caving Code has been issued and the whistle signals used in caving and potholing have been standardised.

The set up is primarily of clubs who operate in the North of England. Practically all are members, and pay two guineas, the only fee asked of them. These clubs form the committee, or at least two delegates plan round the table. They appoint five Wardens, who are selected because of their local knowledge, their previous potholing experience, and their knowing the farmers and local people who may provide help on the surface. The C.R.O. does not own any ropes or ladders. These are freely offered by the clubs, who provide the secretary-organiser with a list of the various ropes and ladders and where they are stored. Similarly those clubs who make out a fixture card send a copy to the Cave Rescue Organisation headquarters.

The Police Forces co-operate to their fullest extent with this work. They provide storage for the equipment, call out teams of rescuers, and back up the rescue work generally. Rescuers are called out by towns, rather than by clubs so that in the event of a serious accident fresh waves of rescuers are sent down below. The rescue equipment includes a Neil-Robertson naval type stretcher, ambulance first-aid bag, pulley blocks, sling, hot water bottles, kettle, primus stove and hurricane lamps. The British Royal Air Force Mountain Rescue Units also co-operate with the C.R.O. and have provided portable radio telephones, the "walkie-talkies" of the war, Verey light pistols, hot food containers, and waterproof sleeping bag and blankets. It might seem strange that a rescue unit designed primarily for crashed air crews should work hand in hand with a caving unit, but each are intended to help the other. In the event of a crashed plane the Wardens of the C.R.O. undertake to organise local rescue parties to comb the moors and mountains for the crew of the plane.

The committee is anxious to add self-heating tins of soup to the emergency stores they hold. Prior to the war they were able to obtain food quite easily, but in post-war Britain this is a problem at present. From experience it has been found that most rescuers rush out without giving a thought to food. This is a wrong idea, and nowadays rescuers are urged to have a good meal before they leave home. Some form of emergency rations, it is thought, would be useful to keep up the condition of the injured caver, and would also be useful in providing hot food during the rescue operations. This is of very great importance if work has to continue throughout the night. All rescuers are told that they must bring lights, extra clothing and a tent with them.

In the event of an accident, no matter to whom it is reported, word is immediately passed on to the District Police Headquarters. They inform the Wardens, have the rescue equipment ready, have speed cars available and warn the first wave of rescuers of the accident. They are told to standby, and do not move out until a second "call out" message is sent. The Wardens take with them the portable radio telephones, and leave one at the nearest house (with telephone) to the accident. Others move forward over the moors, taking with them what equipment might be required immediately, along with other radio sets. Communications are established across the moor by radio, so that the Warden in charge can keep in close touch by radio and telephone with Police Headquarters. A tent is pitched, the primus set going, and a full picture of the accident and what steps are to be taken is gathered. The Wardens are at liberty to remain on the surface or descend the pothole as they think fit. Their main object is to get warmth to the injured caver, or cavers, and apply such first aid (including the administration of pain-killing drugs) ready for the stretcher men. A list of caver doctors is available, and each stretcher party is designed to include a medical man. After this every effort is to get out the injured. As each stretcher party comes into the district they have to call at the District Police Headquarters for instructions and to collect any extra equipment which might be required. Ambulances are available. Farmers have offered carts, sledges and tractors to convey the injured from the pothole to the waiting ambulance. Stress is made that the Police must be kept informed of the progress, so that if the accident proves fatal full protection is given to the rescuers and those in charge.

In addition to the rescue of potholers and cavers, the Cave Rescue Organisation have tried to prevent accidents. Potholers are warned of any special dangers, of loose and dangerous parts of passages and pitches. A Caving Code has been issued, and a full list of suitable telephone points drawn up. Clubs are at liberty to deal with their own accidents if the manpower is considered strong enough, and have access to the rescue tackle. At the same time they are urged to give warning to the Police and the secretary of the C.R.O.

There have been many accidents since the Organisation was formed, three of which have been fatal. In addition the C.R.O. was called upon by the Police when two skeletons were found in North of England potholes. These were not skeletons of remains of early man, but were subsequent to 1940. Their discovery and the problems attached are another article. One thing is certain. The C.R.O. founders in 1934 never thought they might be called upon to bring out skeletons, or for that matter, have to deal with any accident which would result in a dead body being brought out of a pothole.

While also agreeing to help in searches for missing ramblers, the C.R.O. is regarded as the Red Cross of the cavers, and similar rescue organisations have been formed or planned for other parts of England.

Caving Code of the C.R.O.

1. See that all tackle is in good order.
2. Leave word as to destination.
3. In the case of open shafts, always leave a workman or obvious sign that people are below.
4. Use lifelines on all pitches.
5. Carry a whistle and use the standard signals: 1 blast, stop; 2 blasts, haul in; 3 blasts, pay out.
6. Stand clear of a pitch when someone is going up or down.
7. Wear plenty of clothes to keep warm, and a miner's helmet for protection.
8. Remember prevention is easier than rescue.

IN THE EVENT OF AN ACCIDENT

Instructions to those in charge of the patient or those present at the time of accident.

Send quickest person for assistance. If on a Moor send the quickest runner with mechanical conveyance.

Stop all bleeding first of all.

Wrap up patient and keep patient warm.

Don't administer alcoholic stimulants.

If injuries are not of a serious nature, try to work patient forward. If possible put some dry clothes on injured person.

Do not aggravate any injuries; in the case of a broken leg fasten to other sound leg. If both legs are broken, do not move until skilled attention is at hand. Make ready in any way possible for the arrival of rescuers, and the speedy removal of the patient out of the pothole.

Instructions to those remaining at the surface.

Get plenty of clean hot water ready for hot drinks and hot bottles.

If a shooting hut is at hand arrange to secure its use, making a fire ready.

Pitch a tent at the entrance to the pothole or cave for use as a headquarters.

See that there are plenty of good ropes ready for hauling up pitches.

Arrange for all gates to be open for rescuer's cars. If a long way across a moor, please have some assistance ready to carry equipment.

Instructions to person going for help.

Go to the nearest Telephone point and ring up the nearest Police Station (if no Police Constable lives in the village.)

Inform them that the Cave Rescue Organisation at Settle is required.

Give them the following particulars:—

From what Telephone point you are speaking.
What pothole and whereabouts in pot accident has happened.
What injuries are known or surmised.
How many in party are capable of giving assistance underground.
Are any ropes or ladders required.
Whether a doctor or ambulance is required.

Do not leave the telephone until the Police have full particulars.

Should the Police be unable to get in touch with any of the Wardens, either ask them to arrange for the equipment to be sent to the scene of the accident or alternatively send a car for it.

All the equipment is stored in the Police Station, Settle.

TO THOSE RESCUERS CALLED TO AN ACCIDENT.

Car owners are asked to fix a white pennant to the front of their car (handkerchief will do). Under certain exceptional conditions a road to a pothole might be closed to cars which do not display any such sign that they are C.R.O. cars.

Bring with you a tent, change of clothing and food in the case of a prolonged rescue.

Stop at Settle Police Station for any further information unless told otherwise.

Leave your car well clear of the road in case an ambulance is required.

Those who want a lift by car to the scene of the accident are asked to wear a white armlet on the left arm so that rescue car drivers can see them.

(NOTE: At the end of the foregoing Caving Code appears a list of about 10 telephone numbers of police stations fire houses, etc.)

•

Excerpt from "Some Observations on Mr. Penn's Theory Concerning the Formation of the Kirkdale Cave"

"If I rightly apprehend Mr. Penn's ideas, they are these:

Secondary limestones were originally in a soft state.

The waters of the deluge while elevated above England, deposited on it a layer, or bed, of 'a soft and plastic' calcareous matter.

On their departure from the earth, by flowing away towards the north, they floated over England the carcases of a number of tropical animals, clustered together into great masses.

These masses became buried in the calcareous mud.

On the sinking of the waters of the deluge below the surface of England, the bed of the calcareous mud began to dry, and on doing so completely, became the present Kirkdale rock.

The clustered animal bodies enclosed in the calcareous paste, by putrifying, evolved a great quantity of gas, which forced the limestone paste in all directions from them, and thus generated the cave in which Mr. Buckland found their bones."

Source: Smithsonian Miscellaneous Collections, 327, The Scientific Writings of James Smithson. Edited by William J. Rhees. 1879.

The Origin of the Markings In Pig Hole

By JOHN W. MURRAY

Associate Professor of Chemistry, Virginia Polytechnic Institute

The mystery of the strange markings discovered over a year ago by members of the V.P.I. Grotto has been discussed on several occasions in the columns of the N.S.S. News (Volume 6, Nos. 2, 7, and 9). The opinion has been expressed in these writings that the markings were the work of "people of a by-gone day" rather than the work of natural forces. Attempts to decipher the supposed inscriptions were unsuccessful. There seems to be a very prevalent human tendency to ascribe to the hand of an intelligent being any result for which a natural mechanism is not apparent. In the present case, the explanation of these markings as artifacts presents certain physical difficulties. Such an explanation seems to require an easier method of access to the cave than that used by the V.P.I. Grotto in its earlier explorations. This latter method involved a drop of about 160 feet into a sink hole, accomplished with the aid of a block and tackle.

A survey of the cave coupled with a corresponding surface survey suggested that another easier entrance may have once existed from a depression which appears to be a filled in sink hole. As reported in the September 1948 issue of the N.S.S. News, the V.P.I. Grotto has recently dug a new entrance at this point. This development shows that it might have been possible for prehistoric man to carve the markings but does not indicate that he did so.

Pig Hole, otherwise known as Earl's Cave or Porterfield's Cave, is located on the farm of Mr. A. B. Porterfield on the southerly slope of Johns Creek Mountain below the highway to Mountain Lake. It is developed in a highly fossiliferous limestone which has been identified by Dr. B. N. Cooper, head of the Geology Department at V.P.I., as the Ward Creek formation of the Middle Ordovician. The cave is notable for the extensive deposits of bat guano, especially in the passage where the markings on the wall are found. The nature of the rock suggests that the markings may be due to the preferential weathering of fossils or other structures differing in character from the main body of the rock. If this were the case, the bottoms of the depressions which constitute the markings might be expected to contain a residue of the original material or its alteration product which could be differentiated from the main mass of the rock bordering the depression. To test this hypothesis, the following experiment was carried out.

The markings consist of a number of nearly linear depressions ranging up to about four inches in length and to about half an inch in depth. There is some semblance of arrangement into lines resembling letters in a word. Many of the markings were found to contain a soft white

J. W. Murray

MARKINGS on wall of Pig Hole Cave, Giles County, Virginia.

material at the bottom. Scrapings of this material were taken as Sample A. Scrapings of the adjacent wall rock were also taken as Sample B. About four feet to the left of the markings was found a long diagonal crack in the rock separating large blocks of the limestone and showing no apparent relation to the supposed inscriptions. This also contained a soft white filling at the bottom and scrapings of this were taken as Sample C. The samples were examined with a polarizing microscope using the immersion method for refractive indices. Samples A and C, representing the soft white fillings of the markings and the long crack respectively proved to be a finely crystalline mass of gypsum-hydrated calcium sulfate. Sample B representing the wall rock at the side of the markings proved to be ordinary limestone.

A piece of limestone with one rounded and one flat side was found on the guano below a relatively smooth light colored spot on the wall from which it appeared to have fallen. This fragment had several markings on its rounded side similar to those on the wall. The fragment was broken open to reveal the relation between the markings and the underlying structure. It was found that the limestone was intersected by a number of thin veins of calcite, presumably filled in fracture planes, and that the markings on the surface were located at the intersections of these calcite veins with the outer surface of the limestone fragment.

These observations seem to indicate that the markings were formed by the replacement of the calcite in the veins with gypsum at the surface of the rock and subsequent preferential weathering of the softer gypsum. Although all samples of cave waters examined by the author contained traces of sulfate ion, a higher concentration might have been derived from gases resulting from the decomposition of the bat guano which covers the floor of the passage. Hence these markings might be ascribed indirectly to the work of bats rather than humans.

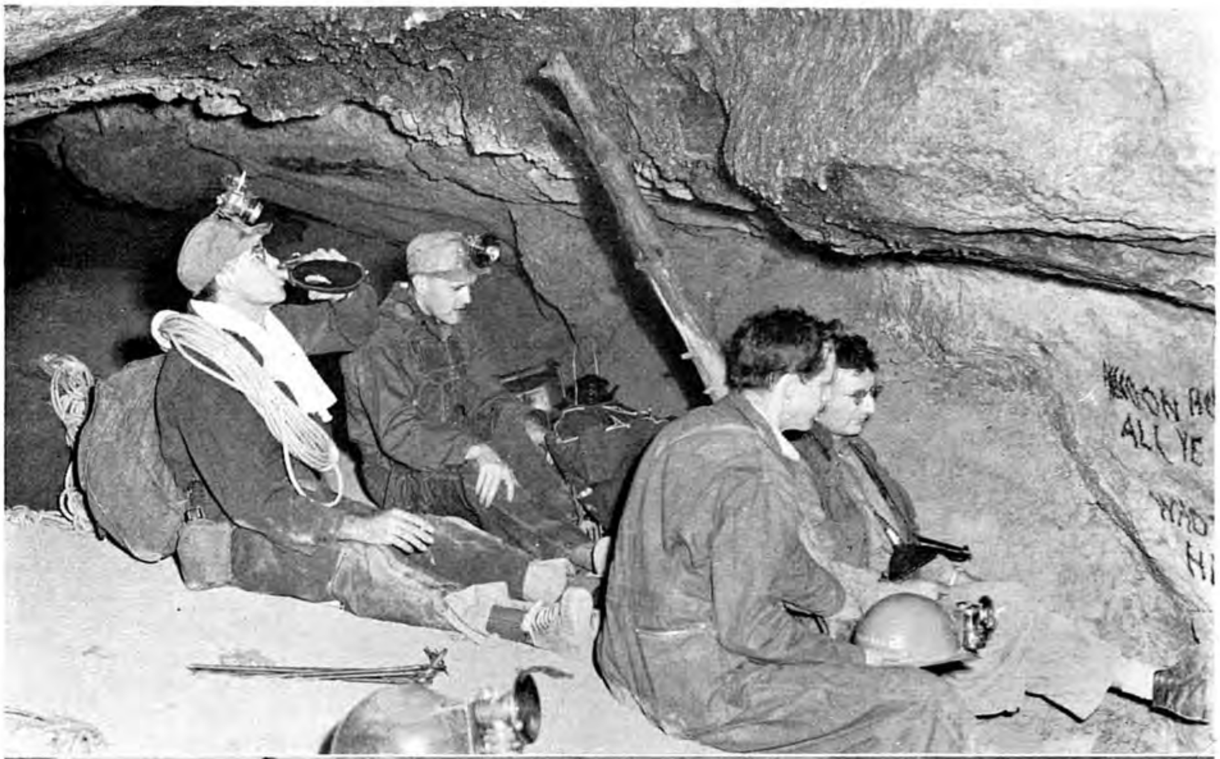
A PICTURE STORY OF SCHOOLHOUSE CAVE

Many a spelunker has encountered his Waterloo in Schoolhouse Cave, located in Pendleton County, West Virginia. Its reputation for rugged, difficult and dangerous climbing to negotiate its depths remains as a challenge, however, to the most experienced caver. The motto "Abandoned hope, all ye who enter here" appearing on the rock wall at the famous Jumping Off Place is fitting evidence that a trip to Schoolhouse is not to be taken lightly. A good night's rest, steady nerves and thorough familiarity with the techniques of the mountain climber are three necessary considerations for safely negotiating its slick walls and abysmal depths.

