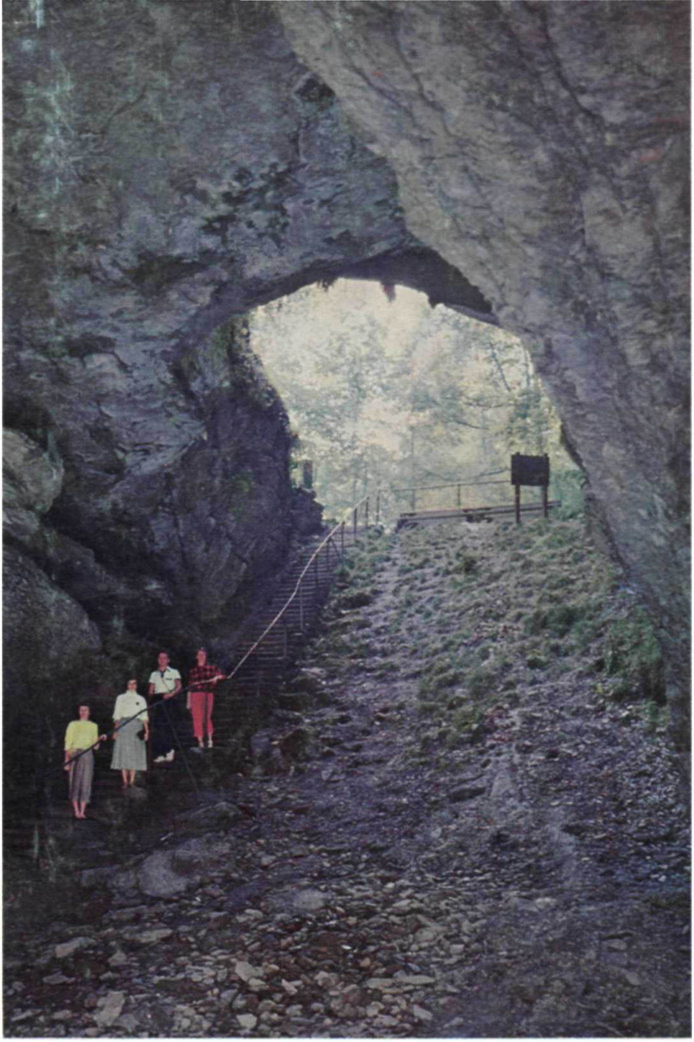


GEOLOGY OF THE MAMMOTH CAVE NATIONAL PARK AREA

KENTUCKY GEOLOGICAL SURVEY 1962
UNIVERSITY OF KENTUCKY, LEXINGTON

KENTUCKY GEOLOGICAL SURVEY
LEXINGTON, KENTUCKY

WALLACE W. HAGAN
Director and State Geologist

Series X
1962

Geology of the Mammoth Cave National Park Area

By Ann Livesay, 1953

Revised by Preston McGrain, 1962

SPECIAL PUBLICATION 7

College of Arts and Sciences
UNIVERSITY OF KENTUCKY

LETTER OF TRANSMITTAL

January 30, 1962

Dean M. M. White
College of Arts and Sciences
University of Kentucky

Dear Dean White:

Geology of the Mammoth Cave National Park Area by Ann Livesay, 1953, is such a popular publication that two printings of 11,000 copies are exhausted. Since the cave trips have been changed and more recent and improved pictures are now available, we have revised this publication in order to update it and increase its usefulness.

This report enhances the individual's appreciation of this natural wonder, Mammoth Cave.

Respectfully,

Wallace W. Hagan
Director and State Geologist
Kentucky Geological Survey

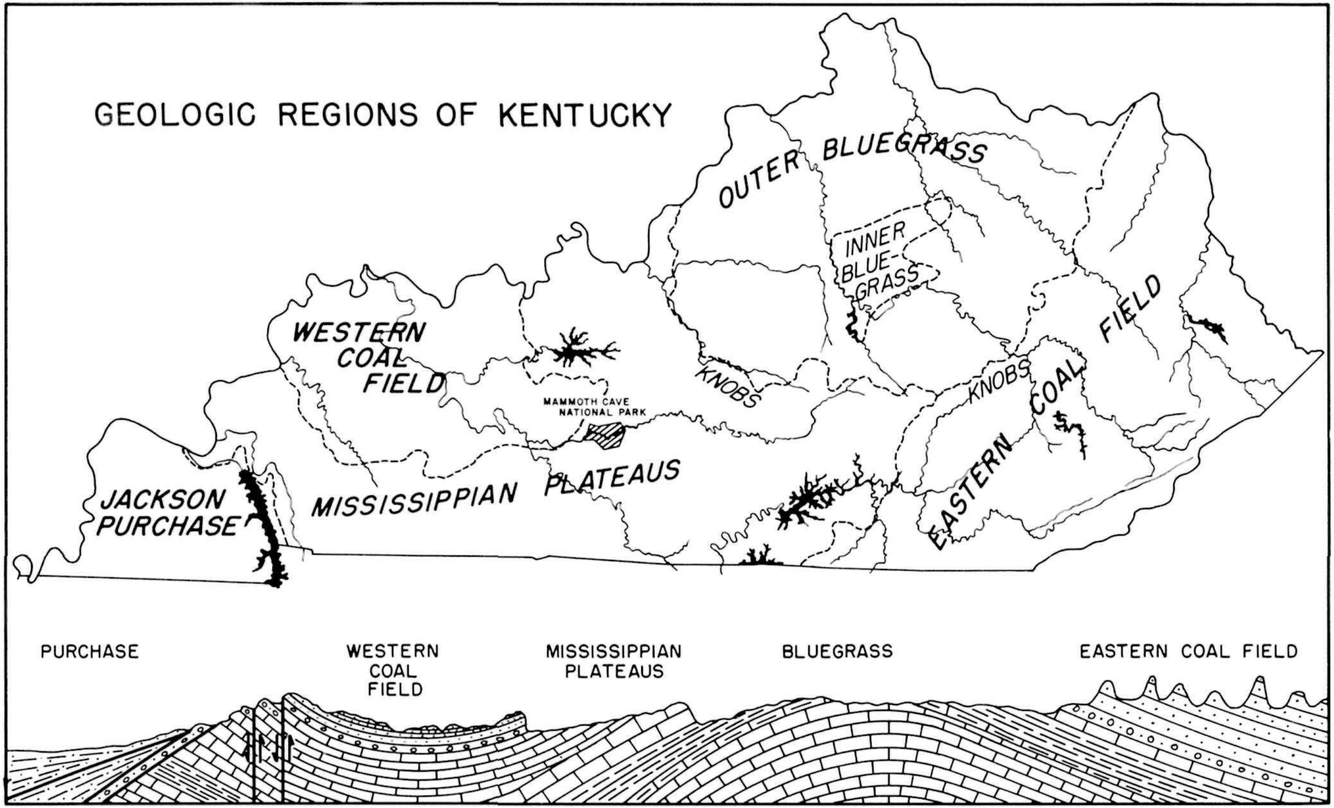
COVER PHOTOS

Front cover. Natural entrance to Mammoth Cave. It is situated in a deep valley near the south bank of Green River. Since 1816, when the cave was first opened to the public, hundreds of thousands of people have passed through this historic entrance to view the wonders of this outstanding scenic attraction. The Echo River, Historic, and All-day trips begin here.

Back cover. Frozen Niagara. This is one of the most spectacular natural features of Mammoth Cave, and was formed by the slow deposition of calcium carbonate from water dripping or flowing down the cave walls and over collapsed blocks of limestone. It is the largest single depositional feature in the cave, being 75 feet high and 50 feet wide, and is featured on the Frozen Niagara trip. It provides mute evidence of the power of water to dissolve limestone and redeposit the mineral material elsewhere.

Photos by W. Ray Scott
National Park Concessions, Inc.

ILLUSTRATIONS



Frontispiece. Outline map of Kentucky showing geologic regions and the location of Mammoth Cave National Park. The oldest (Ordovician) rocks exposed in the State are found in the Bluegrass region and progressively younger rocks outcrop on either side of this area. The coal fields contain rocks of Pennsylvanian age. In the generalized cross section the versical scale is greatly exaggerated.

INTRODUCTION

The Mammoth Cave area, in east-central Edmonson County, Kentucky, is one of the world's famous cave regions. A hunter named Houchins is rumored to have chased a wounded bear into a previously unknown cave in the late 1700's, thus discovering one of the great natural wonders of the world. This booklet is written to provide answers to questions which might arise in the visitor's mind concerning the location and formation of this and other caves of the area. Geological literature contains much information about various aspects of Mammoth Cave and its special features, but no attempt has been made previously to present this material in a semitechnical fashion. Some of the more important scientific references have been included in a list at the end of this discussion for those who may want to study further the technical details concerning cavern development.

REGIONAL SETTING

Age of Rocks—The rocks of the area date back about 325 million years[1] to that division of geological time called the Mississippian Period. Vast regions of this state and many others were then covered by shallow seas in which layer upon layer of clay, silt, sand, and limestone were forming. The limestone was formed from mineral matter in the sea water and from the shells and other parts of animals and plants that lived there. Fossil remains can be seen in these rocks in many places.

Sediments from nearby land sources were carried by rivers and streams to these Mississippian seas and were deposited there as mud, now hardened into shale, and sand and gravel, now hardened into sandstone. Similar processes now in operation are forming layers of sediments in ocean and lake basins. Thus, about 1,200 feet of Mississippian limestones, sandstones and shales came into existence. The caves were formed much later.

Earth Movements Affect Cave Area—At the beginning of the Pennsylvanian Period, crustal movements of the earth caused the seas to withdraw from this area as the whole region was slowly warped upward. During this slow upraising, rivers flowing over the newly

[1] Estimates of various geological age dates are revised from time to time as further information and data are gathered. The time of formation of the limestone in which Mammoth Cave is formed is estimated to be between 310 and 325 million years ago.

formed land surface deposited layers of sand and gravel, some in delta-like form, which were later covered by other layers above to form rocks known to be Pennsylvanian in age. At the close of the Paleozoic Era, the earth's crust in this region was warped upward into a great dome-like structure called the Cincinnati Arch. This feature can be seen in the cross-sectional view of the state (frontispiece). Located on the western flank of the Arch, the rocks of the Mammoth Cave area dip about 30 feet to the mile in a northwest direction, toward the Western Coal Basin.

