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THE GEOLOGY AND PHYSIOGRAPHY
OF THE MAMMOTH CAVE
NATIONAL PARK

By

ARMIN KOHL LOBECK

Assistant Geologist

Associate Professor of Physiography and Geography
at the University of Wisconsin



Illustrated with 39 Photographs, Maps, and Diagrams

Preface



Public opinion long ago recognized the Mammoth Cave as one of the principal features of geological interest not only in Kentucky but in the entire Ohio Valley. As the years have passed countless thousands from all parts of the world have found their way to and through this great cavernous region. Strange as it may seem, though individual effort has done much to popularize the Mammoth Cave and the many other adjacent caverns, official action in this direction until recently has been all but lacking.

With the movement now essentially completed to establish a National Park in this picturesque and delightful region, it has seemed expedient to prepare a popular treatment—a geological and physiographic guide book, so to speak—that might in a readable manner acquaint the traveler with the outstanding surface and subterranean geological features of this district.

In this little booklet Dr. Lobeck, one of the really able physiographers of the United States, has presented an exposition of this character which is outstanding in its illustrations, inked drawings, all from the author's pen, and typical photographs from his camera. In all the extensive literature descriptive of the Mammoth Cave area there is nothing like this—nothing so readable, so scientific, so fine.

July 18, 1928,
Old Capitol Bldg.,
Frankfort, Kentucky

A handwritten signature in dark ink, reading "W. R. Gillman". The script is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

State Geologist

(Reprint of Pamphlet XXI., 1928.)

Illustrations



Fig.	Page
1. Physiographic diagram of Kentucky with geological cross-section	332
2. The Pennyroyal plateau near Cave City	333
3. Train on Mammoth Cave Railroad at Glasgow Junction.....	334
4. General view of Mammoth Cave National Park area.....	335
5. Landscape sketch of Green River gorge, below Mammoth Cave	336
5a. Entrance to Sand Cave	337
6. Landscape sketch of Deer Park, a valley sink	338
7. Typical cultivated upland surface, near cave.....	340
8. Pond on surface of the plateau over Mammoth Cave.....	340
9. Pond occupying a minor depression in one of the valley sinks..	341
10. Sink hole with a pond in valley sink area near New Entrance Cave	342
11. A typical valley sink	344
12. A chain of sinks	344
13. Landscape sketch of upland north of Green River.....	346
14. Landscape sketch of typical gorge in northernmost part of the park area	348
15. Block diagrams showing two stages in the development of the Mammoth Cave region	350
16. Log building used for storing corn and sheltering live stock....	352
17. An old homestead	352
18. Four stages in the normal life cycle of a plateau.....	354
19. Dismal rock on Nolin River	356
20. Four stages in the life cycle of a plateau having underground drainage	358
21. Small sink hole with swallow hole at the bottom.....	360
22. Entrance to Mammoth Cave	362
23. Entrance to Great Salts Cave	363
24. The Mammoth Cave region in detail	364
25. Geological conditions at Sand Cave	368
26. Diagram showing bedding planes and joints	372
27. Four stages in the development of the Mammoth Cave region	374
28. Cave deposits	378
29. Stalactites covered with helectites	379
30. Drapery Dome in Great Onyx Cave	382
31. Vaughn's Dome in Colossal Cavern.....	384
32. Gypsum crystals in Great Crystal Cave	386
33. Examples of cave life	387
34. Diagram of Mammoth Cave	388
35. Terrace columns, Great Onyx Cave	392
36. Railroad ties ready for shipment by boat on Green River.....	394
37. Diagram showing various sources of water supply.....	395
38. An old cemetery in one of the valley sinks.....	399

Contents



	Page
Preface	328
Illustrations	329
Contents	330
Introduction	331
The Mammoth Cave National Park Region	339
Geological Structure of Mammoth Cave National Park Region.....	345
Physiography of Mammoth Cave National Park Region.....	353
The Caves and their Deposits	371
Description of Mammoth Cave	389
Notes on the Human Geography of the Mammoth Cave Region.....	393
Notes on Reading Material	397

THE GEOLOGY AND PHYSIOGRAPHY OF MAMMOTH CAVE NATIONAL PARK

By A. K. LOBECK

INTRODUCTION

Most visitors to the Mammoth Cave National Park region will reach it either by the Dixie Highway or by the main line of the Louisville and Nashville Railroad. Those coming from the north will pass through Louisville; those from the south will go through Nashville. The cave region is about midway between these two cities, approximately one hundred miles from each.