The pictures and map presented herein are not intended to accentuate its glamour as much as to show all who contemplate adding it to their conquests that it is, indeed, an indication of post-graduate caving to say "I have been *through* Schoolhouse".

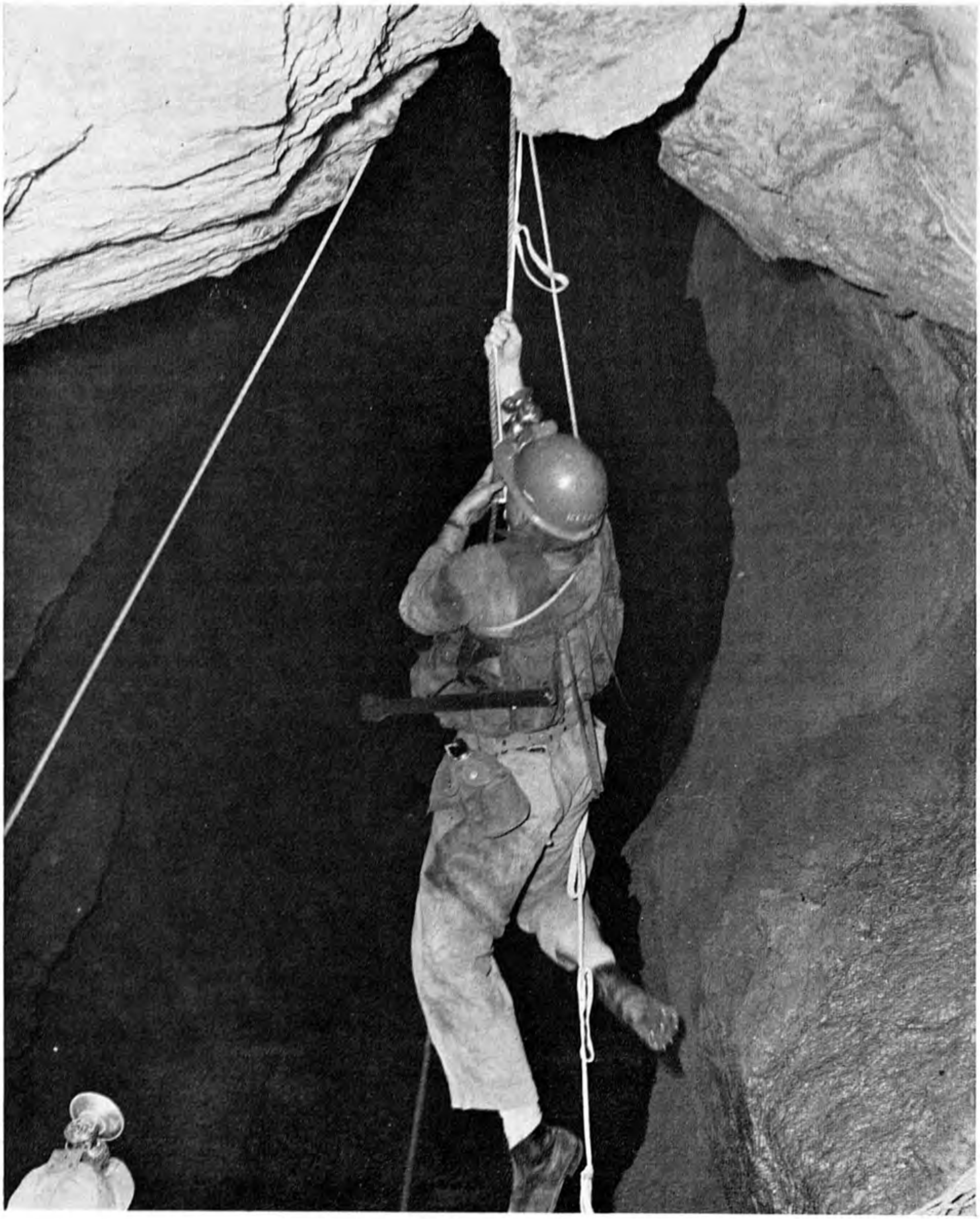
Howard Watkins

John Meenehan prepares breakfast outside Schoolhouse Cave. Sausage and scrambled eggs are in the making.



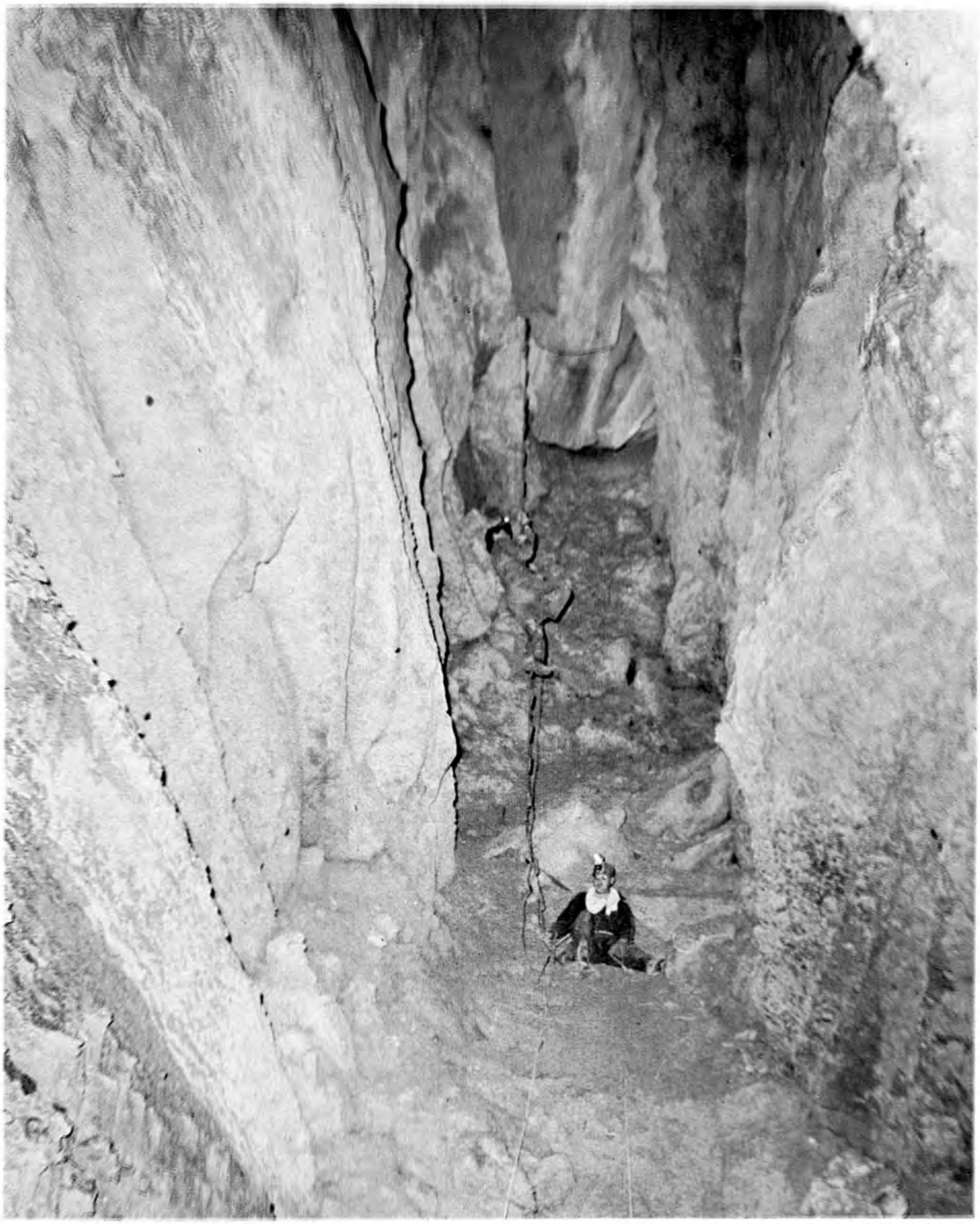
Howard Watkins

UPPER PHOTO taken at the Jumping -off Place. Welsh, Wilson, Fishburn and Meenehan thoughtfully contemplate the long drop into the Cascade Pit. **BELOW:** Lunch time on the Judgment Seat. Petrie, Welsh, Meenehan, Wilson and Bennetts pause for a hot meal before tackling Clark's Climb.



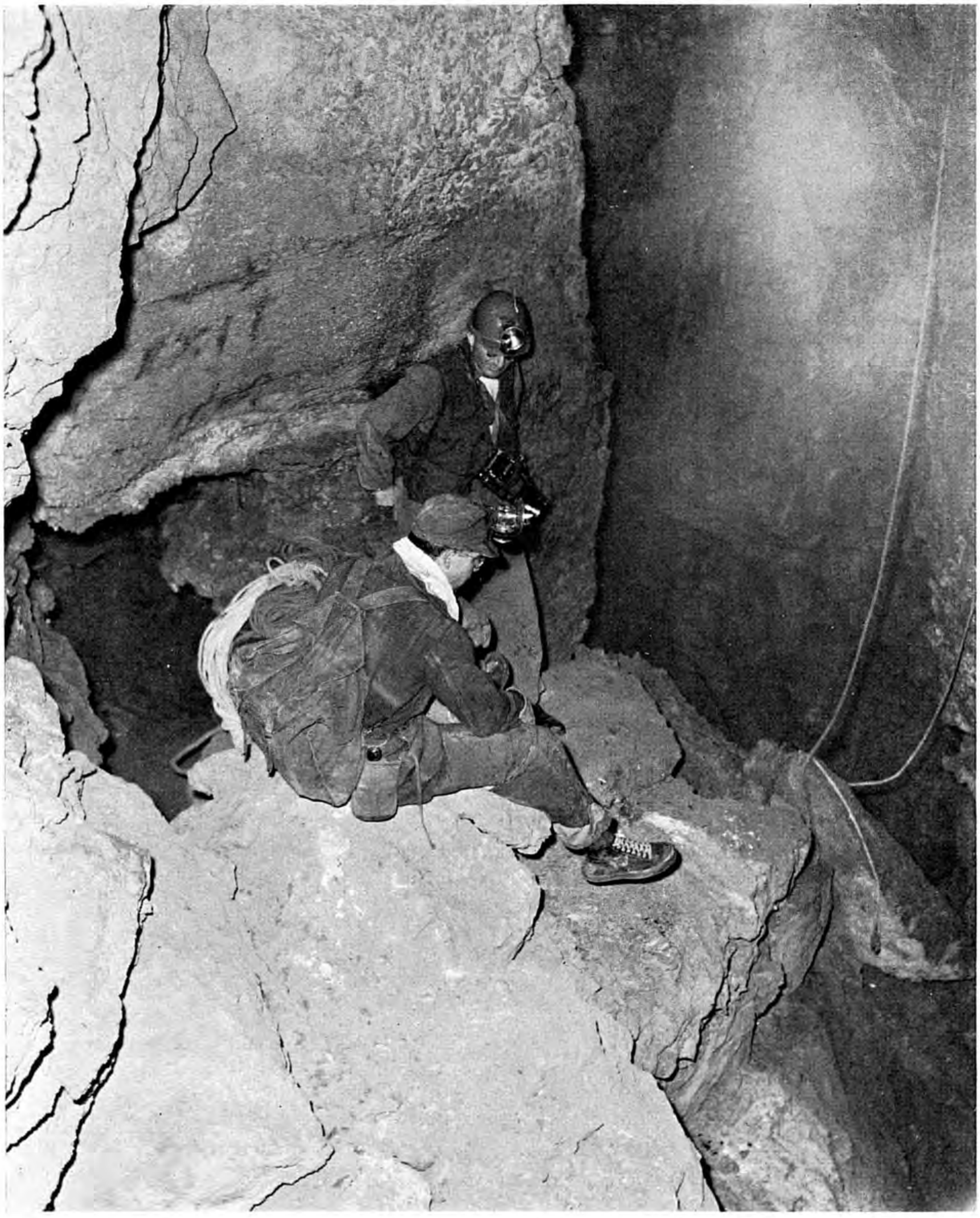
Howard Watkins

Meenehan descending hand over hand into the grotto beneath the Jumping-off Place. The blackness in the background is part of the Big Room. The Cascade Pit is more than 150 feet directly below.



Howard Watkins

Leo's Climb. Fishburn climbs up the ladder which continues up through wedged rocks to the Judgment Seat. Welsh sits at top of the 70-foot mud slope and prepares to "safety" the next man up. Ridges in the walls to left and right are approximately parallel to the ground.



Howard Watkins

Welsh and Meenehan wait on balcony to help guide the next man across the Nick-of-Time at right center. In right background is the North Well which soars up out of sight from this point and drops off into inky blackness below. The Cascade Pit is just out of the picture to the right.

Mineralogical Data In Speleological Work

By WILLIAM J. FOSTER

The study of cave mineralogy constitutes one of the most fascinating and important branches of speleological science. As has been pointed out by the late Dr. R. J. Holden, this subject is far from being a simple one and there are many aspects concerning it which are by no means clearly understood at the present time. The desirability of obtaining all possible data in this respect will, therefore, be most apparent, and it is suggested that on each and every field trip which may be undertaken by members of the Society mineralogical observations and notes of as comprehensive a character as possible, concerning the caves visited, should always be made and that a proper report should be drawn up for submission to the National Committee on Formations and Mineralogy for permanent preservation in the files of the Society. It is with a view to explaining what is required in this respect, as well as a brief description of cave mineralogy generally, that this article has been prepared.

In making a mineralogical survey, some attention should be first given to the bed rock strata within which the cave is formed. Although in most instances such strata are composed of sedimentary limestone of varying degrees of purity, (the component minerals of which are not readily determinable in the field) a general description of the gross characteristics of such rock, for example its color, texture, and hardness, will be of value. In determining these characteristics, it is important that a *freshly fractured* surface of the rock should always be examined, since surfaces thereof which have been exposed to the atmosphere for any length of time will usually exhibit a quite different appearance from that of the mass.

In examining the bed rock strata, the occurrence of any recognizable mineral deposits in the form of veins, pockets, nodules, and the like, should always be noted. Limestone, consisting as it essentially does of calcium carbonate, very frequently contains veins or masses of the pure crystalline material in the form of the mineral *calcite*, and in these deposits very interesting examples of the crystallization of this substance are sometimes found. The mineral *aragonite,* which is another crystalline form of calcium carbonate, may occur in similar fashion, as well as the double carbonate of calcium and magnesium known as *dolomite* and the hydrous sulfate of calcium termed *gypsum* or *selenite*. Silicon dioxide in the dark-colored amorphous form, known as *chert,* very frequently occurs either in veins or as separate rounded or irregular masses and, in some cases, crystals of *quartz* may be found lining cavities in the rock.