The later history of the area is mainly one of erosion, when great thicknesses of rock were removed from the Cincinnati Arch. Some of this material accumulated as sediments which helped to form the younger rocks of the Purchase area in western Kentucky. Later uplifts, occurring to a greater degree in the east than in the west, rejuvenated or reactivated all the streams in the region. Erosive forces thus produced the present landscape features.

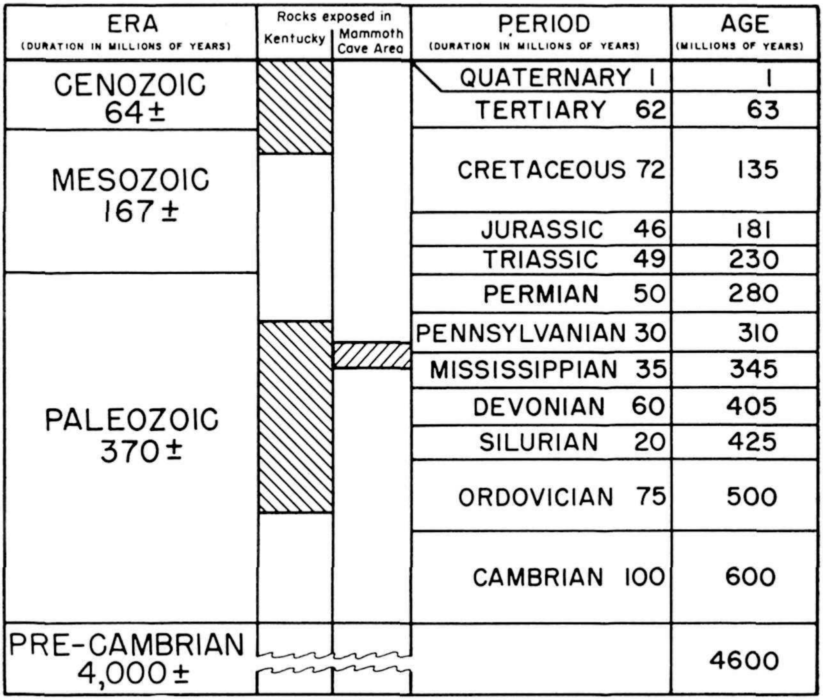


Fig. 1. Geologic time chart showing the relation of the age of the rocks in the Mammoth Cave area to those of the rest of Kentucky. The scenic features of this interesting region have been forming during the last 25 or 30 million years in rocks which are 310 to 325 million years old.

Among the weathering forces at work in the Mammoth Cave area has been one called carbonation. This is a process whereby certain gases from the air, such as carbon dioxide, are dissolved in water to form carbonic acid. Pure water cannot dissolve limestone readily, but most water is not pure. Instead, it contains these dissolved gases and acids which greatly increase the chemical reactions that may occur. When such water comes into contact with limestone, calcium carbonate of the limestone reacts with the carbonic acid to form calcium bicarbonate, which is a very soluble compound. In this form much carbonate material is dissolved in water and carried away. The fact that limestone is soluble in water accounts for the development of many of the features, both on the surface and underground, which intrigue the visitor.

Surface Features—Coming into the park from the southeast, along Kentucky Highway 70, one crosses a rolling flat lowland surface underlain by the St. Louis Limestone. This limestone, being soluble in the water which seeps down through it, has been eaten away until now the surface is literally pitted by depressions which are called sinkholes. The large number of sinkholes has led some geologists to call this the Southern Sink Hole Plain, while others know it as a part of the Pennyroyal Plateau. It also has been referred to as the "Land of Ten Thousand Sinks." To the west a high plateau rises about two hundred feet above the lower sinkhole plain. This conspicuous landscape feature is

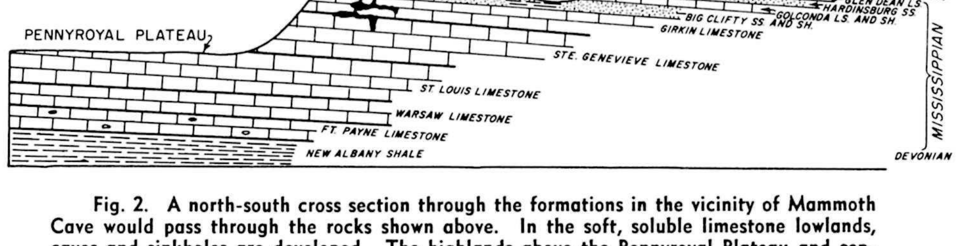


Fig. 2. A north-south cross section through the formations in the vicinity of Mammoth Cave would pass through the rocks shown above. In the soft, soluble limestone lowlands, caves and sinkholes are developed. The highlands above the Pennyroyal Plateau and separated from it by the Dripping Springs Escarpment are protected from rapid erosion by the Big Clifty and Pottsville sandstones.

known as the Dripping Springs Escarpment. It is capped by the Big Clifty Sandstone, beneath which are thick layers of limestone. In certain of these limestones Mammoth Cave itself has been formed.

If one approaches the cave area by way of Park City on Kentucky Highway 255, there is also a striking display of sinkholes in the Pennyroyal Plateau, and about two and one-half miles from Park City on the way north toward Mammoth Cave, the road goes up onto the top of the Dripping Springs Escarpment. The visitor who is interested in the origin of place names can see the spring called Dripping Spring, which has given its name to this escarpment. Located on Route 31W about eight miles west of Park City, this spring issues from the face of the escarpment itself.

Route 255 merges with Route 70 about five miles south of Mammoth Cave. Along both sides of the highway approaching the cave may be seen numerous large, irregularly circular sinkholes. One of the largest in the area is Monroe Sink on the north side of the road about 2½ miles west of Cave City. Another fine example is the New Entrance to Mammoth Cave, a sinkhole which will be seen by all visitors who take the Frozen Niagara Trip.

Fig. 3. Aerial view of Pennyroyal Plateau (sinkhole plain), Dripping Springs Escarpment, and sandstone-capped Mammoth Cave Plateau. The sinkholes in the foreground are in the Ste. Genevieve Limestone. The Big Clifty Sandstone outcrops at the top of the escarpment. Photo by W. Ray Scott, National Park Concessions, Inc.

There are very few surface streams in the cave area other than the Green and Nolin Rivers, despite the average rainfall of about 50 inches. Many streams bear such suitable descriptive names as Lost River and Sinking Creek. A surface stream may suddenly enter a sinkhole or joint in the limestone and disappear. The limestones are honeycombed with openings formed by solution processes, and the water may reach great underground depths by following these openings. Perhaps a mile or two downstream, the water which disappeared will suddenly reappear at the surface as a large spring. One of the most striking examples of such disappearing streams may be seen by taking a short trip along one of the side roads within the park boundaries going in a southwest direction. About four miles from Mammoth Cave, one approaches a large sinkhole shown on the map as Cedar Sink. This is a special type of sinkhole, probably produced originally by collapse of limestone layers over a cavernous opening, that reveals a short section of an underground stream. A stream of water emerges from beneath a steep wall at one end of the depression, flows slowly across the floor of the sink, and disappears at the base of a rocky bluff on the other side.

During a long period of time most of the streams of this area have become adjusted to an underground course and can no longer be seen at the surface. As an indication of this fact, the visitor may note the numerous streamless valleys in the park area. These valleys look exactly like any other steep-sided stream valleys except that none of them has a stream of permanently flowing water in it. When rain falls, the water passes rapidly underground through sinkholes and joints.

The observant visitor may notice, however, that there are several ponds formed on top of the Dripping Springs Escarpment, and he may wonder about their origin. Such ponds are formed locally where there is an impervious layer of shale capping the Big Clifty Sandstone, thus sealing off the underground seepage channels through which the rest of this area is drained.

Many underground streams are still at work today in this region, carving out innumerably more passages. Areas underlain by limestones having such features as sinkholes and disappearing streams are described as having karst[1] topography. This term was applied originally to a mountainous limestone belt along the eastern shore of the Adriatic Sea in Italy and Yugoslavia. Karst topography is extremely well developed in the area around Mammoth Cave.

Importance of Green River—One obvious exception to the underground drainage pattern of the local streams is Green River, which flows quietly along through the park in its winding course about 300 feet below the level of the hotel. Not far from the hotel, Echo River

[1] The term *karst* is derived from the Yugoslavian word *kras* meaning stone, which is the root for the Italian place name, Carso.

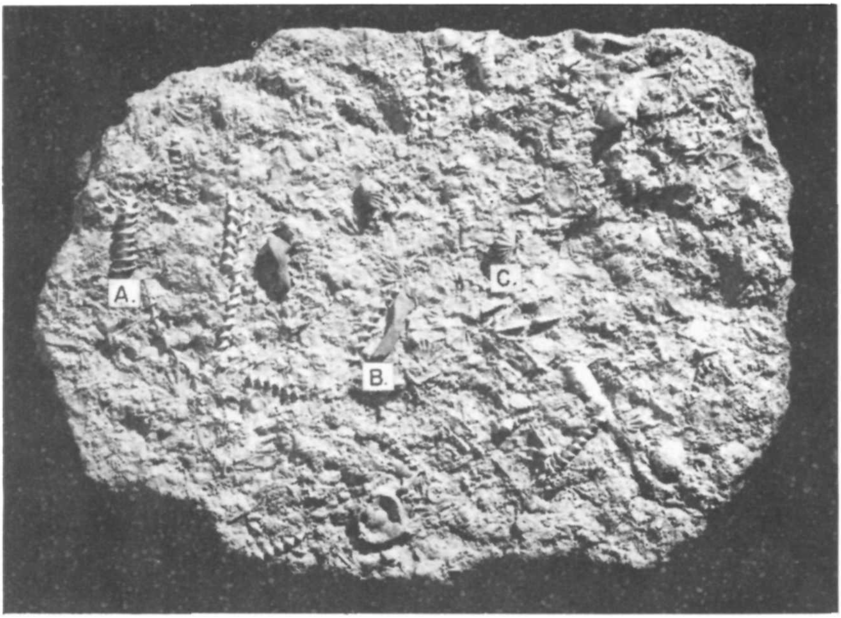


Fig. 1. The Glen Dean formation is one of the fossiliferous Mississippian limestones. It occurs above the limestone in which Mammoth Cave was formed, with other limestones and sandstones intervening. Remains of crinoids, brachiopods, and bryozoans indicate a marine environment while the limestone was forming. Fossils shown include: A. *Archimedes,* a bryozoan; B. fragment of crinoid; C. *Spiriferina,* a brachiopod.