Figure 1 shows in a pictorial manner the chief physical features of the state of Kentucky. The motorist bound southward on the Dixie Highway after leaving Louisville rides for twenty miles or so within sight of the Ohio River and then turning up the valley of the Salt River soon enters the "Knobs" region. These Knobs are simply outliers or remnants of Muldraugh's Escarpment, the margin of the Mississippian Plateau. Muldraugh's Escarpment is sometimes called Muldraugh's Hill, and the Mississippian Plateau often has the name Pennyroyal Plateau.

A long grade on the Dixie Highway is encountered after passing the town of West Point, and amidst rather bold and imposing scenery the motorist finds himself after a few miles on top of the rolling upland, the Mississippian Plateau. This upland continues without interruption almost to Nashville where descent is again made to the floor of the Nashville Basin, a district in many respects similar to the Blue Grass region of Kentucky.

On the railroad the ascent to the top of the Pennyroyal Plateau over Muldraugh's Hill is made a few miles south of the highway near the station called Tunnel Hill. From Elizabethtown south the highway and railroad parallel each other. This is due to the fact that the great route of travel from north to

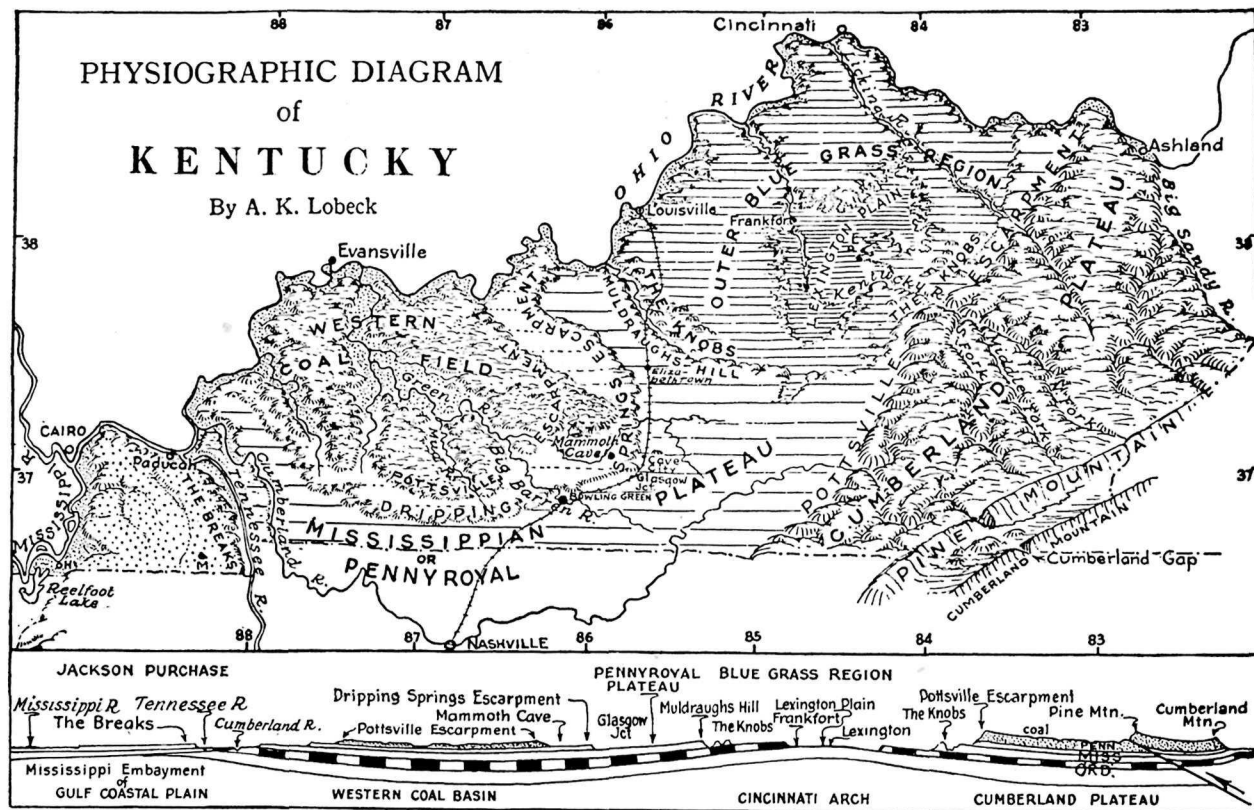


FIG. 1. PHYSIOGRAPHIC DIAGRAM OF KENTUCKY WITH GEOLOGICAL CROSS-SECTION

Mammoth Cave is situated about half way between Louisville and Nashville, in a hilly plateau region a few miles west of the Dripping Springs Escarpment.

south across this region could not follow a direct line to Nashville because of a second plateau rising up to the west, the margin of which is called the Dripping Springs Escarpment.

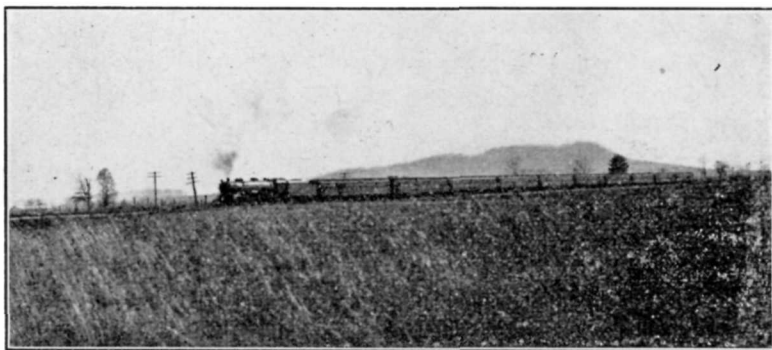


FIG. 2. THE PENNYROYAL PLATEAU NEAR CAVE CITY