Although they are not met with as frequently as the species described above, many other minerals occur in limestone rocks, some of which are certain compounds of the heavier metals iron, manganese, copper, lead, zinc, and others. There is a possibility that deposits of these metals having a commercial value might be discovered during speleological investigations. Such metals generally occur in the form of oxides, hydroxides, carbonates, or sulfides, and the minerals which contain them may often be identified by a distinctive color or luster. For example, a yellowish, brownish, or sometimes reddish coloration usually indicates the presence of iron; manganese minerals are generally black, although they may be of a very distinctive light pinkish shade; a greenish or bluish tone is commonly characteristic of the compounds of copper. The brassy yellow-white metallic luster of iron sulfide or *pyrite* is very distinctive, as is the similarly metallic leaden gray of lead sulfide or *galena*, while the blackish, brownish, or occasionally ruby-red resinous appearance of zinc sulfide or *sphalerite* can hardly be mistaken. A very easily detected characteristic which is common to practically all of these metallic compounds is their relatively high specific gravity.

Turning now to those minerals which have been deposited by the action of water within the actual cavern spaces proper in the form of stalactites, stalagmites, flowstone, and the like, which are usually referred to as cave formations, the presence or absence of such formations should always be noted and, if present, their relative abundance and general overall character. The

*Reprinted from *D.C. Speleograph*, Vol. III, No. 4, April 1949.

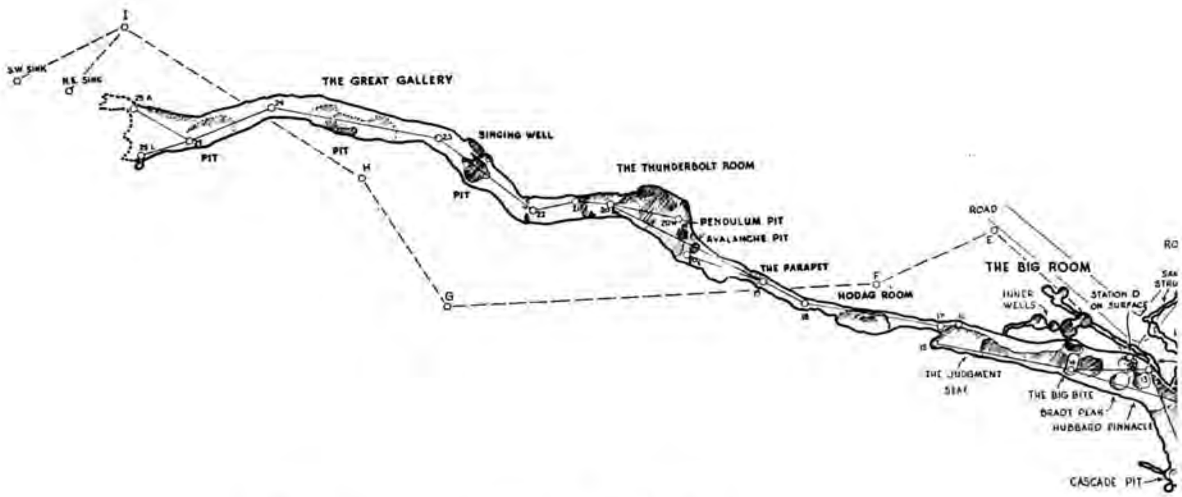
amount and character of activity taking place in connection with them, i. e., the relative amount of water flow thereover or therethrough, should be recorded; if possible, it should be determined whether material is presently being deposited from solution or whether it is being dissolved away from such deposits. In this latter connection, any evidences of recent or current solutional action on the bed rock structure in which the cave is formed will also be of interest. The occurrence of any of the rarer and more unusual types of cave formations such as helectites, anthodites, cave pearls, gypsum flowers, oulopholites and the like, should always be reported.

In making a survey of such cave formations, not only should their grosser characteristics be noted, but the identity of the actual mineral species which compose them should be determined if possible. It has already been pointed out that calcium carbonate, the substance of which by far the larger proportion of these objects are composed, occurs in two distinct forms which, although they are identical in chemical composition, are entirely different in crystal structure. Whereas the more usual mineral form known as *calcite* crystallizes in the rhombohedral class of the hexagonal system, the less common form *aragonite* crystallizes in the orthorhombic system and, in addition, aragonite is of a slightly higher hardness and specific gravity than calcite. However, the best method of distinguishing between these two substances is by their totally different type of cleavage. Calcite when broken will clearly show the rhombohedral faces which characterize it, while aragonite will rather exhibit an appearance of triangular surfaces and, very frequently, a distinctly *radiating* structure, as for example in the case of a stalactite which is broken across. Although many formations consist entirely of one or the other of these two substances, it is not uncommon to observe distinct bands or zones of both of them side by side in the same formation. It should be pointed out that while the crystals of calcite are usually of a more compact and "stumpy" nature, those of aragonite tend to assume a more slender, elongated needle-like form and to develop radiating crystal groups. The peculiarly beautiful branching flower-like forms, which are called *anthodites,* are comprised almost entirely of radiating clusters of aragonite crystals of this character.

It has been stated that some cave formations are composed of dolomite, which is the double carbonate of calcium and magnesium. This material, like calcite, crystallizes in the rhombohedral class of the hexagonal system and is not readily distinguishable from the latter by form or cleavage alone. However, it may be easily detected through the fact that, while either calcite or aragonite will readily dissolve with marked effervesence in any cold mineral acid such as hydrochloric, dolomite will show very little or no such action at all until the acid is heated.

It should also be pointed out in connection with the stalactitic types of formations that, although of more uncommon occurrence than the substances mentioned above, many other minerals are known to assume the stalactitic form upon occasion. The various types of silica, for example, may sometimes form stalactites, as may the hydrous oxides of iron known as limonite and goethite, while the basic carbonates of copper, *malachite* and *azurite,* and the hydrous sulfate of the same metal termed *chalcanthite,* are occasionally to be found in very strikingly brilliant green and blue structures of this character. The coloration of cave formations, which are composed of the white or colorless calcium carbonate, is due to the presence of impurities of these same metallic salts. The vivid yellows, creams, buffs, and browns which are so often seen are ordinarily due to the inclusion of the hydroxides of iron. Ferric oxide, mineralogically known as hematite, sometimes produces a rich and striking red coloration, while manganese oxides or hydroxides will produce a dead black if present in a sufficient amount, or in a lesser concentration will give a bluish-gray appearance. Copper salts may also be present at times, in which case a very delicate pastel blue or green shade may be imparted to the otherwise colorless carbonate. The banded appearance of many deposits, e.g., the well-known "bacon rind" type and "cave" or "Mexican" onyx, is obviously due to the alternate precipitation of pure and impure layers of the carbonate material.

The sedimentary deposits of clay, and other materials which partially or wholly fill the passages and chambers of some caves, sometimes contain recognizable deposits of minerals. For example, gypsum or selenite crystals are more frequently to be found embedded in these clay fills, although they may occasionally occur upon exposed rock surfaces where they form "gypsum flowers" or "oulopholites". These crystals, belonging to the monoclinic system, are easily re-

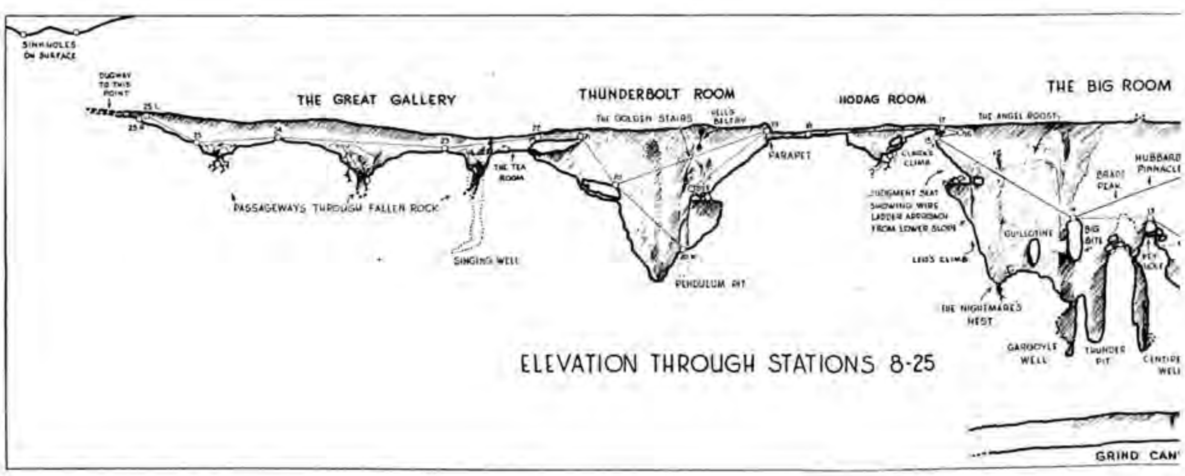


SCHOOLHOUSE CAVE

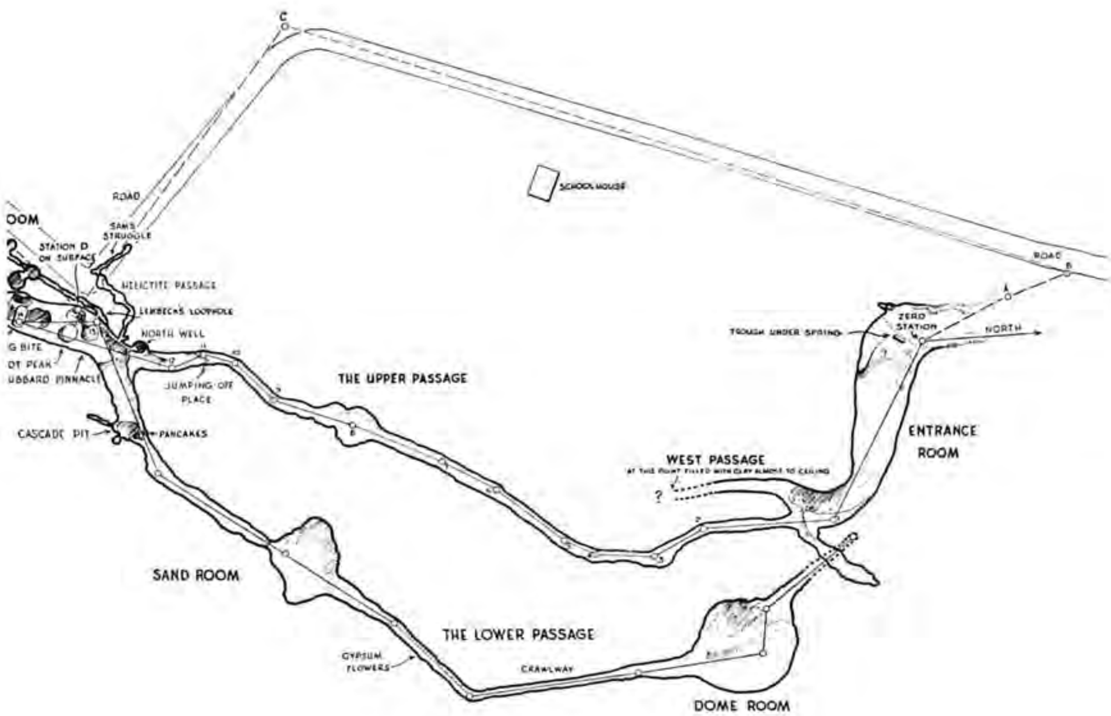
PENDLETON COUNTY - WEST VIRGINIA.

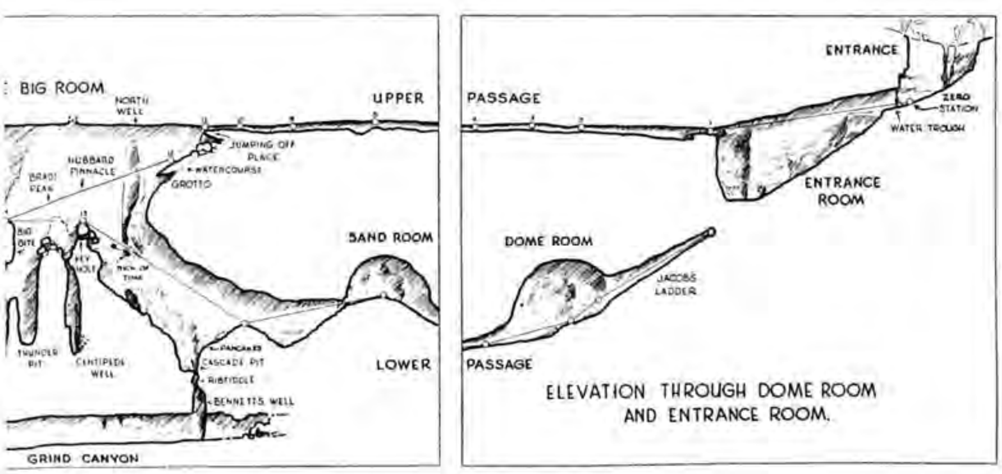
THE SMALL CIRCLES INDICATE STATIONS ON THE SURVEY AND ARE IDENTIFIED by NUMBER IN THE ACCOMPANYING ARTICLE. IN THE SCALE OF THE MAP THESE CIRCLES ARE SIX FEET in DIAMETER. BEING APPROXIMATELY THE HEIGHT OF A MAN, THEY WILL GIVE SOME IDEA OF THE PROPORTIONS OF SCHOOLHOUSE CAVE.

SCALE IN FEET



ELEVATION THROUGH STATIONS 8-25





ELEVATION THROUGH DOME ROOM AND ENTRANCE ROOM.

cognized from their distinctive glassy appearance and by the fact that they frequently exhibit a curved habit of growth. Nitrates too, and more particularly the calcium nitrate which is mineralogically known as *nitrocalcite,* may occur in such clay deposits where there is a marked absence of water. In fact, the researches of Burton Faust regarding cave saltpeter would seem to indicate that there is some relationship between the occurrence of the gypsum and the nitrate although the nature of such relationship is not clear at the present time. It is suggested that samples of the clay from likely situations might well be collected for subjection to microscopical examination and chemical analysis, even though the nitrates appear to be dispersed through the clay of the deposit in such a finely divided condition as to be very difficult to recognize upon gross examination.

Another type of surface deposit which is to be found in caves, and more particularly in the drier portions thereof, is that black, powdery, dust-like substance coating all the exposed surfaces, which was formerly believed by many (including the writer)to be the residue of smoke and smut produced by the pine torches of the early saltpeter miners. However, it is reported by William E. Davies that this material has recently been subjected to spectroscopic and X-ray analysis by the West Virginia Geological Survey and it has been determined to be a form of manganese dioxide which, although it very closely resembles the mineral *pyrolusite,* is not identical with it in structure.

In making a mineralogical survey of a cave, the collection of specimens for permanent preservation as a part of the record may be desirable and, although there is little use in collecting the more ordinary and well-known types with which the museums of the country are for the most part well supplied, the acquisition of the rarer and more unusual forms will not infrequently be indicated. This is more especially true in the case of those formations which are not clearly understood, either in their mode of formation, structure, chemical composition, and the like, and would also hold true for such things as rare mineral species or those of which the occurrence in connection with a cave is in any respect unusual. Anything which is suspected of being either a wholly new type of formation or a new mineral species should, of course, always be collected.