Fig. 2. The cliff-forming Big Clifty Sandstone of the Mammoth Cave area is composed of firmly cemented sand grains. Withstanding erosion more effectively than the soluble limestones, it stands above the low limestone plain to cap the Dripping Springs escarpment (see Figure 3). Photo by W. Ray Scott, National Park Concessions, Inc.

PLATE 1

emerges from its underground course in the cave to join Green River. Echo River contributes to the water supply of the main stream, as do many other springs and underground streams in the limestone belt.

Green River certainly must have played a significant role in the development of the cave. Active circulation of underground water is essential to solution and cave-forming, and there must be some outlet again at the surface if there is to be active water movement. The valley of Green River and its tributaries supply this needed outlet, and it is in the vicinity of these valleys that the caves have been formed.

The cave-forming processes are fairly well limited (though not entirely) to the limestone above the level of the deepest valley. Stream valleys increase in size and as they become deeper the zone of cave development also extends deeper. The lower cave passages are the

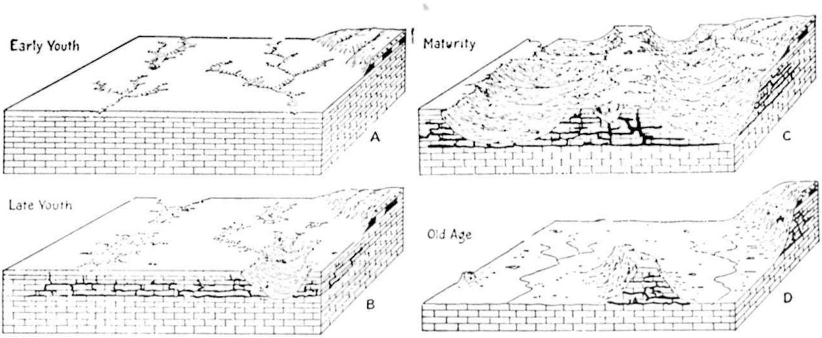


Fig. 4. The successive stages in the erosion cycle of a limestone area such as Mammoth Cave are shown above. Surface streams are diverted underground by way of sinkholes, and crevices are opened in the soluble limestone, thus giving rise to such streams as Sinking Creek and Lost River. (After Lobeck.)

youngest, and as they are progressively formed the upper levels become relatively dry as the water passes on down to the lower levels.

Another factor to be considered is the dip of the limestone beds. Moving water follows porous strata, bedding planes, and joints. In the first two cases, the water will be passing primarily down dip. Thus, water following such beds on the south side of Green River will have an outlet in the valley of Green River, but water on the north side moving down dip will reach the water table level and go down no further. Active water circulation is therefore fairly well restricted to the area south of the river. Since water moves downward along joints on both sides, there will be some cave passages on the north side too, but these will be limited in size and number.

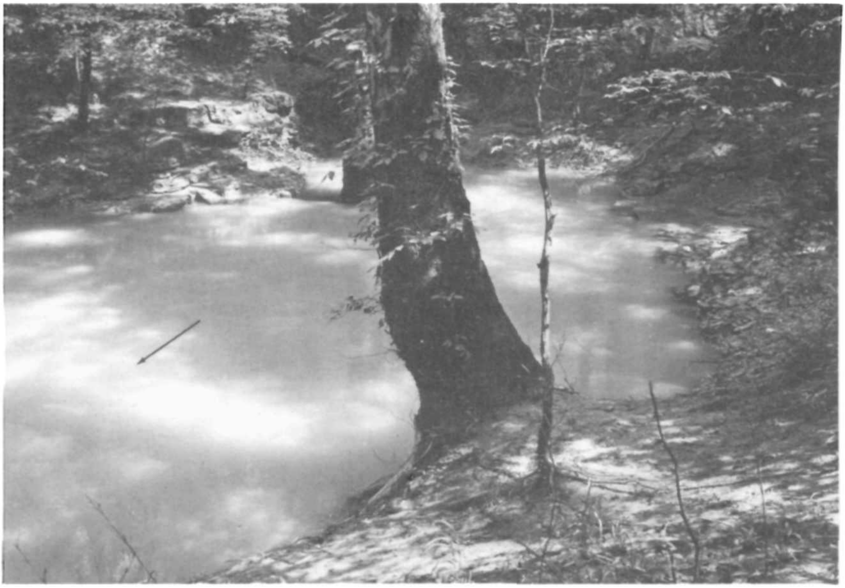


Fig. 1. Through this quiet spring the water of Echo River emerges to join Green River, thus furnishing the active water circulation necessary for the solution processes leading to the formation of the large cavern system. Photo by W. Ray Scott, National Park Concessions, Inc.

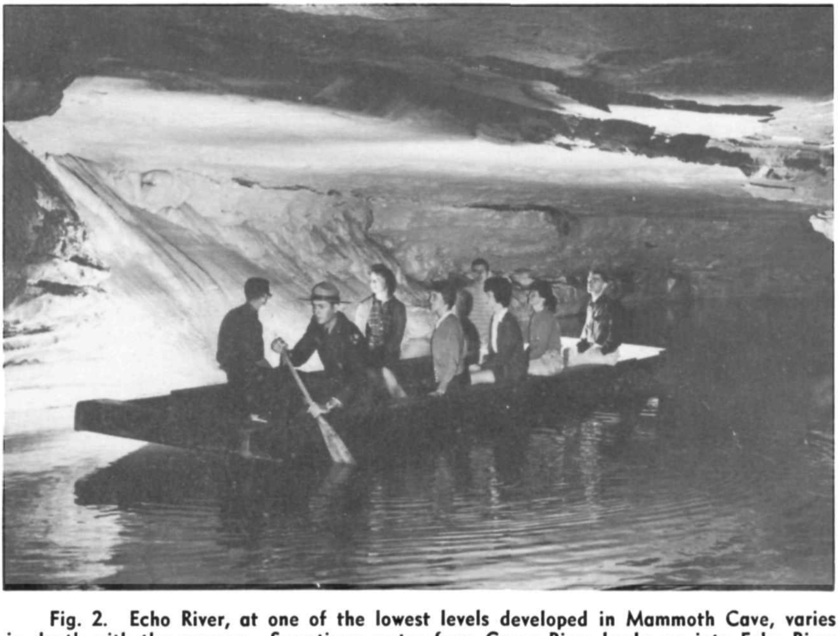


Fig. 2. Echo River, at one of the lowest levels developed in Mammoth Cave, varies in depth with the seasons. Sometimes water from Green River backs up into Echo River filling this channel entirely with water, leaving behind silt and sand. Photo by W. Ray Scott, National Park Concessions, Inc.

PLATE 2

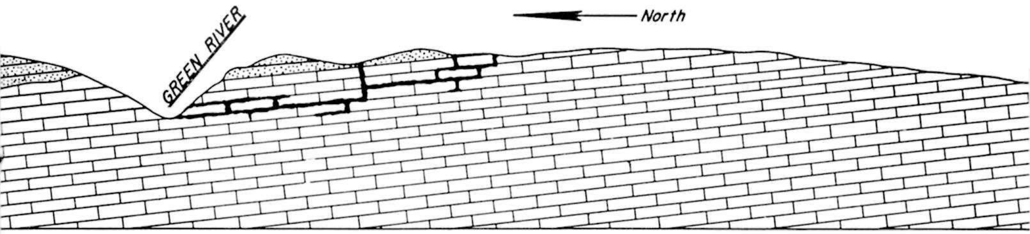


Fig. 5. An early stage in the cutting of the Green River Valley is shown above. Active water circulation in the dipping limestones is limited to the few upper layers on the up-dip side where the water can find an outlet into the Green River Valley lying below.

As lower outlets are made available through valley deepening, additional porous zones and bedding planes become available for active water circulation. It is primarily along such zones that the different cave levels are determined. With any upwarping of the earth's crust, valleys are cut still deeper and the development of solutional features is accelerated.

Thus, it can be seen that in the Mammoth Cave area, where thick layers of well-jointed limestones occur, solutional processes are favored by the presence of the deep Green and Nolin River valleys, situated so that they provide ample outlet for underground water drainage. In addition, these valleys aid in localization of cavern development by furnishing steep gradients for all nearby streams, surface or subsurface. As the slopes become steeper, more tributary streams along valleys in the well-jointed limestone are diverted to underground courses since water will take the easiest and quickest path downward to seek its lowest level.

Locally there is also the hard sandstone caprock which protects the underlying limestone from active destruction by weathering processes. This sandstone lies directly under the soil at the cave hotel and may be seen in several places as one goes down into the valley in which the Historic Entrance is located.

CAVE-FORMING PROCESSES

Solution—After the protective cover has been removed by erosion, water seeps into the limestone below, slowly enlarging openings in the joints, bedding planes, and porous beds through which it passes. A shale bed often forms a barrier to the downward movement, and water is forced to follow the rock layers down dip temporarily until an opening is found through the shale. The water moves slowly at first but as joints and other openings are slowly enlarged, a seepage becomes a trickle, and eventually the trickle becomes a stream.

Some of the limestone is oolitic; that is, made up of rounded grains, and pore space is considerable. The pore space in these oolitic layers provides a principal path of water movement. In the oil fields of western Kentucky these same oolitic limestones have a high porosity and carry both oil and water.

Abrasion—Cave forming starts with solution, but as the seepages become underground streams, erosion similar to that of surface streams occurs. The solution process continues indefinitely, but mechanical abrasion also helps as an erosion agent. Sand grains and gravel serve as cutting and grinding tools as they are carried along by the water, biting and gouging into the soft limestones. With this further enlargement of the passages, lack of support often causes roof collapse, adding still further to the size of the chambers and passages.

Differences of opinion exist concerning the relative importance of solution and normal stream erosion processes. Undoubtedly, solution is the early and continuing process, perhaps the major one. The relative amounts of solution and erosion have varied in different caves and even in different parts of the same cave from time to time. Again there are differences of opinion as to where the main cave-forming processes occur, above or below the water table. Below the water table all open spaces in rocks are normally filled with water. There can be little movement of the water very far below the water table, and processes operating here are mainly solutional. The solutional processes are limited because water which has seeped down to these lower levels has become largely saturated with mineral material. Above is the zone of actively moving water in which both solution and stream erosion are active. As lower and lower passages are opened, water is diverted down to them from the upper levels through enlarged joints.