This is a typical part of the Pennyroyal, with an outlier of the Dripping Springs Escarpment in the distance. The Pan-American, through all-Pullman train of the Louisville and Nashville Railroad takes a siding here to pass its sister train bound south for New Orleans.

All routes of travel were forced to keep farther east than they would normally go and consequently we find highway, railroad, and many villages lying close to its base all the way from Elizabethtown to Bowling Green.

Among these towns is Cave City, at which point the motorist turns toward the west and, rising over this second escarpment, finds himself after ten miles at Mammoth Cave. In a similar manner the traveller by train, leaving the main line at Glasgow Junction transfers to the little branch railroad (Figure 3) which for the first few miles experiences steep grades in its ascent to the plateau in which Mammoth Cave is situated (Figure 24).

It must not be imagined that the Mammoth Cave Plateau region (Figure 4) west of the Dripping Springs Escarpment* resembles very closely the Pennyroyal Plateau. The Pennyroyal Plateau (Figure 2) on the one hand with its many roads and railroads, its frequent towns and villages, its extensive farms

*Recognized and named as a physiographic feature by W. R. Jillson, *Pan-American Geologist*, Vol. XLII, August, 1924.

and broad cultivated tracts, presents a pleasing rolling surface, somewhat prairie-like in its general aspect. The Mammoth Cave region, on the other hand, is ever so much more rugged in its relief. Most people would describe it as being quite hilly. Much of the region is still in woods and waste land. The presence of the many caves would perhaps at first hardly be suspected although, as a matter of fact, a person familiar with cave regions elsewhere would notice certain features in the landscape