In the matter of collecting generally, it is believed that a word of caution is very much in order. The policy of the National Speleological Society which frowns upon the breaking and destruction of the natural decorations in caves, and more particularly upon such breaking and destruction in a wanton and indiscriminate fashion, should be kept well in mind at all times. It is believed that the rule in this respect should be that no formation of any type ,which is discovered *in situ,* should ever be taken *unless it very clearly appears that the cause of science will be served by such removal.* Even more important perhaps is the point that no specimen should ever be collected without the express consent of the owner of the property upon which the cave is situated. As to the collection of mineral specimens from the native rock strata in which the cave is formed ,and the picking up of already broken formations ,of course, this is for the most part entirely unobjectionable; however, in this case also the rights of the owner of the property should always be given paramount consideration, and his permission to remove them should be obtained.

•

Glossary of Minerals and Mineralogical Terms for Speleological Work

ANTHODITE . . . A type of cave formation comprising a cluster of complex, branching needle-like crystals and tubes of aragonite.

ARAGONITE . . . A mineral form of calcium carbonate ($CaCO_3$) crystallizing in the orthorhombic system. It is somewhat harder and heavier than calcite and frequently shows a radiating structure. (Cf. Calcite.)

AZURITE . . . A basic copper carbonate ($2CuCO_3 \cdot Cu(OH)_2$) characterized by its brilliant to dark blue color. (Cf. Malachite.)

CALCITE . . . A mineral form of calcium carbonate ($CaCO_3$) crystallizing in the rhombohedral class of the hexagonal system. It is characterized by its well-marked rhombohedral clevage. (Cf. Aragonite.)

CHALCANTHITE . . . Hydrous copper sulfate ($CuSO_4 \cdot 5H_20$). Naturally occurring blue vitriol, characterized by its brilliant blue color and its solubility in water.

CHERT . . . A dark colored to black amorphous form of silicon dioxide (SiO_2) frequently occurring in limestone.

CLEAVAGE . . . The tendency of certain minerals to break along definitely related plane surfaces due to their internal structure.

CRYSTAL . . . A definite plane-sided geometrical form which may be assumed by minerals and other chemical compounds due to their regular internal molecular structure.

DOLOMITE . . . A double carbonate of calcium and magnesium ($CaMg(CO_3)_2$) which crystallizes like calcite in the rhombohedral class of the hexagonal system. Distinguished from the latter by its lesser solubility in acid.

FRACTURE . . . In minerals ,a breaking which is usually irregular in character, and does not depend upon internal structure.

GALENA . . . Lead sulfide (PbS) crystallizing in the isometric system. Characterized by its leaden-gray metallic luster and its cubic cleavage.

GOETHITE . . . A hydrous oxide of iron (FeO (OH)) crystallizing in the orthorhombic system. Characterized by its yellowish to blackish brown color and its crystalline structure. (Cf. Limonite.)

GYPSUM . . . Hydrous calcium sulfate ($CaSO_4 \cdot 2H_2O$) crystallizing in the monoclinic system. Characterized by its vitreous (glassy) luster and its tendency to form curved crystals. (Cf. Selenite.)

HELECTITE . . . An erratically developing type of cave formation characterized by its random habit of growth with entire disregard of gravitation.

HEMATITE . . . Iron sesquioxide (Fe_2O_3) characterized by its reddish coloration in finely divided form.

LIMESTONE . . . A sedimentary rock which is composed principally of calcium carbonate.

LIMONITE . . . A hydrous oxide of iron (approximately $2Fe_2O_3 \cdot 3H_2O$). Characterized by its brownish yellow to ocher yellow coloration and distinguished from goethite by its lack of crystal structure. (Cf. Goethite.)

LUSTER . . . The surface appearance of a mineral: for example, galena and pyrite have a *metallic* luster, quartz and gypsum have a *vitreous* (glassy) luster, etc.

MALACHITE . . .A basic copper carbonate $CuCO_3 \cdot Cu(OH)_2$) characterized by its bright to dark green coloration. (Cf. Azurite.)

MINERAL . . . A naturally occurring component of the earth's crust, of inorganic origin having a definite chemical composition and (usually) capable of assuming a definite crystalline form.

NITROCALCITE . . . Hydrous calcium nitrate or "cave saltpeter" ($Ca(NO_3)_2 \cdot nH_2O$). Sometimes in silky efflorescent tufts, but usually detectable in cave deposits only by chemical analysis.

PYRITE . . . Iron sulfide (FeS_2), crystallizing in the isometric system. Characterized by its brassy white or yellowish metallic luster.

PYROLUSITE . . . Manganese dioxide (MnO_2); characterized by its dead black coloration.

QUARTZ . . . Crystalline silicon dioxide (SiO_2); occurs either massive or in definite crystals; characterized by its hardness.

ROCK . . . Any solid structural component of the earth's crust. Although a rock may consist almost entirely of a single mineral, it more usually comprises a mixture of several minerals.

SELENITE . . . A form of gypsum (q.v.) exhibiting distinct crystal forms.

SPHALERITE . . . Zinc sulfide (ZnS); crystallizing in the isometric system and characterized by its resinous luster.

STALACTITE . . . A dependent mineral formation deposited in an open space by downwardly flowing mineral bearing solution.

STALAGMITE . . . A mineral deposit built up upon the floor of a space by mineral bearing solution falling from above.

VEIN . . . A joint or crevice in a rock structure which has been wholly or partially filled with mineral material.

VUG . . . An enclosed cavity in a vein or other rock structure which may be lined with mineral matter, and frequently with well-formed crystals.

A Preliminary Study of Cave Ecology

With Special Reference to Tennessee Caverns

By THOMAS C. BARR, Jr.

We reprint below the essay which won for the author a substantial scholarship as a result of a nation-wide competition among high school students conducted by the Eighth Annual Westinghouse Science Talent Search. Though Mr. Barr desired that we use a later-submitted manuscript it was the opinion of the Editor and of the Editorial Committee that this one more nearly meets the tastes of our readers.

For untold ages caves have been of great interest to mankind, but it is only recently that they have been studied scientifically. The first significant publications on cave biology in the United States appeared at the turn of the century and were written by such men as Eigenmann, Banta, and Packard. In the twenties important studies were made by Europeans—Jeannel, Morton, and Racovitza. There have been numerous papers of a minor nature since and during that time, but it was 1938 before another major work on the subject—Pearse's *Fauna of the Caves of Yucatan*—made its appearance. At present there are in England, France, and the United States active speleological organizations engaged in many lines of research.

There are two chief reasons for a study of cave ecology. One is that the speleological environment keeps many ecological factors relatively constant, resulting in optimum conditions for the field study of those which fluctuate. The other is that many hypogean fauna present environmental adaptations which make the species of value in evolutionary and paleogeographic study.

An examination of the principal literature of cave biology and observations in approximately 50 caves in Kentucky, New York, Tennessee, and Virginia during 1947 and 1948 have been used as a basis for hypotheses drawn in this paper.

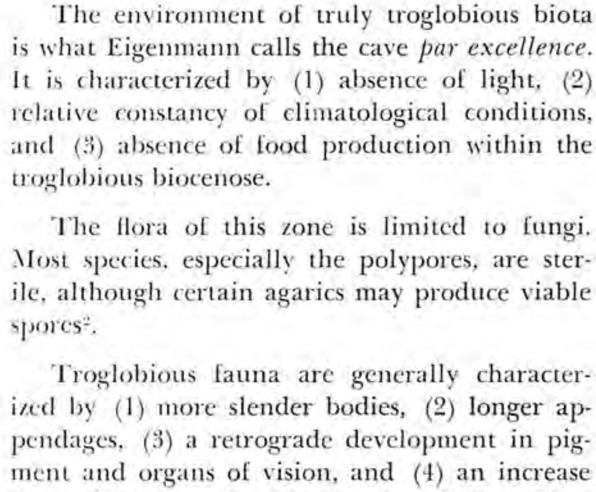
Cavernicolous organisms have been divided into three categories[1]: (1) troglobies, primary biota usually found only in the recesses of caverns, (2) troglophiles, secondary species found in the twilight zone, or as in the case of some fauna, passing freely between hypogean and and epigean, and (3) trogloxenes, or accidentals.

The environment of truly troglobious biota is what Eigenmann calls the cave *par excellence*. It is characterized by (1) absence of light, (2) relative constancy of climatological conditions, and (3) absence of food production within the troglobious biocenose.

The flora of this zone is limited to fungi. Most species, especially the polypores, are sterile, although certain agarics may produce viable spores[2].

Troglobious fauna are generally characterized by (1) more slender bodies, (2) longer appendages, (3) a retrograde development in pigment and organs of vision, and (4) an increase in sensitivity to stimuli other than light[3]. They are poikilothermic.

There are two classes of troglophilous biota. Class I includes forms living in that portion of caverns reached by sunlight, direct or indirect.



GROTTO in miniature in Apple's Cave, Goodlettsville, Tennessee. At the base of these formations lie shallow pools of water. On January 3, 1948 7-mm long larvae of the cave salamander "Eurycea lucifuga" were found in these pools.

Class II consists of animals, predominantly birds and mammals (e.g., the *Steatornithidae, Procyon, Neotema,* and especially the chiroptera), which fulfill the biocenological function of importing food into the recesses of the cavern.

The environment of Class I, the twilight zone, is characterized by (1) variable light intensity from normal epigean sunlight at the cave mouth to zero candle-meters at incipience of the total darkness zone, (2) a tendency to less variable climatological conditions than the immediate epigean, and (3) more easily available food, which may be produced by troglophilous flora and may be readily introduced from the exterior.

STALACTITE grotto in Apple's Cave, Goodlettsville, Tennessee. Bats, cave salamanders and cave crickets enter this cave through a long crawlway.

Algae, lichens, and bryophytes intergrade as dominants in this zone with "shade-loving" pteridophytes and spermatophytes in inverse proportion to light intensity, with edaphic and temperature factors at a conditional optimum. Troglophilous vascular plants[4] are delicate, with long shoots bearing large, thin leaves which have enlarged epidermal cells, fewer stomata, and lack palisade parenchyma.

Twilight zone troglophilous fauna are characterized by (1) natural pigments, (2) negative phototropism (in some cases possibly stereotropism), and (3) poikilothermism.

Ecologically it is convenient to group caves on a moisture basis for two reasons: (1) of the three major climatic factors moisture in the natural cavern is most variable; (2) its presence or relative absence in varying amounts may be taken as an index of the chronological progression of the cave in which it occurs or fails to occur.

I should like to propose such a classification, which would embrace three main divisions: (1) the hydrospoele, or wet cave, (2) the mesospoele, or damp cave, and (3) the xerospoele, or dry cave. Under normal conditions cavern progression is in the order shown, from hydrospoele to xerospoele. This geological progression is relatively slow compared to most biological processes, and the three hypogean environments may be considered separately.

Three type caverns in Middle Tennessee were chosen for intensive investigation and studies begun in the late Fall of 1948.

The xerospoele is characterized by dry, dusty corridors and rough, weathered formations. The example of this type of cave chosen for study was Hubbards Cave, near Irving College, Warren County, Tennessee. It is in the St. Louis limestone[5].

The entrance is a pit-like hole 70 feet in diameter and 30 feet deep. There are two branches, the west and the south. The west branch is an example of the extreme xerospoele. Dead, desiccated specimens of *Myotis* and *Ceuthophilus* were the only evidence of life in this passage, and they seemed accidental to this portion of the cave.

BAT COLONY on the walls of Hubbard's Cave, McMinnville, Tennessee. These are Indiana bats, "Myotis sodalis."

The relative humidity of the south branch is higher than that of the west passage, and little dust is present. The entrance to the south branch is very large and in April and November, 1948, a thin stream of water was flowing into it but sinking into the floor of the passage; the Collins River, drainage stream for the area, is far below explored sections of the cave. No water was seen in late December, 1947, or May, 1948. *Myotis sodalis* is found in this branch in great numbers. Thousands were seen hibernating in December of 1947 and November of 1948.

Within the pit-like hole, formed by the collapse of the passage roof eons ago, were mosses, liverworts, pteridophytes, a few scattered grasses, and chance dicotyledons. Several araneida which had erected webs in sheltered crevices and a large *Spirobolus* were noted. Under near-by logs were captured *Eurycea longicauda, Plethodon glutinosus*, and *Pseudotriton ruber*.

In the mesospoele small pools of water or intermittent streams may be present during the wet season, and water dripping from the ceiling often gives rise to much secondary formation. Selected for study as a mesospoelic environment was Godwins Cave, near Columbia, Maury County, Tennessee. It is in the Hermitage limestone of the Mohawkian series; the drainage stream for the area is the Duck River, 1.8 miles southeast of the cave. The entrance is about 5 feet high by 15 feet wide and is at the bottom of a sink in a strip of woods in an open field. In Godwins Cave the floors of the labyrinthine passages are damp and in some places muddy, but no formations occur.

On June 5, 1948, *Eurycea lucifuga, Rana palustris, Ceuthophilus gracillipes*, and tipuloid flies were found in this cave near the entrance. Two of the *Eurycea* were gravid females. The stomachs of the amphibians contained tipuloids, coleoptera, unidentified diptera, a minute gastropod, and bits of rock and plant material.

On November 28, 1948, a light rain had been falling for 24 hours, and a stream was flowing into the cave. Animals had moved back into the recesses, but as a rule did not proceed much farther than 200 yards from the entrance. Fauna observed included tipuloids, *Ceuthophilus*, and *Pipistrellus subflavus*. A dead bat had been attacked by fungi and saprophytic arthopods.

A fibrous ascomycete was found on wood debris along the stream bed on both of the above dates.

The hydrospoele chosen was Mill Creek Cave, near Antioch, Davidson County, Tennessee. It is in the lower Carters limestone of the Nashville group, Ordovician system. The entrance, about 8 feet high by 25 feet wide, opens in a low bluff on the north bank of Mill Creek, and is surrounded by second or third growth trees. A stream, varying in depth from one to 25 inches, flows throughout the quarter-mile length of the cavern, and empties into Mill Creek. The main passage, draped with large and numerous stalactites, averages 5 feet wide and 6 feet high.

Epigean crayfish, some of them very large, are very abundant in the stream at all points. On August 28, 1948, *Myotis lucifugus, Eurycea lucifuga, Rana sylvatica, Ceuthophilus gracillipes*, and unidentified diptera, stream isopods, and cyprinid fishes were seen in this cave. On October 3 fish, crayfish, isopods, *Ceuthophilus*, and a spider *Lycosa* were observed. By December 9 the number of species seen dwindled to cyprinids, crayfish, and *Ceuthophilus*.

With each bit of data accumulated the myriad ramifications of such a study become more and more apparent. In the future I hope to continue study along the outline presented in this paper, especially in the quantitative aspects of the subject and contribute toward making the cavern one of the best known ecological environments.

Thanks are due to Mrs. G. R. Mayfield, Mr. S. F. Boyd, and Mr. John Koen, of Hillsboro High School, Nashville; Dr. Jesse M. Shaver, of George Peabody College for Teachers, Nashville; Dr. R. W. Stone, president of the National Speleological Society; Dr. Fred Wolf, of Vanderbilt University; and especially to Dr. James J. Friauf, of Vanderbilt, without whose advice and criticism I should have accomplished very little toward the preparation of an outline of study.

[1]Jeannel, René: Faune cavernicole de la France avec une étude des conditions d'existence dans le domaine souterrain; 334 pp., 15 pl., 74 fig.; P. Lechevalier: Paris, 1927

[2]Mahfu, Jacques: La mycologie obscuricole souterraine américaine; *Bull. Trimest. Soc. Mycol. Fr.* 42 (½): 130-138; 1926 (abstr.)