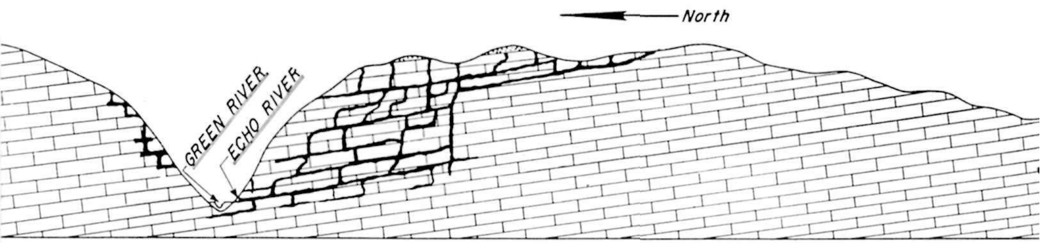


Fig. 6. A later stage in the deepening of the Green River Valley is shown. As more of the limestone layers were exposed, active water circulation went deeper and formed more intricate erosion patterns.

Fig. 1. View of portion of Cedar Sink, a large spectacular sinkhole in Mammoth Cave National Park which reveals a short section of an underground stream. The bottom of the sink is almost 300 feet below the sandstone-capped Mammoth Cave Plateau. Photo by W. Ray Scott, National Park Concessions, Inc.

Fig. 2. The entrance to Hidden River Cave, near Mammoth Cave, is in a sinkhole developed by solution, and aided by collapse of unsupported limestone layers. Photo courtesy of E. R. Pohl.

PLATE 3

The maze of passageways formed is intricate and different for every cavern system. In general those openings which follow bedding planes or porous beds are broad with low ceilings. Those passages whose development has been guided by joints are high and narrow. Intersection of joints may result in the formation of particularly high "domes" or deep "pits." If one looks up into such features, they are referred to as domes; if one peers down into them, they are called pits.

In describing the probable formation of these dome-pits, Bretz (1942) suggested that most of these features developed in the following manner: first, there are two bedding-plane water courses developed, one above the other; second, the upper bedding plane is segmented by water descending vertically to a lower surface along a previously unused joint plane. There follows a period of solutional enlargement along this joint plane, largely by water trickling down. Domes and pits are generally easily distinguished from other cave features by their great height and depth and by vertically grooved walls formed by the solutional activity of running water.

Passages referred to as the main cave "levels" are probably best thought of as controlled by different zones of very porous limestone. It is doubtful that such "levels" develop independently, and it is much more likely that several of the so-called levels had their beginnings simultaneously below the water table.

All irregularities and differences in the limestone played a part in determining the location of underground passageways and openings. What may seem to be a very twisting, winding maze of underground passages with no predictable course has a controlled pattern of formation. It is a pattern which has been formed by the movement of water through limestone, always seeking available openings and the easiest path downward to a lower level and finding some limestones more soluble than others. The long passageways of the cave follow the northwestward dip of the rocks toward the Western Coal Field.

With the forming of a cavern system, surface streams become almost non-existent, because the limestone is so riddled with solutional openings that nearly all the water falling on the land surface soon enters the underground system. Carried downward in the water are loose particles of sand, mud, and silt from overlying soil. Some passages have been filled entirely with such materials. Some of the soft clays and silts come from impurities in the limestone or from the shales. Backwater from floods on surface streams into the lower cave levels furnishes still another source of clay fill.

Deposition Begins—In the upper cave levels, vacated by the underground streams and now comparatively dry, there is little solution of

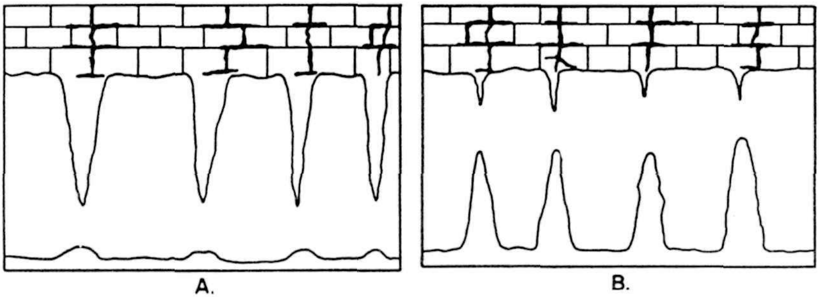


Fig. 7. Formation of stalactites and stalagmites.

A. With slow dripping, each drop of water remains on the stalactite for considerable time, and as evaporation takes place much of the carbonate is deposited. The stalagmite below thus receives little material.

B. With rapid dripping, no drop remains suspended long enough for evaporation to proceed, and the growth of the stalactite is slow. Most of the carbonate is received by the stalagmite below. If the dripping is too fast, water will pond or run off on the floor and no stalagmite is formed.

limestone except in those openings which carry water continually downward to lower levels. The slow process of deposition begins and eventually intricate patterns of dripstone and flowstone are developed.

Dripstone—It is virtually impossible to describe every form of the thousands of deposits in Mammoth Cave, but most of them are variations of three or four common types. The major number of forms are essentially dripstone patterns. Water seeping slowly down through cracks in the limestone of ceilings and walls evaporates when exposed to the air. In its downward journey the water has dissolved calcium carbonate from the limestone through which it has passed. The percolation of the water through the limestone beds causes a dripping or flowing action from the cave ceiling. When drops of water are suspended for some time from the ceiling, part of the limestone carried in solution is deposited to form an icicle-like, hollow tube or stalactite. Sometimes the drops of mineral water seep through the cave ceiling at a rate so rapid that most of the carbonate solution falls to the floor. Then a deposit may build up in the shape of an inverted cone called a stalagmite, each one having its "feeding" stalactite above. However, if the rate of dripping should be very rapid, the carbonate solution will generally result in ponds or terraces of mineral material along the floor rather than forming stalagmites. Gradually the opening in the center of a stalactite becomes choked with deposited limestone and then water trickles down the outside, and deposition of material causes an increase in the width and length of the stalactite (fig. 7A, 7B).

Growth Rates—Cave deposits are formed slowly, and no doubt some of them are thousands of years old. The rate of growth varies in different parts of the cave and in the same parts of the cave at different times. One estimate states that an "average" rate of growth for dripstone would be about a cubic inch in one hundred years. Evidence that dripstone growth rates vary from time to time is shown in the ringed appearance which these structures have in cross section. There are distinct concentric layers which resemble growth rings of trees. They mark interruptions in growth of the stalactite or stalagmite and do not represent seasonal growth as do the rings of trees. Cessation of dripping for one reason or another causes the surface of the deposit to dry out, and during this nongrowth period it becomes discolored brown by weathering (iron oxide forming from iron carbonate in the original deposit). Resumed deposition yields another clear layer of calcium carbonate. Because of the slow rate of growth of the cave formations and their fragility, visitors are not permitted to destroy the beauty of the cave by handling or breaking off any part of them.

When a stalactite and its corresponding stalagmite continue to grow for a long time, the two join together to form a pillar or column. If enough calcium carbonate continues to be furnished to the growing column, a huge, impressive size may be reached.

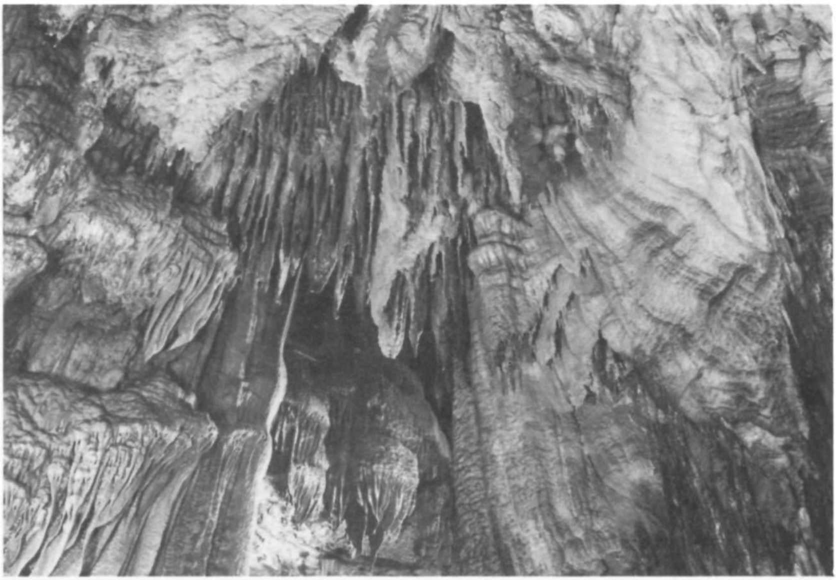


Fig. 8. Drapery Room. Photo by W. Ray Scott, National Park Concession, Inc.

Another variation of dripstone which sometimes forms is known as a drapery or sheet effect, often formed by a row of stalactites joining together as they grow downward from a crack in the limestone ceiling of the cave. Impurities such as iron present in the seepage water bring out a brownish or reddish stain on the surface of the formation during dry periods. When lighted from behind, these colored stains, due to the iron or other impurities present, produce weird and fantastic effects, as is demonstrated by the Breakfast Bacon seen in the Drapery Room.

Flowstone—Flowstone results from water flowing over instead of dripping from a rock surface. Some of the massive deposits seen in Mammoth Cave, which look like petrified waterfalls or some related feature, were formed in this way, by deposition from flowing water saturated with calcium carbonate. A thin sheet may become quite thick through continued deposition. As in dripstone a banded effect may be produced by intermittent periods of growth.

When water seepage is rapid, the water collects into small pools of standing water occupying any irregularity on the cave floor. Calcium carbonate is deposited around the rim, again as a result of evaporation. The longer the pool exists, the higher will be the limestone rim formed around its edges. Some of these built-up rims are as much as a foot high and may be circular, crescentic, or irregular in outline. When irregular with scalloped edges, these deposits have been called "lily pads." When they block the floor of a passageway, such deposits form dams.