[3]Banta, A. M.: The fauna of Mayfield's Cave; *Carnegie Inst. of Wash. Publ. No.* 67; 1906

[4]Morton, Fr., und Elise Hofman: Ökologie der assimilierenden Höhlenpflanzen. Mit einem Beiträg über Höhlenpflanzenanatomie; Forschr. d. Naturw. Forschung 12 (3): 151-234; 3 pl., 12 fig.; 1927 (abstr.)

[5]Bailey, T. H.: Report on the caves of the eastern Highland Rim and Cumberland Mountains; *Resources of Tennessee;* Tenn. Geol. Div.; 1917

Table I

CLIMATOLOGICAL MEASUREMENTS IN THE TYPE CAVES

Sta.	*Description of Station*	*Time*	*Air Temp.*	*H_2O Temp.*	*Rel. Hum.*	*Dew Pt.*	*Vapor Press.*
			GODWINS CAVE November 28, 1948				
1.	Room by intermittent stream; 100 yd. from entrance.	5:35 p.m.	57.5°F.	50°F.	100%	—	0.473
2.	N. end of main passage, no stream, 200 yd. fr. ent.; biotic extension limit.	5:40 p.m.	58°F.	—	91%	55°F.	0.482
3.	S. end of main passage, by stream; 200 yd. upstream fr. ent., 100 yd. by shortest route.	5:45 p.m.	57.2°F.	52°F.	99%	56°F.	0.468
			MILL CREEK CAVE December 9, 1948				
1.	Entrance of cave. Air press. 29.51″ by US dep't Comm. Weath. Bur.	5:05 p.m.	42°F.	Not determined this date (12-9)*	77%	35°F.	0.266
2.	Around curve about 50′ fr. ent.; dry ledge on left, str. 6 ft. wide.	5:10 p.m.	46°F.		82%	41°F.	0.310
3.	1st room, about 150 yd. fr. ent.; str. 4′ wide.	5:35 p.m.	57.7°F.		99%	56.7°F.	0.477
4.	2nd room, 250 yd. fr. entr., much flowstone; stream 3′ wide.	5:40 p.m.	59°F.		94%	57°F.	0.499
5.	Large stalactite over stream; H_2O fr. ceil. at 5 gal/hr.; ent. 300 yd.	5:50 p.m.	59°F.		97%	58°F.	0.499
6.	Flowstone, S-curve, silt ledge 40 ft.^{2}	6:00 p.m.	58.5°F.		91%	55°F.	0.490

*H_2O temp. Oct. 3 was 60°F. at No. 1, Mill Creek Cave, and bore almost a straight line relationship at 61.5° in the interior with distance from the entrance.

Table II

PRELIMINARY LIST OF ORGANISMS FOUND IN TENNESSEE CAVES

(Species are listed regardless of ecological classification)

Animals

Opossum	Didelphis virginiana
Little Brown Bat	Myotis lucifugus lucifugus
Indiana Bat	Myotis sodalis
Say's Bat	Myotis keenii septentrionalis
Pipistrelle	Pipistrellus subflavus
LeConte's Big-eared Bat	Corynorhinus macrotis
Alabama Raccoon	Procyon lotor varius
Allegheny Wood Rat	Neotema magister
Eastern Phoebe	Sayornis phoebe
Eastern Box Turtle	Terrapene carolina carolina
Common Tree Toad	Hyla versicolor versicolor
Wood Frog	Rana sylvatica
Pickerel Frog	Rana palustris
Long-tailed Salamander	Eurycea longicauda
Cave Salamander	Eurycea lucifuga
Red Salamander	Pseudotriton ruber
Bronzed Salamander	Aneides aeneus
Zigzagged Salamander	Plethodon cinereus dorsalis
Slimy Salamander	Plethodon glutinosus
Dusky Salamander	Desmognathus fuscus
Cave Blind Fish	Forbesichthys agassizii
Moth	Scoliopteryx libatrix
Cave Cricket	Ceuthophilus gracillipes
Cave Crayfish	Cambarus bartonii tenebrosus
Comm. Millipede	Cambala annulata
Wolf Spider	Lycosa sp.
Millipede	Spirobolus sp.
Unidentified species	
	Cyprinidae
Minnow	
Gastropod	Tipulidae
Flies	Culicidae
	Stratiomyidae
	Asilidae
	Carabidae
Ground Beetle	Lepismatidae
Thysanuran	
Isopods	
Millipede (troglobious)	
Araneids	

Plants—Specimens are being sent to authorities for identification. Only definite species is *Camptosorus rhizophyllus*, found at Hubbards Cave; other forms include *Dryopteris*, *Polypodium*, grasses, a few dicotyledons, mosses, liverworts, fungi, algae, and lichens.

Table III

PARTIAL LIST OF CAVES STUDIED

1. Apple's Cave, Davidson County, Tennessee
2. Anderson Cave, Davidson County, Tennessee
3. Big Bone Cave, Van Buren County, Tennessee
4. Bottleneck Cave, Davidson County, Tennessee
5. Bull Cave, Blount County, Tennessee
6. Burton's Cave, Dickson County, Tennessee
7. Cave Springs Cave, DeKalb County, Tennessee
8. Columbia Caverns, Dickson County, Tennessee
9. Corynorhinus Cave, Warren County, Tennessee
10. Cove Hollow Cave, Smith County, Tennessee
11. Craighead Caverns, Monroe County, Tennessee
12. Dixie Caverns, Roanoke County, Virginia
13. Dixon's Cave, Edmondson County, Kentucky
14. Fisher Cave, Smith County, Tennessee
15. Flynn's Lick Cave, Jackson County, Tennessee
16. Gin Bluff Cave, DeKalb County, Tennessee
17. Godwins Cave, Maury County, Tennessee
18. Gregory's Cave, Blount County, Tennessee
19. Haile's Cavern, Albany County, New York
20. Haile's Cave, Jackson County, Tennessee
21. Higginbotam Cave, Warren County, Tennessee
22. Hubbard's Cave, Warren County, Tennessee
23. Hudson Cave, Dickson County, Tennessee
24. Hunt's Cave, Dickson County, Tennessee
25. Las Cassas Cave, Rutherford County, Tennessee
26. Leonard Cave, Macon County, Tennessee
27. Lost Cove Cave, Franklin County, Tennessee
28. Mammoth Cave, Edmondson County, Kentucky
29. Mill Creek Cave, Davidson County, Tennessee
30. Nesbitt Cave, Smith County, Tennessee
31. Overall Cave, DeKalb County, Tennessee
32. Petty's Cave, Marshall County, Tennessee
33. Piper Cave, Smith County, Tennessee
34. Potato Hole Cave, Dickson County, Tennessee
35. Rich Mountain Caverns, Blount County, Tennessee
36. Rogers' Cave, Warren County, Tennessee
37. Robinson Cave, DeKalb County, Tennessee
38. Scout Cave, Davidson County, Tennessee
39. Snow Hill Cave, DeKalb County, Tennessee
40. Williams' Cave, DeKalb County, Tennessee
41. Ruskin Cave, Dickson County, Tennessee
42. Jewel Cave, Dickson County, Tennessee
43. Judd's (Burial) Cave, Jackson County, Tennessee
44. Blowing Cave, Sevier County, Tennessee

CAVES IN EASTERN CANADA

By HAROLD B. HITCHCOCK

Department of Biology, Middlebury College, Middlebury, Vermont

My introduction to the caves of Southeastern Ontario and adjoining parts of Quebec came through an interest in bats. In order to study their life cycle it was necessary to discover where they hibernate. When I began my search for caves in 1938 I knew of none in the region, but with the help of many individuals cave after cave was reported, the most interesting of which are listed below. The list is not intended to be complete, but may serve as an introduction to some of the caves, and furnish clues as to likely spots in which to find others.

In 1860 Sir George D. Gibb published an article in The Geologist entitled "On Canadian Caverns". In it he described thirty formations from Labrador to Lake Superior. Some of these formations are listed as "probable" caverns, detected by the hollow rumbling of coach wheels passing over exposed rock, and others are formations believed to have once been a part of caverns. Nine years later, when a large cave near Ottawa was discovered, the Canadian Naturalist and Quarterly Journal of Science summed up the Gibb report in the following words: "Though Sir Duncan Gibb has enumerated no less than thirty Canadian caverns, they are for the most part insignificant and scarcely deserving of the name". With such an evaluation I cannot vigorously disagree, so far as I have been able to judge from the caves I have visited (which are but a few of those Gibb listed). Compared with caves in other parts of the continent they are, with one exception, insignificant. The exception is the Wakefield (now Lafleche) Cave, about 18 miles from Ottawa, in Quebec.

Much of eastern Ontario is underlain with limestone belonging to the Niagara formation, which extends across the province from the Niagara River to the Bruce Peninsula and Manitoulin Island. Small caves have been reported throughout this formation, but only in a few instances have caves of more than a few feet in extent been formed. The apparent reason for the small size of the caves here is the very fractured nature of the rock, which collapses about as fast as hollowing out occurs. Commercialized caves near Collingwood are advertised, but I have not seen them. Reports of them indicate that they are not extensive, but are like others found along the same escarpment, such as Bruce's Cave, near Oxenden. All caves I have visited in Canada are in limestone with the possible exception of one on the Bronte River, where the rock removed seems to have been sandstone. I have included two mine tunnels since in their abandoned condition they have become essentially caverns.

Ontario Caves and Mines

Flowerpot Island, Bruce County, Ontario. The island is a national park and has paths leading to the several caves. These caves are on the face of cliffs, and are open and dry for the most part. In one the interior is much more moist than the others. A trip by chartered boat from Tobermory is well worth the cost, not only because of the caves but also because of the "flowerpots", tiny limestone islands near the shore, shaped like flower pots and growing spruce trees. There is a pavillion for picnicking, and a lighthouse as a further attraction.

Mar, Albermarle Township, Bruce County, Ontario. This is a small cave on the farm of Archie Given, about a mile east of the crossroads. As it is in the woods, without trail, it is difficult to locate without assistance. It is entered through a narrow chimney ten feet deep and is chiefly a circular chamber about fifteen feet in diameter with beautiful white incrustations on the walls.

Bruce Cave, near Wiarton and Oxenden, Keppler Township, Bruce County, Ontario. This is a well known picnic spot on the face of the escarpment, about four miles east of Wiarton. It is a high ceilinged spacious room with a good view across Colpoy Bay. Along the base of the escarpment are countless small caverns into which one may crawl, but because of the loose rock roofs and rough floors are neither very safe nor comfortable.

Rockwood, Wellington County, Ontario. This cave is on the face of a limestone cliff a few feet from the road, on the south-east bank of the Eramosa River, near an old lime kiln. The outer part is wide, high and exposed. From the rear wall a very narrow crawlway leads into somewhat less constricted passageways of limited extent, where the floor is muddy and the air stagnant.

Grand River and Gorge at Elora, Wellington County, Ontario. Along the steep banks are several small, exposed caves of modest proportions. The area is scenic because of the gorge, and worth a visit.

Lowville Bluff, Nelson Township, Halton County, Ontario. There are several caves at the top of the escarpment, facing north-east, on what is designated as Mount Nemo on the Hamilton topographic sheet. I was guided to them by a Mr. Lucckese, a resident of the area, and proprietor of a Canadian Youth Hostel. The largest is a fissure back a short distance from the edge of the escarpment. It is wide enough to walk in without scraping, and too high for my light to pick out the top. I went in over a hundred feet, where water stopped my progress, though the fissure continued.

MacKenzie Cave, near Merton, Halton County, Ontario. The cave is on the north bank of the Bronte River, about a third of a mile north-west of the Queen Elizabeth Highway. The entrance is broad and low, but the height increases toward the rear so that one may stand erect. There is a small pool at the end, about 60 feet from the entrance. This cave seems to have been formed by the removal of sandstone beneath limestone.

Fifth Concession, Tyendinaga Township, Hastings County, Ontario. The cave is on the north side of the county road that runs easterly from Corbyville, about a half mile west of its intersection with the county road from Shannonville to Roslin. It is entered through a sinkhole in a field, a few hundred feet from the road. The main passage extends back fairly straight from the sinkhole, and is broadest and highest at the

A CAGE of bats ready for banding. Tyendinaga Township Cave.

front, with perpendicular walls rising to a height of twenty feet. Midway down this passage, on the right, where the floor rises, is a narrow crawlway leading back almost parallel to the main passage, toward the sinkhole. Except for the first ten or fifteen feet this passage is wide and high enough to be walked through. Ice stalagmites form in the main passage during the winter, but the smaller passage remains above freezing throughout the year.

Brockville, Leeds County, Ontario. Nearly opposite the grounds of the Ontario Hospital is a cleft in the precipitous rock wall that rises from the St. Lawrence River. One can penetrate this cleft for some distance, and at times daylight shows from far below. When I visited it, in April, ice finally blocked the way, and I do not know how far one may penetrate when conditions are normal. One has the feeling that the rock on the river side of the cleft may topple over into the river if pushed. I must admit I was glad to get out of the place, though it may no doubt actually be much safer than other caves in which the danger is less dramatic.

COLLECTING bats in cave in Tyendinaga Township, Ontario.

Myer's Cave, Frontenac County, Ontario. This name appears on road maps, but so far as I could discover there is no true cave in the neighborhood, merely a shallow excavation, obviously man-made.

Puzzle Lake, Sheffield Township, Lennox and Addington County, Ontario. This cave is between Puzzle Lake and Little Gull Lake, and contains a stream flowing from the former to the latter. It is best approached from the Arden to Erinsville road at the end of Gull Lake, following high ground along the east side of the lake, across the outlet from Puzzle Lake to Gull Lake, to the far side of a small valley at the extreme southern tip of Puzzle Lake. The cave is a rough, rock-strewn passage, wet underfoot, and carpeted in places with porcupine dung, but passable from one end to the other.

Copper mine at Eldorado, Hastings County, Ontario. At one time Eldorado was a booming mining center, but today nothing but a few mine dumps and passages, mostly water-filled, give a hint of its glamorous past. I have visited a 60 foot tunnel of a copper mine about a half mile west of the settlement. Directions for reaching it may be obtained locally.

Corundum mine at Craigmont, Renfrew County, Ontario. This is a tunnel several hundred feet long behind the mill buildings. During World War II the mill operated, reworking the dump piles from previous separations, but the place is now abandoned. The tunnel itself has not been used for many years. In it can be seen good crystals of corundum. During the winter water draining from the mine freezes at the entrance forming an ice dam that causes flooding of the front part of the tunnel. Extensive ice columns also develop near the entrance, effectively blocking the passage.

Fourth Chute, Knightington, Renfrew County, Ontario. The cave is in a knoll on the north bank of the Bonnechere River, just below the dam, near the highway bridge. Water from the river flows through some of the passages. In several places large sinkholes have developed, through which entrance can be gained. Near the river, as well as in some other regions, the cave is unsafe because of loose rock in the ceiling, but the innermost part, entered through a small aperture from a sinkhole, is quite safe, consisting of narrow passages in firm rock. A sizeable stream flows through the largest of these passages, emerging on the opposite side of the knoll from the river. This is the most spectacular of the Ontario caves I have seen. Several of the passages are of grand proportions, and two sinkholes have formed a natural bridge. The rapids in the Bonnechere River beside the cave add to the beauty of the place. Plans to commercialize the spot were afoot a few years ago, but have apparently been abandoned.

Quebec Caves

Lafleche (Wakefield) Cave, near St. Pierre de Wakefield, Gatineau County, Quebec. This cave, about 18 miles from Ottawa and Hull, is the only commercial cave in the province. It is by far the most extensive cave I have seen in Canada, and has the most interesting formations. Its roomy entrance is on a steep hillside, above a small lake, and slopes downward to a chamber from which several passages lead. The longest of these terminates in a well, 90 feet deep. Electric lighting has been advantageously employed to display stalactites, stalagmites and other formations. The cave is thought to be on the old shore of the ancient Champlain Sea, at an elevation of about 700 feet. Roads around Ottawa are supplied with markers to the cave. The proprietor, Mr. Zephir Lafleche, is to be commended for protecting the bats which hibernate therein.

Les Dalles, Montcalm County, Quebec. Near Les Dalles, a settlement which takes its name from a picturesque stretch of the Oureau River, on the road between Joliette and St. Jacques, is a small cave or, as it is known locally, *trou de fee*, which can best be located by inquiry among local inhabitants. The cave is entered through a 60 foot passage that slopes gently down to a small stream. At this point one can squeeze through a low passage at the right into a chamber about 100 feet long and high enough for standing erect in places. This appears to be the cave described by Gibb as Bouchette's Cave at Kildare. If so, an error was made in locating it, and the dimensions have shrunk considerably, a phenomenon not unknown to speleologists.

Caves in the Montreal Area

St. Paul de Vincent. I have been only to the mouth of this *trou de fee,* not entering because inappropriately dressed for such a narrow and wet passage. It is in the river bank, near the dam, and known to residents of the neighborhood.

Rosemere, near Pont David. This cave is in a field, about a half mile from the beautiful old stone residence of a Mr. Garth, owner of the property. When I visited it, on January 15, 1944, the sinkhole at its mouth was completely filled with drifted snow, and it took two of us a couple of hours to shovel our way in. We penetrated about 80 feet, where water blocked further exploration. Leaves and other stream-borne material caught high on the walls and ceiling showed that the cave is flooded periodically.

Rue Cote St. Michel. In Gibb's article this is listed as Gibb's Cave, as he first described it. Today, however, Gibb has been forgotten, and the cave is just a *trou de fee* to the people of the neighborhood who are acquainted with it. It can be reached by following a farm lane running north from Rue Cote St. Michel, about a half mile east of its intersection with Rue Pie IX. The cave is about 75 feet deep, with water at the end. The entrance is narrow, but one can stand erect inside.

Summary

These caves, though not imposing because of dimensions or formations, are interesting to a speleologist prepared to get his hands and clothes soiled. They have the advantage, most of them, of being in scenic regions. No doubt many more caverns exist and can be found by making inquiries locally.

Significance As Hibernating Places for Bats

Until this investigation was started little was known of the bats hibernating in this part of Canada. The following species have been regularly found in certain of the larger caves:

Myotis keenii septentrionalis, long-eared little brown bat

Myotis l. lucifugus, common little brown bat

Myotis subulatus leibii, least bat or masked bat

Eptesicus f. fuscus, big brown bat

Pipistrellus subflavus obscurus, northern pipistrelle bat

Because the caves are of modest proportions and the numbers of bats in them limited, rather complete collections of practically all present have been possible. The majority of them have been banded and released at the caves. From the banding operations data have been secured regarding their life span. A complete report of the bat investigations entitled "Hibernation of Bats in Southeastern Ontario and Adjacent Quebec," was printed in the March-April issue of the Canadian Field-Naturalist, 1949, pages 47-59.

Appendix

Geological formations listed by Sir George D. Gibb in the Geologist, 1860.

(a) Those which at the present time are washed by the waters of lakes, seas, and rivers, including arched, perforated, flower-pot, and pillared rocks which have at one time formed the boundaries or walls of caverns, and all of them unquestionably the result of aqueous action:

1. Caverns on the shores of the Magdalen Islands
2. Caverns and arched rocks at Percé, Gaspe
3. Gothic arched recesses, Gaspe Bay
4. The "Old Woman", or flower-pot rock, at Cape Gaspe
5. Little River Caverns, Bay of Chaleur
6. Arched and flower-pot rocks of the Mingan Islands

(continued on page seventy-two)

A STORMWATER CAVERN

In the Lost River Region of Orange County, Indiana

By CLYDE A. MALOTT,

Indiana University

The caverns of the limestone belt of southern Indiana are features of subterranean drainage, though many of them are now above drainage level and are dry. All the longer explored caverns either have, or once had, definite sources of water supply. The waters which are discharged through them, or which once used them as underground drainage courses, come largely from areas of surface supply. Their phreatic water drainage is relatively small. It is true that most of the stream-coursed caverns get some of their waters from seepage through the general overlying and contiguous bedrock which slowly feeds clear waters into them. Such a supply of waters to the cavern streams is relatively continuous and uniform. But most of the stream-coursed caverns of the limestone belt receive surface waters from definite places of intake, and their stream volumes are subject to large fluctuations. The excess waters of rainy periods are usually charged with muds, silts, sands and gravels, similar to the stormwaters of surface streams. Some of the stream-coursed caverns carry only stormwaters from surface areas and have intermittent flows of water. Such caverns occasionally have higher levels which are subject only to influx of storm-born waters that overtax the lower routes, and occasionally they may have sections or levels completely above the inflooding storm-born waters.

The stream-coursed caverns, especially those that are thoroughly flooded with stormwaters gathered from the surface, offer little attraction as scenic features and are seldom visited by the public. Only a few of them have been described in detail, and still scantier attention has been given to them as subterranean drainage routes. It is the purpose of this paper to present some of the details of a stormwater course of underground Lost River in Orange County, Indiana, locally known as Hudelson cavern. This cavern was entered and mapped by the author and Robert Shrock in August, 1929, during a study of the underground features of the Lost River region. Few people know about the presence of the cavern and only a small number have actually been in it. It is an unattractive, muddy cavern and in addition it may be considered dangerous.

Lost River, carrying waters from 53 square miles of drainage, sinks in various small and several large swallow-holes along its middle course. The underground drainage is through a sinkhole belt some 10 miles in width and the course of the winding "dry-bed" is about 20 miles in length. The waters reappear at the surface 8 miles west of the first sink of the stream, but the underground course is undoubtedly much longer. The "rise" of Lost River is 120 feet lower than its first principal sinks. In periods of exceptionally heavy rains the dry-bed channel is occupied by stormwaters which descend from east to west. During these periods the subterranean channels are filled to capacity.

Very little is known about the underground course of Lost River. It is not a simple course, but is characterized by many channels developed along routes hewed out of the joint system in the upper part of the St. Louis limestone in which it is developed. The underground routes in the region of the first sinks of the surface course are but little below the surface channel, but they descend as much as 40 feet below the dry-bed in the vicinity of Hudelson cavern several miles down stream. During flood periods the underground waters occupy levels much above the low water routes, coursing through routes as high as the dry-bed itself. Thus, the underground system has both low and high water levels, corresponding to the low and high water levels of surface streams. Hudelson cavern offers a view of the characteristics of some of the varying levels of the underground system.

Hudelson cavern takes its name from a former owner of the farm on which the sink hole entrance is located. The land at present is owned by Austin Chastain. The entrance is in the eastern part of the SW of NE¼ of sec. 14, T. 2 N., R. 1 W., about midway between Orleans and Paoli, Orange County, Indiana. It is 360 yards north of the Chastain residence and 550 yards south of the dry-bed channel of Lost River. (See Fig. 1) The Hudelson cavern is in the midst of the sink hole plain through which the dry-bed channel passes. The relief of the sink hole plain is relatively small, though in about one mile to the south of the cavern entrance the edge of the rugged Chester sandstone escarpment rises as much as 200 feet above the sink hole plain.

The cavern itself is developed at three levels beneath the sink hole plain. The first floor immediately beneath the entrance is about 25 feet down and extends northward at an altitude of about 595 feet. The middle floor is at an altitude of about 575 feet, and was mapped for a distance of nearly 1,900 feet. The lowest floor is at or near the permanent watertable at an altitude of 555-560 feet. It was traversed through a distance of about 625 feet. All the floors of the cavern are developed in the St. Louis limestone, though the uppermost one is near the contact with the Ste. Genevieve limestone which composes the surface lands of this part of the sink hole plain.

The sink hole entrance to Hudelson cavern is about 15 feet across and depressed only about 5 feet below its rim. The opening in the bottom of the sink hole is only about 2½ feet across. It extends vertically through 12 feet of rock to the ceiling of an expansive room 8 feet above a rather flat floor. The room is 40 feet across in an east-west direction. The floor is composed of blocks of mud-covered rock, indicating that muddy stormwaters rise upon it. Northward is a passage which was followed for a distance of about 400 feet. This passage, along with the entrance room, constitutes the top floor of the cavern. The passage is a high-level escape route of the stormwaters at or near the level of the dry-bed channel of Lost River. Its floor and ceiling are irregular, and in places the passage is rather constricted. Everywhere the route indicates the passage of muddy stormwaters. At 380 feet from the cavern entrance the passage was only 3 feet high and 5 feet wide and was not followed farther.

Southward from the entrance room the floor descends slightly, and in about 75 feet descends abruptly into muddy pits into which stormwaters disappear during highwater periods. Irregular pits extend also along the eastern wall of the entrance room. The pits mark the terminus of the explorable part of the 575-foot floor

Fig. 1. Traverse map of Hudelson Cavern and inset map showing its relation to the dry-bed drainage of Lost River, Orange County, Indiana.

level. Evidently the floor of the entrance room is composed of fallen material which blocks the down-end of the 575-foot level. The floor of this level is marked by a well defined stream channel cut in the mud floor of the cavern. Up-stream it extends south-southeast for a distance of 575 feet and then turns northeastward. (See traverse map, fig. 1.) A little water trickles along on the narrow floor of the mud channel. This channel is 5 to 10 feet in depth, and the cavern ceiling is 5 to 15 feet above its narrow floor. The cavern itself is 12 to 25 feet in width. A small trickle of water enters from the east (left side) at 320 feet from the cavern entrance, another at about 400 feet, and still another at about 540 feet. Water drips noisily from a hole in the roof at 525 feet and a shallow plunge pool is present in the mud floor here.

After turning northeastward, the narrow bottom of the mud channel is directed into a small hole in the floor at a distance of 675 feet from the cavern entrance. The northeastward stretch of the mud-floored channel shows little change. It turns slightly here and there, and the mud wall is first on one side of the cavern and then on the other. The cavern ceiling is slightly uneven in an undulating manner, but is not rough. It is usually 6 to 9 feet above the mud floor of the channel. The cavern sides are 12 to 20 feet apart, averaging about 15 feet. The rock everywhere is covered with mud. The surface is minutely uneven, and locally stands out in small, semi-globular, shiny masses resembling grapes. An occasional stalactite is present here and there, also well covered with mud. Nowhere does rock show on the floor of the cavern.

At 1,270 feet from the entrance, the cavern is so filled with mud that it is necessary to crawl for a distance of about 120 feet. Here the roof is 2 to 3 feet above the shallow mud channel of the floor. At 1,485 feet from the entrance the mud channel becomes double, one channel coming from the left (nearly due east) and the other from the right (southeast). The cavern widens into a room about 60 feet across. The channel on the right comes out of broken-down rock next to the right wall of the cavern. It did not appear big enough to enter, and no attempt was made to follow it. The channel on the left comes through broken-down rock also, and a ridge of mud rises sharply between the two channels. The left channel was followed by going over mud-coated rock slabs adjacent to its right wall, and in about 75 feet the mud channel was again entered.

The mud channel continues northeasterly to a large room 1,835 feet from the entrance to the cavern. The ceiling of the room is 15 to 20 feet above the floor ,and on the northwest the mud floor rises to the ceiling in a distance of about 40 feet. A hole above allows water to fall into the room, and a ditch-like channel leads from the plunge basin southeasterly under the rock ceiling to the holes leading to a lower level. Apparently surface waters enter here during rains. At the southeast end of the big room, close under the ceiling, ragged holes in the rock floor lead to the low-level route of the cavern developed at an altitude of 555-560 feet. These holes are 1,905 feet from the entrance of the cavern. It is quite apparent that stormwaters fill the lower route to its full capacity and then rise through the holes and flood the next level above.

The 555-560-foot floor level of the cavern is at or near the permanent water table of the region. It extends in a northwest-southeast direction. It is developed in the very cherty phase of the St. Louis limestone and presents a rough and ragged appearance as a cavern channel. Rough cherty masses extend from the walls and ceiling, and the floor is strewn with loose chert masses. Excavated holes in the rock floor add to the unevenness. The stormwaters appear to pass through the cavern with great force in a northwest direction. The rugged route is 6 to 10 feet in height and 10 to 15 feet in width, with occasional wider places. A mud coating is present on the walls and ceiling, but the floor is relatively free from mud.

After descending through the ragged holes to the lower level, the passage was mapped northwest in a down-stream direction. At a distance of 70 feet, a pool of clear water was encountered measuring 5 feet or more in depth and with a low ceiling. Up-stream from the entrance holes, the low-level cavern route was mapped for a distance of 550 feet and 2,425 feet from the entrance to the cavern. Here the traverse was stopped by a pool of water occupying a plunge basin beneath a waterfall ledge 3 feet above water level. A blind fish fully 5 inches in length was observed in the remarkably clear water of the pool. At 320 feet from the entrance holes, a lead goes off to the right (south-southwest). It is smaller than the main channel and is nearly filled with loose rock. Apparently stormwaters from the main channel feed into it. Ripple marks and etched rock clearly indicate water passage into it. Its floor 75 feet back from the main channel is considerably higher than that of the main channel. It is possible that the waters which follow this lead are fed into the 575-foot level in the room 1,485 feet from the sink hole entrance to the cavern system.

The Hudelson cavern was entered and explored in the hope that it would lead to the low-water route of the main channel of the underground Lost River. It seems quite probable that the explored part of the cavern is south of the main through-water channel of Lost River. Swallow-holes in the dry-bed just to the north of the cavern are directed southward, evidently leading into the underground route of Lost River somewhere between the mapped part of the cavern and the dry-bed channel. The cavern was again entered during a dry period in June 1931, and a further attempt was made to trace the low-level route to the main course of underground Lost River. The cavern route was extended for 100 feet or more by wading through water varying from knee to waist deep, avoiding the deeper places. Numerous white blind crawfish were noted, and two blind fish up to 4 inches in length were observed in the clear water. The total traverse of the cavern system aggregated 3,200 feet.

The stormwaters which course through the triple-floored Hudelson cavern rise as high as 605 feet in altitude, as much as 45 feet above the low-water route at or near the watertable of the region. There are two possible sources of these stormwaters. It is possible for them to come from the surface streams which descend from the Chester escarpment south and southwest of the cavern, where several ravines send their rain-born waters into individual swallow-holes on reaching the sink-hole plain. These waters undoubtedly reach into the underground system of Lost River, though their actual routes are unknown. The second possible source of the muddy stormwaters is from the dry-bed channel of Lost River entering through the numerous Turner swallow-holes near the centre of the NE¼ of sec. 13, about one mile east of the cavern entrance. (See inset map, Fig. 1.) It appears quite probable that here is where they come from. The traverse of the cavern system ended at the up-stream end 1,400 feet nearly due east of the cavern entrance and directly toward the area of the dry-bed swallow-holes. It is regrettable that the traverse was not continued in this direction in spite of the deep pool of water which discouraged further exploration. This source is highly adequate, and the behavior of the waters flowing through the cavern system seems to indicate such a source.