Helectites—The helictite is one of the most interesting of cave deposits. Helictites begin their growth in much the same fashion as stalactites. But something seems to go haywire, and the stalactite starts to branch out at the free, downward-pointing end or even to curve upward, so that the whole deposit resembles a complex fish hook. Sometimes the small branchlets seem to sprout out from the sides of the midsection. Just why these helictites branch so peculiarly, growing outward and upward again, is difficult to explain. One suggestion has been that the helictites may be formed because the openings at the ends of the growing tubes are constricted, resulting in a slow outward squeezing of the calcium carbonate solution. Capillarity may be part of the answer. At any rate, though not common, helictites are found in the drier parts of a cave.

Gypsum—Gypsum furnishes an unusual group of cave deposits, occurring in a wide variety of beautiful forms. The mineral is calcium

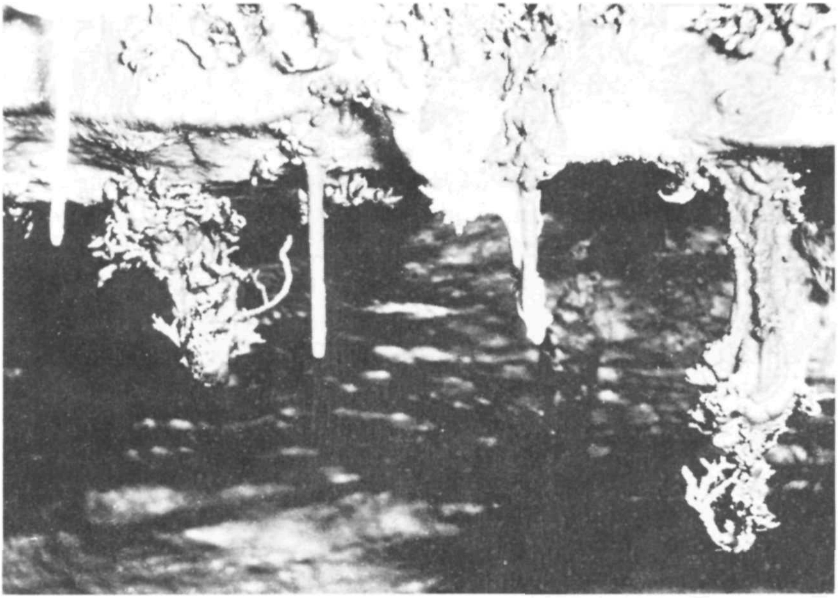


Fig. 1. Helictites, branching and curving weirdly, are calcium carbonate deposits which occasionally develop in drier parts of caves. The reason for their peculiar shapes is not completely understood. Photo by Caufield and Shook, Louisville, Ky.

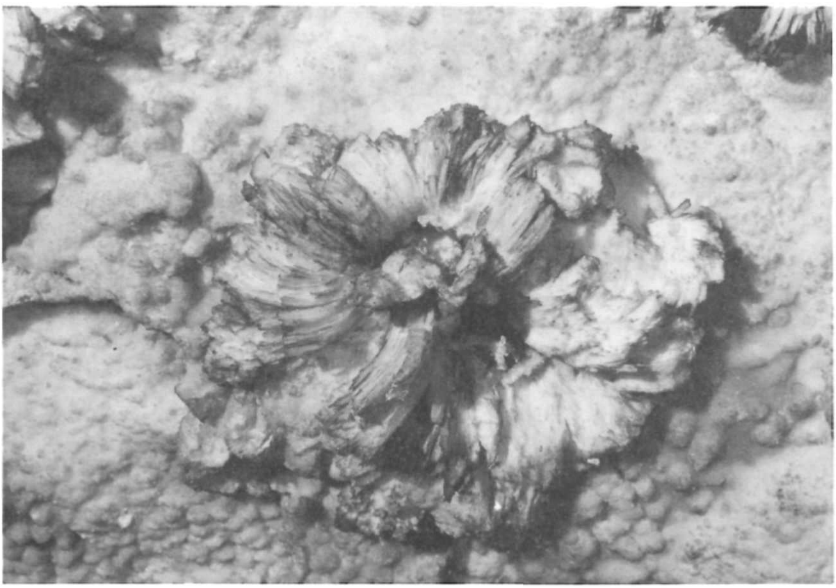


Fig. 2. Delicate gypsum rosettes are found only in the drier parts of caves, where slow evaporation of calcium sulfate through porous limestone causes the gypsum crystals to be forced outward into the cave. Blisters form, break, and result in "flowers." Photo by W. Ray Scott, National Park Concessions, Inc.

PLATE 4

sulfate plus water in contrast to the calcium carbonate of the dripstone. Generally the pure white appearance of the gypsum and the forms that it assumes will help the visitor to distinguish this unusual mineral from the dripstone.

The first cave known to contain gypsum was Mammoth Cave. Gypsum seems to be restricted to drier passages and is never found where dripstone is forming. Sometimes after gypsum deposits have been formed, the passages again become moist. The gypsum is then dissolved rapidly and disappears. However, although gypsum will not tolerate much water, it is itself a water-laid deposit, but only where there is slow seepage through limestone. Apparently the more porous limestone layers, usually oolitic, have been more favorable for the formation of gypsum, because the solution containing the dissolved calcium sulfate evaporates in the open pores of the limestone near the surface and forms a coating of mineral matter. Crystals are forced outward by the continued deposition of more gypsum in the pore spaces behind the original crystals. This process is much like the growth of ice crystals from a wet soil during the winter, for such crystals grow and curve in a similar manner. In this way gypsum commonly forms a "crust" over an entire cave ceiling or wall. Some layers form "blisters" when the gypsum is pushed outward, because of local, unequal crystal growth rates. With continued growth these blisters or ball-like protuberances burst and open into flower-like forms.

A possible source of the calcium sulfate is a question that requires more study, for there are no known beds of gypsum above to provide the material. Disseminated gypsum is not known in the limestone. Marcasite (an iron sulfide mineral related to pyrite or "fool's gold") oxidizes to form sulfuric acid which in turn will react with limestone to form gypsum. This may provide an answer to the problem, since marcasite does occur above the cave limestones, particularly in an impure coal and dark shale which often occur in the Big Clifty Sandstone. Pohl (1935) has suggested that the marcasite source is a zone within the lower Golconda (Chester) formation. The gypsum source must be local, for gypsum deposits are not known in many of the caves in the Mississippian limestones of Kentucky and adjoining states.

Some of the most extensive and delicate gypsum formations are found in the New Discovery section of Mammoth Cave which has not yet been opened to visitors. Here one finds entire passages whose walls and ceilings are covered with an amazing variety of gypsum "flowers," many long, slender needles, and fine masses of filmy gypsum so light in weight that the slightest whisper of the visitor is enough to make them sway back and forth. This is an underground wonderland which the park service hopes to open to visitors at some time in the future.

FEATURES OF THE CAVE TRIPS

The discussion of cave-forming processes and surface features of the Mammoth Cave area presented above has been given in order to provide a background for the description of the specific features seen on guided trips into the cave. Features seen and routes followed on these trips will vary from time to time, but those described here are the outstanding ones now being shown.

The Echo River Trip—For those who cannot stay long enough to take an all-day trip, shorter trips showing smaller portions of the cave are offered. One of these shorter trips is the Echo River Trip which starts through the Historic Entrance and takes about three hours. On the path leading to the cave entrance, the observant visitor will note that he walks down into a steep valley which has cut through the Big Clifty Sandstone into the cave-forming limestone below. In one side of this valley is the Historic Entrance, formed by solution eating into the limestone layers along the side of the valley and aided by collapse of thin, unsupported layers of limestone.

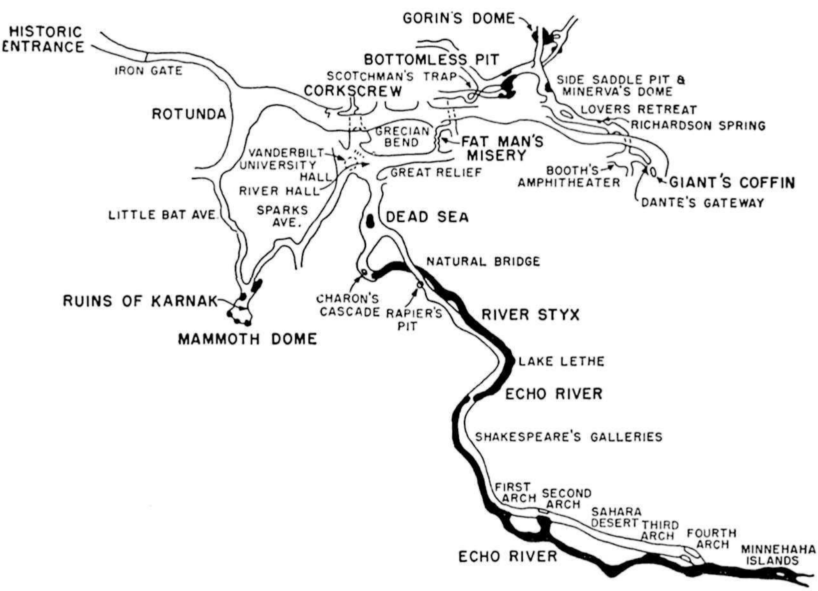


Fig. 9. Route map of Echo River Trip.

Fig. 1. The Ruins of Karnak furnish spectacular evidence of the sculpturing action of water trickling down cave walls, enlarging cracks, leaving these tremendous limestone columns. Photo by W. Ray Scott, National Park Concessions, Inc.

Fig. 2. Bottomless Pit, 105 feet deep, a fine example demonstrating the power of water to dissolve limestone along vertical cracks or joints leading downward from one cave level to another. Photo by J. Wellington Young, National Park Concessions, Inc.

PLATE 5

On this trip essentially the same features are seen as on the All-Day Trip, at least down as far as Echo River. One of these features is the Bottomless Pit, situated just beyond the rockfall known as Giant's Coffin. This pit has a depth of about 105 feet. Directly above the pit is a dome-shaped circular "well" some 63 feet high. These pits and domes are developed at many points throughout the cave and are formed along vertical joints which tap some large water source lying above them. In many cases water drips or flows down through the pits and domes from higher levels or from the ground surface above. Sometimes waterfalls of this sort produce deep gouges in the walls through both solution and abrasion. Occasionally there are surface sinkholes directly above the domes.

After reaching Echo River and taking a boat ride on this underground stream, the visitor on this short trip is conducted out of the cave by way of Mammoth Dome and the Ruins of Karnak, a remarkable example of huge columns formed by continued sculpturing of limestone by water seeping down the walls, slowly carving out reentrants in the soluble rock.