It is apparent that the stormwaters course through the cavern with considerable velocity during an early period of flow, but later the waters become stagnated or flow very slowly. The high velocity period is associated with the filling period when large quantities of water enter the Turner swallow-holes from the dry-bed. Later, the underground routes become filled with stormwaters and the velocity of flow is checked, chiefly because of the stormwaters which occupy the down-stream part of the system. Decreased volumes then enter the swallow-holes in the up-stream part of the system, and the excess stormwaters descend to the dry-bed channel. The stagnated muddy waters deposit muds in the underground routes of the system, especially in the higher levels, such as the 575-foot level of the Hudelson cavern. The walls and ceiling become heavily coated with mud and dead-end channels become filled. These waters stand as high in the system as the flood waters in the dry-bed channel, and they cannot be evacuated until the dry-bed waters are lowered or emptied. Following the cessation of flow in the dry-bed, the stormwaters in the subterranean system subside and eventually cease to flow. Only clear waters seeping into the system from groundwater sources then flow through the lowest routes, except for the passage of the through-waters from the upper part of the surface system which is spring-fed.

It appears quite likely that the compound vertical components of a system like that of Hudelson cavern are the results of the development of successive levels as the water table is lowered, and that the older and higher levels are maintained and further developed by the inflooding waters from the surface. The upper levels are maintained as long as the underground tubes are not too much clogged by breakdowns in them, or as long as stormwaters rise up and pass through them. Later stages in their history are associated with incoming flood waters which do not flow freely because of occasional breakdowns in the system. These stages are associated with accumulations of clays and silts brought in by the muddy waters which may fill the dead-end passages and largely eliminate them. Such clays are highly characteristic of dry caverns now above the reach of inflooding stormwaters and high above the water table. New levels are initiated at or near the water table by the normal phreatic waters along the permissive bedding planes and the joint system of the limestone. As such the initiated water passages are small and of little significance. When taken over, however, by high-pressure flood waters from the surface, they become enlarged into through passages, and the selected routes of subterranean drainage are established from those more favorably located or those which have become etched out more quickly and become subject to the inflooding of stormwaters gathered from surface areas. The caverns into which they develop are the result of subterranean drainage, not so much by the phreatic waters, but by the stormwaters directed into and through them.

Speleological Abstracts

Compiled by EDWARD F. MOORE and E. L. KRINITZSKY

This installment of *Speleological Abstracts* is devoted to speleological journals and magazines. Every effort has been made to include the names of every publication of each speleological society, and of every journal which deals mainly with any aspect of speleology, except that ephemeral newsletters have not been listed. It has been necessary to give some of the abstracts in very incomplete form, where the inaccessibility of the journals makes it impossible to consult them. In particular, no copy of Nos. 29, 36, or 51 is known to exist in the United States, and any information about these is from indirect sources and may be incorrect. But their names have been included, and it is hoped that the small amount of information given may prove of some value.

In general the periodicals listed are very useful and concentrated sources of information about specific caves and general speleology. It is hoped that this list will increase the general knowledge about them and encourage their use. The authors would appreciate information about any speleological periodicals which are not listed, incompletely listed, or incorrectly listed here.

In order to facilitate the giving of accurate and intelligible bibliographic references, the recommended standard forms of abbreviations of the titles of all of the periodicals have been given. The abbreviations chosen have been according to the usage of the *Code International d'abbreviations des Titres de Périodiques*, Paris (1930, 1932).

The abstracts are presented in the following format: FULL TITLE OF JOURNAL, [*Recommended Abbreviation:* Extent of publication, (Dates of publication). Language. Statement as to availability of back issues, giving address from which they can be obtained, if possible. Location symbols of libraries which have a collection of this journal, indicating by an asterisk* those whose collection is known to be complete.]—A brief history and description of the journal.

It has been decided to transfer the list of recent publications into the *N.S.S. News*, where it will be available sooner because of the greater frequency of publication. Therefore, this and future installments of *Speleological Abstracts* will be devoted exclusively to abstracts dealing with various special aspects of speleology.

Part 2—Speleological Periodicals

26. ACTES DU PREMIER CONGRÈS NATIONAL DE SPÉLÉOLOGIE, [*Act. Prem. Congr. Nat. Spéléol.*: 76pp., (1939). In French. Available [3] from R. de Joly. Location. DGS*, DNSS*, EFM*.] — This pamphlet was published by the Société Spéléogique de France, containing the papers presented at a meeting held at Mazamet, France, on March 30-31, 1939. It contains articles on crystalline deposits, deep caves (gouffres), and other subjects.

27. ANNALES DE SPÉLÉOLOGIE, [*Ann. Spéléol.*: 2+vols., (1946-). In French. Available [3] from R. de Joly. Location: DGS, EFM*.]—This journal (which also goes under the subtitle of

Spelunca, 3e series) is published cooperatively by the Société Spéléologique de France and the Club Alpin Français. Most of the articles are detailed accounts of the caves of particular parts of France.

28. ATTI DEL I CONGRESSO SPELEOLOGICO NAZIONALE ORGANIZZATO DAL CLUB ALPINO ITALIANO, [*Atti I Congr. Speleol. Naz.:* 252 pp., (1933). In Italian. Not available. Location: DLC*]—This book contains the proceedings of a national Italian congress of Speleology held in Trieste on June 10-14, 1933. It contains articles on hydrology, geophysics, air circulation, biology, and other subjects.

29. BARLANGVILLAG—This publication, whose title means "the cave world", was published before World War II by the Hungarian speleological society.

30. BIOSPÉOLOGICA, [*Biospéologica:* 6 + vols., (1907-). In French. Available from H. Le Soudier, 174, Boulev. Saint Germain, Paris VIe, France. Location: DNSS, ICJ*, MH*, PPAN*, NNM*, RPB*]—This is a series of articles on various aspects of cave biology, which appeared from time to time in the journal *Archives de Zoologie Expérimentale et Générale*. Reprints of these articles have been collected together into volumes of about 1000 pages each and offered for sale by the publisher mentioned above. Besides the strictly biological information, a list of caves from which biological material had been collected was included from time to time, with a detailed description of each cave.

Bristol University Spelaeological Society: see 45.

31. THE BRITISH CAVER, [*Brit. Caver:* 18 + vols., (1936-). In English. Current issues available [3] from Gerard Platten, Rotherfield, Fernhill Lane, New Milton, Hants, England. Location: BM, DNSS, EFM.]—This journal is not controlled by any organization, being edited, printed, and published personally by Mr. Platten. The title of the first five volumes was *Journal of the Mendip Exploration Society*. A number of small English caving clubs use it as a medium of publication of their explorations and cave finds. Contains descriptions of caves in England and elsewhere, and miscellaneous nontechnical articles on caves. Small pamphlets and brochures from commercial caves, etc., are occasionally bound in.

British Speleological Association: see 18, 33.

32. BULLETIN ILLUSTRÉ DE LA SOCIÉTÉ BELGE D'ÉTUDES GÉOLOGIQUES ET ARCHEOLOGIQUES, [*Bull. ill. Soc. Belg. Étud. Géol. Archéol.:* 13 + vols., (1907-). In French. Some issues available from J. Fraipont, 14, Place J. Willem, Chênée, les Liége, Belgium. Location: DNSS.]—The title of the first issue of this journal was *Bulletin de la Société Royale Belge d'Études Géologiques et Archéologiques*, and its title has varied similarly since, with the further complication that the society which publishes it is also known as "Les Chercheurs de la Wallonie." This society is devoted to archeology and speleology, and their *Bulletins* contain articles on various aspects of these subjects.

Bulletin: see also: 45, 49.
Cave Research Group: see 19, 20, 21.
Cave Science: see 18.

33. CAVES AND CAVING, [*Caves and Caving:* Vol. 1, Nos. 1-5, (1937-1938). In English. Nos. 1, 3, 4, and 5 available [3] from British Speleological Association Publications, Duke Street, Settle, Yorkshire, England. Location: BM, DGS, DNSS*, EFM.]—This short-lived journal, which was terminated by the war, was published by the British Speleological Association. It contains a number of popularly written, interesting, and informative articles about anthropology, cave exploration, and the activities of various foreign speleologists.

Chercheurs de la Wallonie: see 32.
Deutsche Gesellschaft für Karstforschung: see 40.

34. GROTTE (LE) D'ITALIA. (Postumia. Instituto di Speliologia) [*Grotte d'Ital.* Ser. 1, 8 vols. (1927-34). Ser. 2, 3 vols. (1935-38). In Italian. Not available. Locality: CSfA, CaOG, CaTR. CtY, DGS* DLC* DSI-M, MBN*, MH-Z, NNA, NNC, NNM, PPAN*.]—This publication, also called Revista dell' Instituto Italiano di Speleologia di Trieste, was edited by Eugenio Boegan. It has an excellent bibliography on Italian speleology. Articles are of a scientific nature and are very well illustrated. Alpine work is also frequently covered as the local spelunker must also be a good climber.

35. GROTTES ET GOUFFRES, [*Grottes et Gouffres:* Vols. 1 + , (1948-). In French. Available for 175 francs per year from Editions J. Susse, 13, rue de la Grenelle, Paris 7e, France. Location: DNSS, EFM.]—This bimonthly publication contains news of the individual speleological societies in France. It is sponsored by the Comité National de Spéléologie.

36. HÖHLENFORSCHUNG, — This publication, also called *Barlangkutatas* (both of the titles mean cave research) was published by the Hungarian speleological society.

Istituto Italiano di Speleologia: see 38, 39.
Journal: see 31, 52.
Mendip Exploration Society: see 31.
Memoires: see 38, 39, 49.

37. MEMORIAS DE LA COMISIÓN DE INVESTIGACIONES PALEONTOLÓGICAS Y PREHISTÓRICAS, Madrid, [*Mem. Com. Invest. Paleont., Madr.:* Nos. 1-30. Series 2, Nos. 1-8, (1914-1930, 1934-1938). In Spanish. Location: BM, DLC, DGS*, NNM.]—A large percentage of these memoirs deal with the archeology or art of Spanish caves.

38. MEMORIE DELL' ISTITUTO ITALIANO DI SPELEOLOGIA, SERIE BIOLOGICA, [*Mem. Ist. Ital. Speleol., Ser. Biol.:* Memories 1-3, (1931- ?). In Italian. Not available. Location: DSI.]—This journal was devoted to the fauna of Italian caves.

39. MEMORIE DELL' ISTITUTO ITALIANO DI SPELEOLOGIA, SERIE GEOLOGICA E GEOFISICA, [*Mem. Ist. Ital. Speleol., Ser. Biol.:* Memories 1-3, (1934- ?). In Italian. Not available. Location: NNM, DGS.]—This journal was devoted to the geological and geophysical aspects of speleology.

40. MITTEILUNGEN DER DEUTSCHEN GESELLSCHAFT FÜR KARSTFORSCHUNG, [*Mitt. Deutsch. Gesell. Karstforsch.:* Nos. 1-4 + , (1947-). In German. Available from Deutsche Gesellschaft für Karstforschung, Altenfurt ü Feucht, Nürnberg, Germany. Location: DNSS.]—This partly printed, partly mimeographed publication is devoted to Karst research, and hence overlaps somewhat with speleology.

41. MITTEILUNGEN DES VEREINS FÜR HÖHLENKUNDE IN ÖSTERREICH, [*Mitt. Ver. Höhlenk. Öst.:* Nos. 1-18, (1908-1911). In German. Not available. Location: PPAN.]—

42. MITTEILUNGEN ÜBER HÖHLEN UND KARSTFORSCHUNG, [*Mitt. Höhlen Karstforsch.:* 19 vols. (1924-1943). In German. Not available. Location: BM, DLC, DNSS, NNM.]—This periodical was the journal of the Hauptverband Deutscher Höhlenforscher. It contained a varied collection of detailed and comprehensive articles, with many bibliographies. Biological articles were especially common. The issues for the years 1941-1943 (which are in the N.S.S. Library) appeared under the title *Zeitschrift für Karst- und Höhlenkunde,* and were published by the Forschungsstätte für Karst- und Höhlenkunde der Forschungs- und Lehrgemeinschaft, with other organizations.

43. MITTEILUNGEN DER SECTION FÜR HÖHLENKUNDE DES ÖSTERREICHISCHEN TOURISTEN-CLUB, [*Mitt. Sect. Höhlenk. Öst. Tour.-Cl.:* Jahrg. 1-7, (1882-1888). In German. Not available. Location: DLC*.]—This oldest cave journal is much like its successors all over the world, with articles on individual caves and on subjects related to speleology, together with bibliographies and book reviews of contemporary literature.

44. MONDO SOTTERRANEO (Circolo Speleologico ed idroligico Friulano) [*Mondo Soterr.* 19 vols., (1904-1923). In Italian. Unavailable. Location: CU, PPAN*.]—This journal was published by the Speleological Soc. at the Technical Institute of Udine and covers all aspects of caving. A few new species were described in the earlier vols.

45. NATIONAL SPELEOLOGICAL SOCIETY BULLETIN, [*Nat. Speleol. Soc. Bull.* 1-11 , (1940-). In English. Available from National Speleological Society, 510 Star Building, Washington, D. C. Location: DGS, DLC*, DNSS*, VBP*.]—This is the periodical in which these abstracts are printed. It contains a wide assortment of articles about American caves and various aspects of speleology. Bulletin No. 1 appeared as *Bulletin of the Speleological Society of the District of Columbia,* Vol. I. Bulletin No. 2 was not numbered, but was dated May, 1941. Bulletins 1 and 2 were mimeographed, with only about 50 copies of each produced, so these issues are quite rare. All since then have had at least 500 copies printed. Nos. 3 and 4 are out of print, but all

other Bulletins are available at the prices indicated: No. 5, $2; No. 6, $1.50; No. 7, $1.50; No. 8, $2; No. 9, $1.50; No. 10, $2. (No. 10, Cloth bound, $3.).

Österreichischer Touristen-Club: see 43.

46. PROCEEDINGS OF THE SPELEOLOGICAL SOCIETY, UNIVERSITY OF BRISTOL, [*Proc. Spelaeol. Soc., Bristol:* Vols. 1-5 + , (1919-). In English. Available [3] from R. D. Stride, Hon. Secretary, "Oldfield," Park Hill, Shirehampton, Bristol, England. Location: BM, DGS, DLC, DNSS, MH, NNM, PPAN.]—This journal is devoted primarily to the archeological aspects of speleology, although it contains some articles on other subjects. None of the prewar numbers (Vol. 1-Vol. 5, No. 2) of this journal are available because they were destroyed during the blitz.

Société: see 26, 27, 32.

Society: see 45, 46.

47. SPELÄOLOGISCHE JAHRBUCH, [*Speläol. Jb.:* Jahrg. 1-17, (1920-1936). In German. Complete sets available from Dultz & Co., Curt Brumme, München 2, Sendlinger Str. 75, Germany. Location: DLC, NNM*.]—This was the annual publication of the Speläologisches Institut, Vienna, Austria, and was edited by Dr. George Kyrle. It contained scientific articles on various aspects of speleology.

48. SPELÄOLOGISCHE MONOGRAPHIEN, [*Speläol. Monogr.:* Vols. 1-13, (1923-1932). In German. Complete sets available from Dultz & Co., Curt Brumme, München 2, Sendlinger Str. 75, Germany. Location: DLC, NNM*, PPAN*.]—This was a series of books on various aspects of speleology, published by the Speläologisches Institut, Vienna, Austria.

Speleological: see 18, 26, 27, 29, 31, 33, 38, 39, 47, 48, 49, 50, 51.

49. SPELUNCA, [*Spelunca (1),:* 15 Tomes, 98 Nos., (1895-1914). In French. Sets lacking only No. 41 available from Laboratoire de Géo-Physique de la Sorbonne, Paris, France. Location: BM, DLC*, DGS*, EFM*.]—This single name applies to a series of 3 related journals published by the Société de Spéléologie, Paris. These are distinguishable as follows: A—Spelunca, Bulletin de la Société de Spéléologie, Tomes I-VI, Nos. 1-24, 1895-1900. B—Memoires de la Société de Spéléologie, Tomes I-IV, Nos. 1-24, 1896-1900. C—Spelunca, Bulletin et Memoires de la Societe de Speleologie, Tomes IV-IX, Nos. 25-74, 1901-1914. B and C have blue paper covers, while A has yellow paper covers. These journals were all edited by Martel, and contain many articles by him, as well as many other interesting articles on caves of all parts of Europe and America. Extensive bibliographies are also included.

50. SPELUNCA, *Spelunca (2),* Nos. 1-10, (1930-1943). In French. Available [3] from R. de Joly, President, Société Spéléologique de France, Uchaud, Nimes, France. Location: DGS*, DNSS, EFM.—This journal was at first published by the Speleo Club du France, which later became the Société Spéléologique de France.

Spelunca: see also 26.

51. TRAVAUX DE L'INSTITUT DE SPEOLOGIE, [*Trav. Inst. Speol.:* Vol. 1 (193?-). Available (?) from P. A. Chappuis, Inst. of Speologie, Strada Mico No. 5, Cluj, Roumania.]

Verein für Höhlenkunde: see 41.

52. YORKSHIRE RAMBLERS CLUB JOURNAL, [*Yorks. Rambl. Cl. J.:* Vols. 1-7 + , Nos. 1-24 , (1899-). In English. Available [3] from E. E. Roberts, 12, Southway, Arthur's Avenue, Harrogate, England. Location: BM, DLC, DNSS, EFM.]—This journal is devoted both to cave exploration and mountain climbing, since the members of the Yorkshire Ramblers Club share both these interests. It contains well-written non-scientific articles and accounts of individual explorations.

Zeitschrift für Karst und Höhlenkunde: see 42.

[3] American orders accepted by LeRoy Foote, R. D. No. 1, Middlebury, Conn.

Caves In Eastern Canada

(continued from page sixty-three)

7. Pillar sandstones, north coast of Gaspe
8. Niagara caverns
9. Flower Pot Island, Lake Huron
10. Perforations and caverns at Michilimacinac, Lake Huron; the latter now known as Mackinac Island, Michigan
11. The Pictured Rocks, Lake Superior
12. St. Ignacius Caverns, Lake Superior
13. Pilasters of Mammelles, Lake Superior
14. Thunder Mountain and Paté Island Pilasters, Lake Superior

(b) Those caverns and subterranean passages which are situated on dry land, and so far as we know are not attributable to the same cause in their origin as those in (a):

15. The Steinhauer Cavern, Labrador
16. The basaltic caverns of Henley Island
17. Empty basaltic dykes of Mecattina
18. Bigsby's Cavern, Murray Bay
19. Bouchette's Cavern, Kildare. (See text for location).
20. Gibb's Cavern, Montreal
21. Probable caverns at Chatham, on the Ottawa
22. Calquhoun's Cavern, Lanark
23. Quartz cavern, Leeds
24. Probable caverns at Kingston, Lake Ontario
25. Mono Cavern
26. Eramosa Cavern
27. Cavern in the Bass Islands, Lake Erie; now part of Ohio
28. Subterranean passages in the Great Manitoulin Island, Lake Huron
29. Murray's Cavern and subterranean river, Ottawa
30. Probable caverns in Iron Island, Lake Nipissing

Features of Cave Breakdown*

(continued from page thirty-five)

1. Broad flat ceilings without stalactites indicate bedding plane solution and the possibility of Ceiling Slab breakdown.
2. Open ceiling joints are a criteria of Ceiling Block breakdown.
3. Polygonal joints or thin beds are indicative of Scaling Plates.
4. In vertical beds, sections of cave wall that show separations from the parent rock or faces of the wall at angles with the dip of the strata are potential rock falls.
5. In horizontally bedded limestones, the intersections of cave passages are areas of weakness.
6. In traversing passages where danger of collapse is suspected keep close to the wall as observations indicate that collapse, except the Ceiling Block type, does not extend to the walls.

WHO'S WHO IN BULLETIN ELEVEN

THOMAS C. BARR, JR., an enthusiastic caver in his own right before he joined the NSS in January, 1948, is particularly interested in ecology, the science which treats of the mutual relationships between organisms and their environment. While still a high school senior he won a $400 scholarship in competition with students from all over the United States and is continuing his interest in caves with further scientific researches.

WILLIAM E. DAVIES was born in Cleveland, Ohio in 1917. He is a professional geologist now with the U. S. Geological Survey in Washington after having been with the Army Map Service for three years. Before that he was in the Army. Davies became interested in caves in 1940 while working with the Pennsylvania Geologic Survey (influence of Dr. Stone obvious). Since then he has covered the caves of Maryland and a report is now nearing completion for publication by the Maryland Geologic Survey. Last Summer he was with the West Virginia Geological Survey and investigated the caves of that State for a report that is now in press by the W. Va. G. S. Right now he's clearing up some work on the terraces of the Potomac river in which there will be some data on the relation of caves and river terraces. After that he hopes to get back to his true love—the application of electrical surveys to the mapping of cavern systems from the surface. This work got under way in 1947 but with the other commitments coming along it was sidetracked. The information on which the present article is based was gathered from an examination of caves in the east, with the bulk from West Virginia, of course.

BURTON S. FAUST, N. S. S. member, 237, Chairman of Program and Activities Committee, Director of the 1948 and 1949 National Conventions, originator of the International Salon of Speleological Photographic Art, quandam Chairman of Richmond (Va.) Grotto, proxy member of Board of Governors of N. S. S. and a charter member of Florida Academy of Sciences, has visited, explored, photographed, and studied caves since 1922. His special interest in Speleology is the historical, procedural, chemical, and archeological aspects of salt petre mining as it was conducted in caves circa 1740-1865. He has devoted considerable study to these problems and written extensively on the subject. A number of his articles have appeared in the D. C. Speleograph as well as in other publications. His second interest is photographing in color examples of formations and geological phenomena of unusual interest and type. He has appeared at numerous group meetings as guest speaker on caves and caving. He is presently employed as a Patent Examiner in the U. S. Patent Office.

WILLIAM J. FOSTER is chiefly interested in the mineralogical aspects of caving. He is a charter member of the N. S. S. and has spent about 250 hours in 80 caves since 1943. He has just completed his 23rd year as an Examiner in the U. S. Patent Office. Courses in mineralogy at George Washington University and under Dr. E. P. Henderson of the U. S. National Museum gave him the background for his mineralogical writings. Last May he married an enthusiastic caver and amateur mineralogist, Gwendolyn M. Wilson of Omaha, Nebraska.

ROBERT J. HACKMAN is a Junior at Stanford University majoring in geology. He is 26 years old and has spent 6 years in the U. S. Navy. He has explored caves in Alaska, the Hawaiian Islands, and Bermuda as well as numerous others in Virginia, West Virginia and California. He spent a summer excavating fossil remains with a field party of the University of Nebraska and two summers in Alaska with the U. S. Geological Survey doing topographic work.

W. R. HALLIDAY received his B. A. at Swarthmore in 1946 and his M. D. at George Washington University in 1948. He became interested in caves while taking parties of campers through Clark's Cave when a councilor at a nearby boy's camp in Virginia. His major field accomplishment was the reopening of the blasted entrance to Blowing Cave. He is a charter member and Chairman of the Southern California Grotto. His speleological explorations have included about 60 caves in 10 states.

DANIEL KIRK HAMILTON was born at Goldsboro, N. C. on March 4, 1923. His education consists of an A. B. at the University of North Carolina, M. S. at the University of Kentucky and Ph. D. at the University of North Carolina. After graduating from the University of North Carolina he spent a summer in the position of Geologist with the North Carolina Geological Survey. At the end of the summer he went with the Strategic Minerals Division of the United States Geological Survey and joined the Ground Water Branch of the U. S. G. S. in 1944. Since that time he has been concerned with the occurrence of ground water in the limestone terrains of Kentucky. He is now teaching geology at the University of Kentucky, and is Geologist in Charge of Water Resources Investigations for the Kentucky Geological Survey. Publications relating to limestone solution are as follows: "The Occurrence of Ground Water in the Bedrock beneath the Glacial Outwash at Louisville, Kentucky". Mimeographed 1944. "Some Solutional Features of the Limestone near Lexington, Kentucky". Economic Geology, Vol. XLIII, No. 1, Jan.-Feb., 1948.

E. P. HENDERSON from 1919 until 1929 was with the U. S. Geological Survey in their Chemical Laboratory and from 1929 until the present time has been with the U. S. National Museum as an Associate Curator in Mineralogy and Petrology. His interests have been minerals, meteorites, and gems, and he is considered one of the country's leading authorities on meteorites.

GEORGE F. JACKSON has published well over 100 articles on caves and cave photography. He spent several years during school vacations as a guide in Indiana's famous Wyandotte Cave and has explored every nook and cranny of that great cavern. At present he is continuing his color photo work in caves and is working on a detailed map of Indiana cave locations while at the same time completely re-writing his "Cave Region of Indiana" which will contain all known facts about all Hoosier caves.

E. L. KRINITZSKY received training in geology at the Virginia Polytechnic Institute, University of North Carolina, and Louisiana State University. For a time he was Assistant Professor of Geology and Geography at the South-western Louisiana Institute and is at present an Engineering Geologist with the U. S. Waterways Experiment Station located at Vicksburg, Mississippi. He has published several papers relating to cave geology and done considerable cave exploration in the southern Appalachians.

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

J. D. LAWRENCE, JR. was with the Army Air Forces in Yunnan Province, China in 1945 when he visited his first undeveloped cave. He joined the V. P. I. Grotto in 1948 and serves as its secretary. Now a Junior at V. P. I. he studies electrical engineering when it doesn't interfere with his caving. He married last June and converted a sweet young girl into a muddy cave woman who assists him with his other love—the mapping of caves.

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

CLYDE A. MALOTT, a native Hoosier and long connected with Indiana University, has made special studies of the karst features and underground drainage phenomena of the limestone belt of southern Indiana. He is familiar with its many caverns and has given special attention to their connections with water sources which were responsible for their development. Among them is the noted Lost River region of Orange County which offers unusual opportunities for the study of cavern phenomena and the relations of caverns to the subterranean waters which develop them. Out of these studies has come his invasion theory of cavern development, in which accent is placed upon cavern development by rainborn surface waters which ream out and align initial and rudimentary subsurface joint openings into long and integrated cavern systems at or near the watertable. The present paper, in addition to the description of a dangerous and rarely visited cavern, indicates the adequacy of stormborn waters in cavern development.

EDWARD F. MOORE's hobby is collecting books, articles, journals, and pamphlets about caves. His personal collection now includes over 400 items in 5 languages. He also helps the N. S. S. collect foreign publications for its library by assisting with the foreign correspondence of the society and arranging for the exchange of publications with foreign speleological societies. He was one of the charter members of the V. P. I. Grotto in 1942, and has caved mainly in Virginia and West Virginia, but has visited caves as far away as Hawaii. He is now working toward a Ph. D. degree in mathematics at Brown University.

DR. JOHN W. MURRAY gravitated into the realm of speleology at the invitation of some of his chemistry students in the V. P. I. Grotto. It furnished a natural outlet for his varied past interests in geology, photography, hiking and rock climbing as practised by the mountaineer. He is interested in working out the factors which determine the nature of cave formations. He serves as an unofficial adviser to the V. P. I. Grotto on matters of cave safety and mineralogy.

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

DR. RALPH W. STONE, retired State Geologist of Pennsylvania, is serving his second year as President of the National Speleological Society. Nearly 25,000 copies of his two bulletins on "Pennsylvania Caves", published in 1930 and 1932, have been circulated. They helped pave the way for and to stimulate the growth of the N. S. S., while scores of talks which he has delivered before civic, professional, educational, and scientific groups have introduced speleology to a large audience. A life member of the N. S. S., No. 80, and one of its first members outside Washington, Dr. Stone was selected Honorary Member in 1943. His long editorial experience, during much of his twenty years with the U. S. Geological Survey, in the Pennsylvania Geological Survey from 1922-1946, and for the Pennsylvania Academy of Science for fifteen years, has been of inestimable assistance to editors of N. S. S. bulletins. Dr. Stone's enthusiasm for speleology and his particular interest in the origin of caves, may be traced directly to the influence of his beloved professor of geology at Harvard University, the late W. M. Davis, author of the classic work, "The Origin of Limestone Caverns" (1930). A biographical sketch of the N. S. S. President appeared in the May 1948 NEWS.

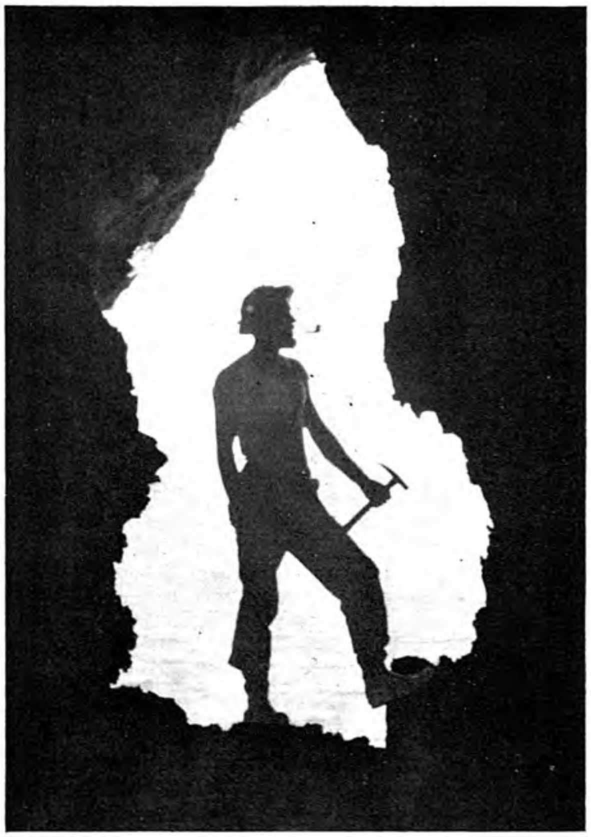


Photo from Robert J. Hackman