The return route takes the party up a flight of stairs in the Mammoth Dome itself to a higher level at Little Bat Avenue and thence through Audubon Avenue, back to the Rotunda and the Historic Entrance. Mammoth Dome rises to a height of 192 feet within the cave.

The Frozen Niagara Trip—The relatively short, one and one-half hour trip, called the Frozen Niagara Trip, has retained its long-standing popularity through the years. An amazing variety of salactites, stalagmites, columns, and flowstone formations are observed during the course of this trip. A bus brings the visitor down along the road directly into the sinkhole which is responsible for the New Entrance to the cave. If one pauses here at the entrance and looks up he gets a fine view of the Big Clifty Sandstone capping the soluble limestone in which this sinkhole is formed.

Entering the cave, the visitor first sees a number of pits and domes formed by water running down from the surface along joints in the limestone. After a heavy rain, water drips or flows through most of them, passing on down to lower levels. Some, like Roosevelt's Dome and Wilson's Dome, are, on an average, 130 feet high, and the visitor can look down into Silo Pit and other deep holes, averaging 160 feet deep. These are fine examples of the solutional power of running water in limestone.

The party proceeds along one of the five passageways leading into Grand Central Station. Nearby is the "Big Break," where collapse of a tremendous quantity of rock from the cave ceiling has littered the floor with rocks of all sizes. The broad, unsupported section of ceiling formed along the base of a single limestone layer seen farther on

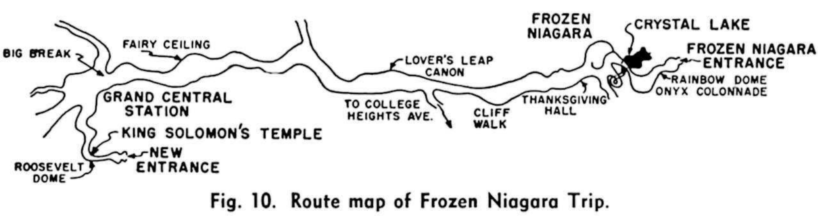


Fig. 10. Route map of Frozen Niagara Trip.

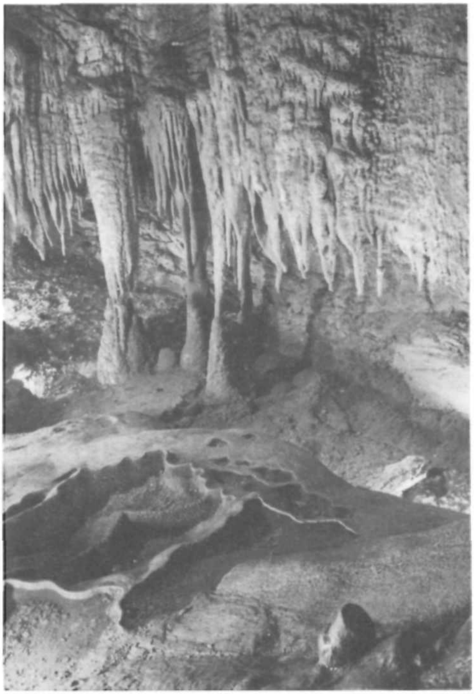


Fig. 1. Stalactities, stalagmites, and rimstone dams in Mammoth Cave. The small rimstone dams or terraces in the lower part of the picture have developed where flowing water is slightly agitated or riffled by an irregular bottom surface. Photo by W. Ray Scott, National Park Concessions, Inc.

Fig. 2. Boone Avenue furnishes a good example of the narrow, steep walled type of cave passage formed by solution along a vertical joint in the soluble limestone. Photo by W. Ray Scott, National Park Concessions, Inc.

PLATE 6

has been variously called the "Plastered Ceiling," "Smooth Ceiling," or "Fairy Ceiling." Blocks from this ceiling will come down sooner or later.[1]

The visitor then views Frozen Niagara, the largest single travertine deposit of the cave. This impressive flowstone feature, a large mass 75 feet high and 45 feet wide, was formed through centuries of slow deposition of limestone from water flowing and dripping down into this portion of the cave over blocks of fallen wall and ceiling rock. A

[1] The collapse of rocks from the ceilings of cave passages is a very slow process, and no visitor to Mammoth Cave has ever been injured by such a rockfall.

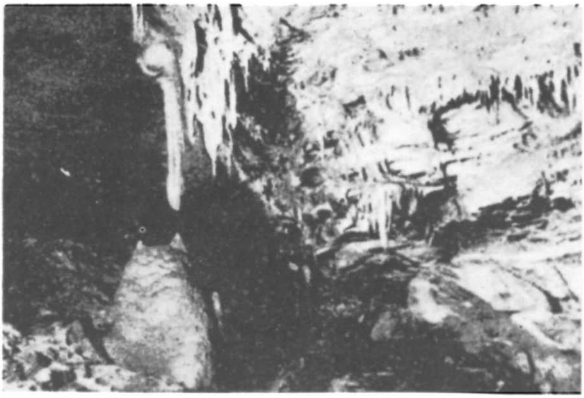


Fig. 11. The Cat, an odd shaped stalagmite in Colossal Cave.

stairway directly in front of Frozen Niagara leads down into the Drapery Room, so named because of the curtains or draperies formed by rows of stalactites growing together and by flowstone deposits of limestone over the surfaces of fallen rocks. Attractive dripstone formations may be seen in all directions. One person's attention may be caught by a stalagmite resembling a cactus; someone else may see an owl, a turtle, or a cat among the dripstone oddities. Interruptions and variations in the rates of dripping have contributed to the individuality of these formations. The guide may show the group a "strip of bacon" by placing a light behind a thin limestone deposit containing brownish streaks of iron, formed by oxidation during periods of nongrowth. One beautiful flowstone deposit in the Drapery Room is the Golden Fleece. Diffused by a lovely golden hue, it derives its color from the oxidation of iron minerals exposed to the air. Someone acquainted with Greek mythology no doubt named the formation for its resemblance to the famous golden ram's fleece in the story of Jason.

Further inside the cave and 60 feet below the observation point of the visitor lies the lovely green water of Crystal Lake, a small pool formed by the damming up of a stream behind a stalagmite that grew across the narrow passage here. On the water's edge is a stalagmite that resembles a bathing beauty when a light is turned on behind it. By varying the lighting effects, the bather, who is poetically called September Morn, can be made to change her costume.

Next the group enters a small passage called the Onyx Colonnade where there is a bewildering variety of columns, stalactites, and stalagmites. Many of these deposits have been given imaginary names, such as Wedding Cake, a stalagmite that has the layered appearance

Fig. 1. Along Onyx Colonade are seen examples of stalactites and stalagmites growing together to form columns. Stalactites are also present here in rows, the solution forming them having come down along cracks in the ceiling. Photo by W. Ray Scott, National Park Concessions, Inc.

Fig. 2. Crystal Lake probably owes its existence to some impervious rock layer lying beneath its surface, which prevented water dripping down constantly from above to continue on down to a lower level. From the lake one looks upward into Moonlight Dome, formed by the enlargement of a joint in soluble limestone. Photo by W. Ray Scott, National Park Concessions, Inc.

PLATE 7

of a cake, and Lion's Cage, a section composed of rows of columns that look like the bars of a lion's cage. Each column was formed by a stalactite from above and a stalagmite from below joining. A few helectites are also present here.

In the Onyx Chamber again there is a wide variety of dripstone and flowstone deposits, many of them tinted in a variety of reds, purples, and yellows. The colors are due to the oxidation of minerals such as iron and manganese during interruptions in the growth of the formations. Located on one side of the Onyx Chamber is Rainbow

Dome, a small dome 45 feet high, displaying many of the color effects noted above. One side of this dome is covered by a deposit of flowstone, Stage Curtain, showing the delicate folds of a thin theater curtain. Onyx Chamber itself contains one section of innumerable thin, fragile stalactites known appropriately as the Macaroni Factory. These slender hollow tubes are good examples of the early stages of stalactite growth. Their wet, shining surfaces show that they are still growing and their small size indicates rapid dripping. Rather than forming large stalagmites below, most of the water here flows off depositing calcium carbonate to form dams along the cave floor. Examples of terraces and dams built up around the edges of standing pools of water are numerous here. One particularly interesting long travertine dam has been called the Great Wall of China.

The Historic Trip—For those particularly interested in history, there is a special trip of about one and one-half hours duration to inspect features of historical significance. In the Historic Trip, the cave is entered through the Historic Entrance, and the group passes first into the Rotunda. There is ample time for close inspection of the saltpeter mining that made Mammoth Cave famous during the War of 1812, for the mining operations inside the cave furnished some four hundred thousand pounds of nitrates critically needed in making gunpowder. Many visitors ask about the origin of the saltpeter. Some authorities believe that it was derived from bat guano; others, though, prefer an origin from bacteria or other source in the dry cave earth.

Going down Broadway the visitor soon comes to Booth's Amphitheater, a large room formed in the soluble limestone and named for Edwin C. Booth, the famous Shakespearean actor. Booth visited the cave in 1876 and in this chamber he climbed up on a large ledge of rock and recited famous lines from Shakespeare from the natural stage.

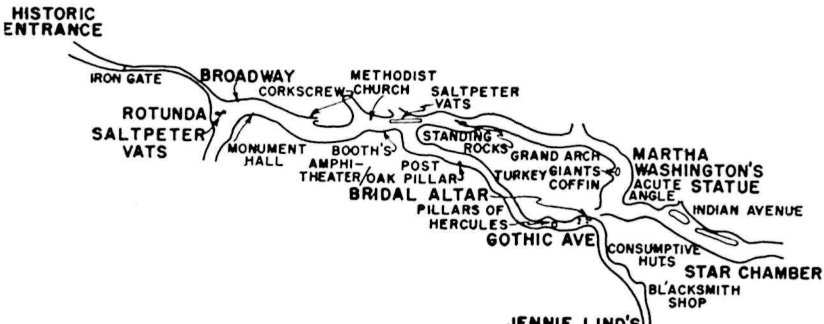


Fig. 12. Route map of Historic Trip.

Fig. 13. Portion of the saltpeter mining operations which was carried on in Mammoth Cave during the War of 1812. Vats were used in the leaching of nitrates from the dry cave earth. These and other features of the operation may be seen on the Historic Trip. Photo by W. Ray Scott, National Park Concessions, Inc.

As a party of visitors proceeds along the winding passage, the guide tells them to stop and look back. Silhouetted against the wall in the background is a perfectly outlined figure, Martha Washington's Statue. It is really a section of cave wall hidden from view by the dark curving walls in between, except for one small opening which, when backlighted, gives the effect of a statue in outline. This is much like looking through a keyhole into a lighted room.

Star Chamber is another feature of interest. In the subdued light of this part of the cave, the name seems very appropriate. As the guide turns up the light, the visitor can see white gypsum crystals standing out as "stars" against the background of a ceiling stained dark black by the manganese and iron oxides deposited there by water. The new growths of gypsum, pushing outward into the cave, have broken off the dark coating in places and have revealed the white star-like growths.

Of considerable anthropological interest is the famous mummy of an Indian, who has been named Lost John, found in the cave. Items

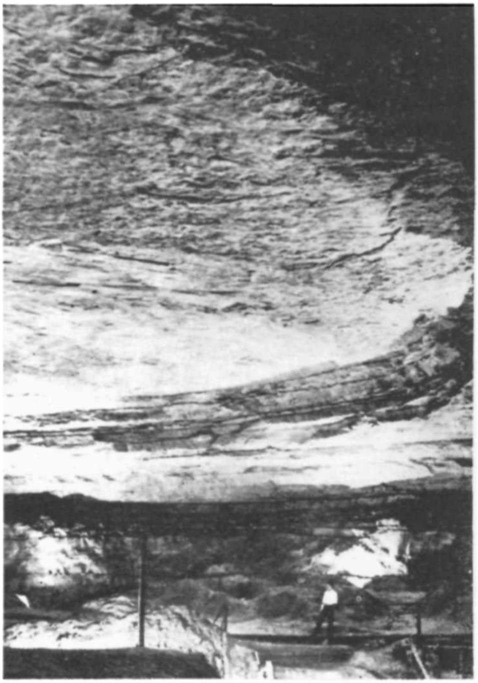


Fig. 1. The Rotunda is a huge chamber 139 feet wide and 40 feet high, developed by collapse of large amounts of thinly bedded limestone from the ceiling over a long period of years. Photo by W. Ray Scott, National Park Concessions, Inc.

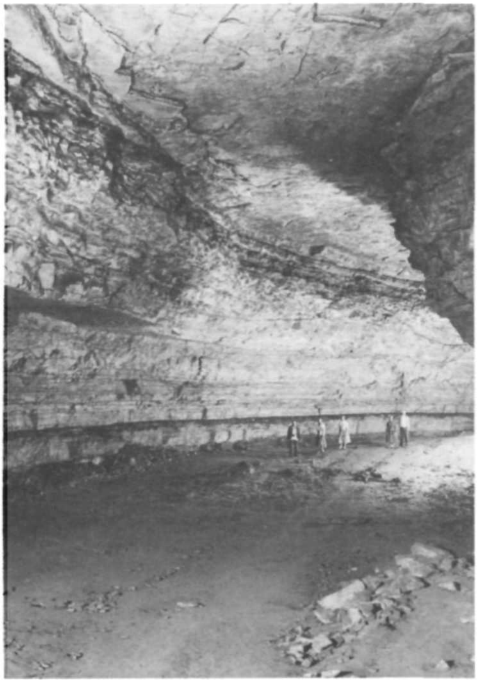


Fig. 2. Audubon Avenue, one of the large flat-ceiling passage ways that is so typical of Mammoth Cave. The cave is developed in an almost uninterrupted limestone sequence representing Ste. Genevieve and Lower Chester ages. Photo by W. Ray Scott, National Park Concessions, Inc.

PLATE 8

associated with the mummy have been carbon-dated to 2300-2400 years ago. Evidence of human occupation of Mammoth Cave is limited to the upper passages. This particular Indian, whose remains were found in 1935, apparently met an accidental death while collecting gypsum along a nearby ledge. He loosened rocks along the ledge and was crushed to death when a huge block weighing about five tons gave way. The mummy has been well preserved in the dry atmosphere of this part of the cave, which is not conducive to bacterial decay. The mummy is that of a man about 45 years old and five feet three inches tall.

Evidence may be seen along Broadway of an experiment that was attempted in Mammoth Cave in 1842 and 1843, when little was known about tuberculosis. It was believed that the constant temperature of 54 degrees and the humidity of the air might benefit those suffering from tuberculosis. Thus, 12 huts were constructed along Broadway to house the fifteen or so persons suffering from this disease. They were brought into the cave and remained for several months without coming out. During the course of the experiment, all patients became worse, and at least two of them died.

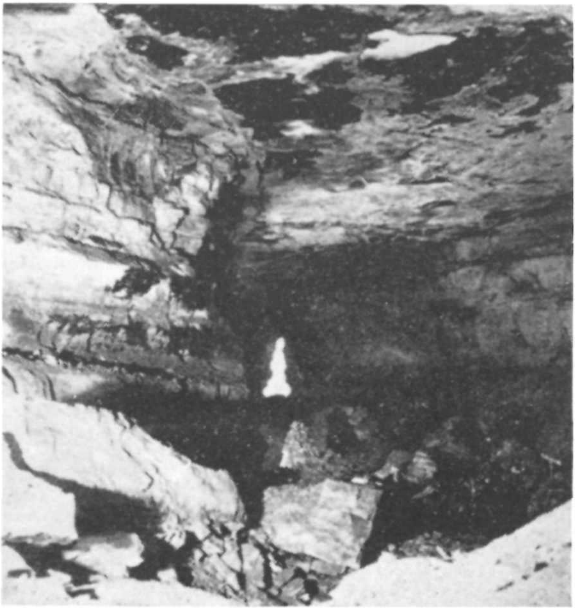


Fig. 14. Martha Washington's Statue, a silhouette formed by cave walls.

The All-Day Cave Trip—The most interesting journey through the cave, for those who have the time, is the one featured as the All-Day Trip. In seven hours the visitor sees the greatest possible variety of underground features. Starting at the Historic Entrance, this trip takes the visitor down slope past the wooden leaching vats and pipes used in the manufacture of saltpeter. The visitor then enters a large chamber known as the Rotunda. This tremendous rounded room, although referred to as a "dome" has not been developed by the solution processes commonly associated with dome-pit formation. The Rotunda was formed instead by the collapse of large amounts of thinly layered lime-

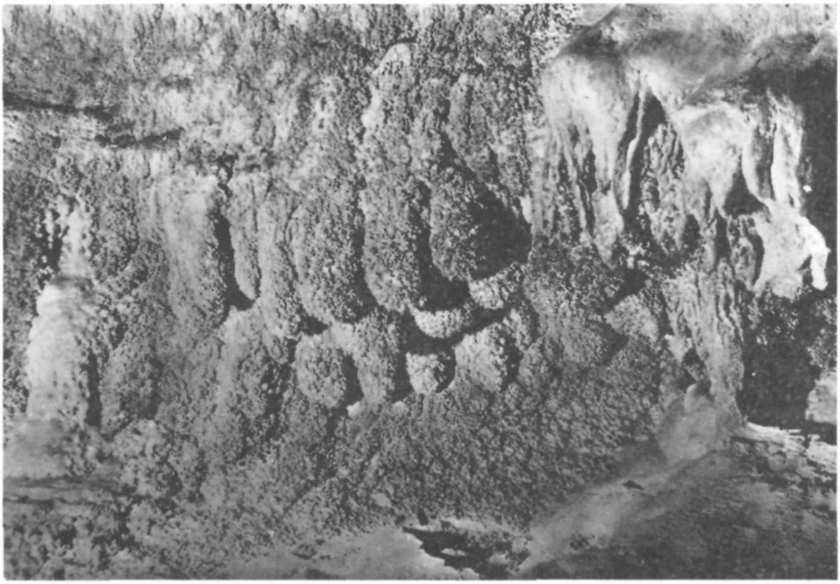


Fig. 1. Spongy growths of calcium carbonate like this along Coral Avenue in Mammoth Onyx Cave are due to the carbonate deposition from solution seeping through the porous limestone. Photo courtesy of E. R. Pohl.

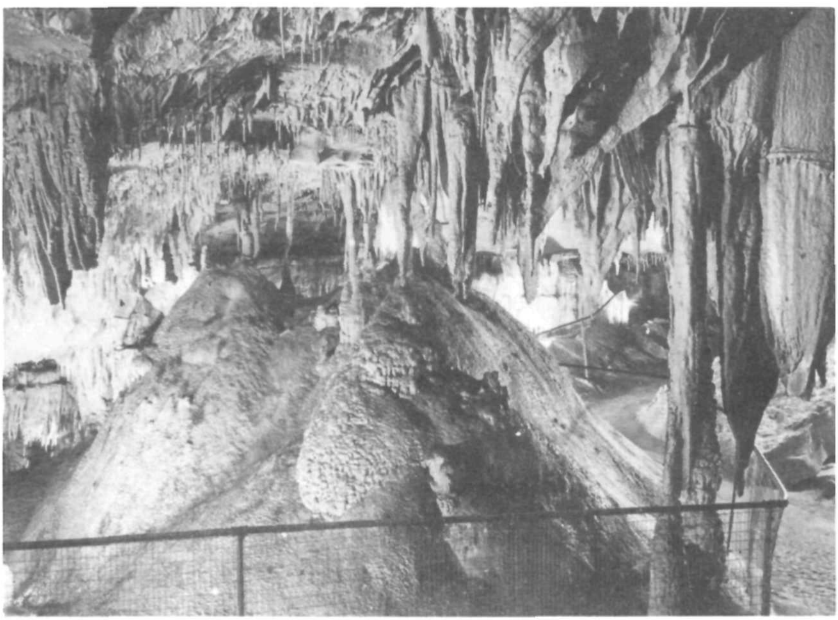


Fig. 2. St. Peter's Dome, in Onyx Chamber of Mammoth Cave, shows a profusion of dripstone features. Rapid dripping results in small stalactites and large stalagmites below. Photo by W. Ray Scott, National Park Concessions, Inc.

PLATE 9

stone over a long period of time, resulting finally in this huge chamber which is 139 feet wide and 40 feet high. It is the largest structure of this sort in the cave.

Broadway is a long, high-level corridor, about three miles in length and on an average of 40 feet high and 60 feet wide. Only a short portion of this extensive passage is shown on the present cave trips. It is a remarkable example of a broad cave passage developed originally along a porous limestone layer. Here Martha Washington's Statue and Giant's Coffin are seen.

Giant's Coffin is a huge block of fallen limestone lying on the cave floor. It is 50 feet long, 20 feet wide, and 16 feet high with the edges rounded by solution. This block has been estimated to weigh 2,000 tons. Many cave passages, particularly those with broad, flat ceilings, have been enlarged partly by the fall of rocks such as this. Cave enlargement by collapse or sapping is a common phenomenon and a natural consequence of the enlargement of passages with broad unsupported ceilings. Blocks are loosened by solution along the bedding planes and joints. Earthquake tremors may serve to bring down these

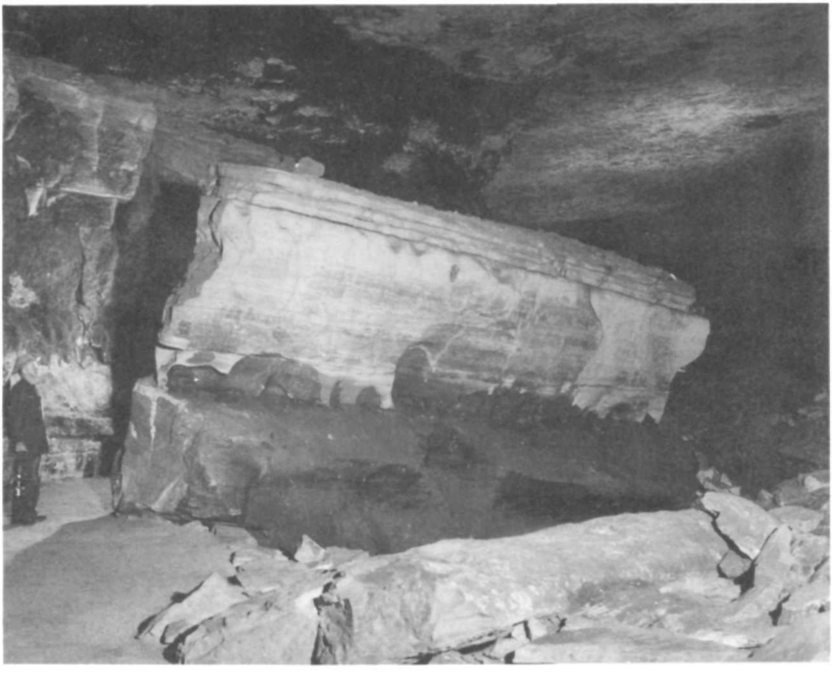


Fig. 15. Giant's Coffin, a large block of limestone estimated to weigh 2,000 tons. Photo by W. Ray Scott, National Park Concessions, Inc.

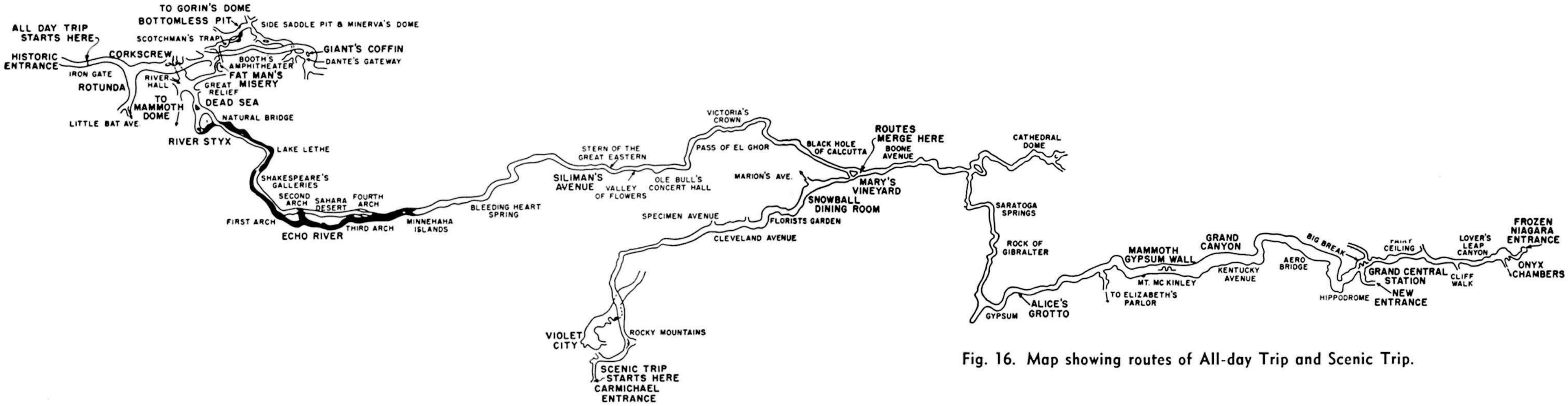


Fig. 16. Map showing routes of All-day Trip and Scenic Trip.

blocks earlier than otherwise, but the fall would normally occur, anyway. Therefore, fallen blocks of limestone within the cave do not in themselves constitute evidence of earthquake shock. As previously stated, no visitor in this cave has ever been injured by such a rockfall. Beyond Giant's Coffin visitors follow lower passages.

Fat Man's Misery is a narrow winding passage which derives its name from the stooped and cramped position one must assume while passing through it. This extremely narrow channel was formed by a cave stream cutting down through a narrow joint in the limestone. Someone was so glad to get through this passage that he named the large chamber beyond Great Relief Hall.

Lower in the cave signs of water still at work can be seen. First, one comes to Dead Sea, an isolated pool of water which has an underground connection with Echo River to keep the pool supplied with water. The River Styx, another part of the Echo River system, is sometimes isolated but at times connected with Echo River, when water level in Green River is high and backs up into the cave. Most famous of the underground water is Echo River itself, several miles long and forming at present the main underground stream of the cave. Hydrologic studies suggest that Green River at high stages usually does not flow into the cave at Echo River but rather prevents Echo River from flowing out, thus ponding water underground and preventing visitors from entering lower parts of the cave.

By means of a short boat ride across the river, famous for its blind fish, the visitor reaches another of the main solutional channels, Silliman's Avenue. Here for the first time, the group sees some of the famous gypsum "flowers" in this dry part of the cave. Farther on in this same passage is another of the large "rooms" formed by the solution of limestone along cross-cutting fissures. Since the great Norwegian violinist, Ole Bull, gave a concert here in 1851, this chamber has been dubbed Ole Bull's Concert Hall. The end of Silliman's Avenue is marked by Mary's Vineyard, an interesting display of grapelike formations in the limestone deposits on the cave ceiling. These clusters are formed when drops of water carrying calcium carbonate are suspended for considerable time on the ceiling, allowing most of the solution to harden there.

A sharp turn to the right brings the visitor to a most welcome sight, Snowball Room. Here the group stops for lunch in surroundings which are not duplicated in any other dining room. "Snowballs" which cover the ceilings are gypsum "blisters" formed as the mineral is pushed outward into the cave by more gypsum forming behind.

After lunch the party proceeds to the narrow, steep-walled Boone's Avenue, a good example of one of the cave passages formed by water working its way down along a joint. Through the winding channels, past most fantastic gypsum crystals and needles in Kentucky Avenue, the party reaches Grand Central Station where five passages converge. Such a spot is formed by solution along intersection joints in the limestone plus stream erosion to widen and deepen the original channels. From this point on, the group comes into the upper cave levels which contain a fascinating variety of dripstone and flowstone. These deposits always bring forth exclamation of delight from all. This is the part of the cave where replenishment and growth of formations is best developed. Frozen Niagara, Drapery Room, and Onyx Colonnade make a fitting climax for this longest trip in Mammoth Cave. (For description of the last mentioned features, see Frozen Niagara Trip.)

The Scenic Trip—Visitors have expressed much interest in a trip which is shorter than the All-Day Trip but still provides an opportunity to lunch in Snowball Room. In order to answer this need, the

Fig. 17. Snowball Room in Mammoth Cave. The "snowballs" were formed by layers of gypsum forced outward by the crystallization of gypsum in a porous limestone beneath. As growth continues such blisters often break open to form "flowers" (see Plate 4, Fig. 2). Gypsum is restricted to the drier parts of the cave. Lunch is served in this room for visitors on the All-day Trip and the Scenic Trip. It is 267 feet below the surface of the ground. Photo by Ray Scott, National Park Concessions, Inc.

park service has set up a four and one-half hour trip appropriately called the Scenic Trip. Entrance is made through one of the man-made openings, Carmichael Entrance. Suitable points for these man-made openings were located by study of the geological conditions both on the surface and in the cave, and by making corings and soundings in order to determine those spots nearest the surface.

A short way inside the entrance a rockfall known as Rocky Mountains is seen. This is again evidence that the cave passages have been partially enlarged through the process of collapse and sapping. Soon the group sees the first of the wide variety of gypsum "flowers" developed so well in the dry part of the cave along Cleveland Avenue and some of the shorter passages leading from it. In Specimen Avenue and Florist's Garden are gypsum formations resembling roses, sunflowers, and other plants. Snowball Room is observed shortly thereafter, with its famous gypsum blisters resembling snowballs. Here the group pauses for lunch before proceeding down Boone's Avenue. From Snowball Room on, this Scenic Trip route merges with that of the All-Day Trip and the same features are seen.

Brief mention might be made of certain features which will be seen and which have not been previously described in the All-Day Trip. Such features would include two more rockfalls, one of which is called Mt. McKinley. Another is Grand Canyon, where the floor of one passage dropped down through the ceiling of another, thus producing a deep canyon. Proceeding onward, the group comes to Aero Bridge Canyon, so named because there used to be a cable car operating here to carry visitors from one side of this passage to the other.

Beyond Grand Central Station, past another rockfall known as Big Break, the visitors see the long broad expanse of Smooth Ceiling. Here one also observes the rock called Compass Needle, so named because numerous tests with a compass show this rock, which is shaped like a finger, points directly north. Farther on, the group passes Lover's Leap Canyon. No one has ever leaped into the canyon formed here, but a large number of fallen blocks of rock are visible in the canyon. From here the visitor ascends to the upper levels of the cave where dripstone and flowstone formations are so well developed.

Emerging from the cave into the outer air and light, the visitor may be startled by the sudden change in landscape and scenery, but he will never forget entirely the impressions of the cave trips he may have chosen through these "caverns measureless to man."

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