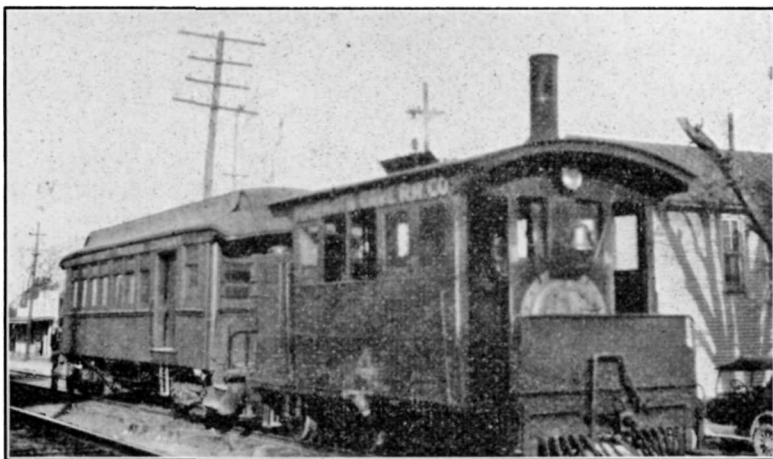


FIG. 3. TRAIN ON MAMMOTH CAVE RAILROAD AT GLASGOW JUNCTION

which would tend to suggest their presence. Most obvious of these external features are the numerous sinks or depressions, the so-called "valley-sinks", or extensive valley systems without outlets, the almost entire absence of surface streams, the occasional exposure of limestone formations revealing solution cavities, and even the presence on the surface of the hillsides of cave deposits due to the collapse of parts of caves along the valley slopes.

Before entering upon a discussion of the meaning of the various details to be seen here it will probably be more interesting to review the broader aspects of the Park area in order to gain a picture of the region as a whole. This will be followed by an explanation of the geology and physiography of the region, after which the caves and the various cave deposits will



FIG. 4. GENERAL VIEW OF MAMMOTH CAVE NATIONAL PARK AREA

The valley of the Green River lies several hundred feet below the plateau surface. To the left is the region of caves, to the right is the rugged hill country north of the river.



FIG. 5. LANDSCAPE SKETCH OF GREEN RIVER GORGE, BELOW MAMMOTH CAVE

The river here is entrenched 300 feet below the plateau, and at this point swings in a majestic arc whose radius is about one-half mile. The bluffs on the outside of the bend upon which the observer stands are steep, almost vertical cliffs, with outcrops of limestone and sandstone. Across the river, on the inside of the bend is an alluvial flat whose elevation is approximately 40 feet above the river level. These flats date probably from glacial time and represent deposition made by Green River to keep pace with the deposition made by the Ohio. Such flats are cultivated wherever they occur. The slopes directly back of them are usually gentle and show limestone outcrops, and are covered with residual limestone soil. When cleared they rapidly develop gullies but as soon as the soil is removed so that the water can reach bed rock limestone, into which it quickly disappears, downward cutting no longer proceeds and gullying practically ceases. The upper slopes, even when not cliff-like, are almost invariably left in timber which consists at the top, where the sandstone capping conserves the water supply, of deciduous or broad-leaved trees, but farther down on the lower limestone slopes pines and cedars are prominent.

be described. Finally, in order to round out the picture, a few words will be devoted to the activities of the people who now abide in this area.



FIG. 5a. ENTRANCE TO SAND CAVE

This photograph was taken at the time the Floyd Collins rescue was in progress. Note the icicles on the ledge above. The worst of weather conditions operated to delay Collins' recovery until after his death. Meanwhile one of the greatest individual human interest stories was developed day by day by the American Press. Collins' grave is within the Mammoth Cave National Park boundary.

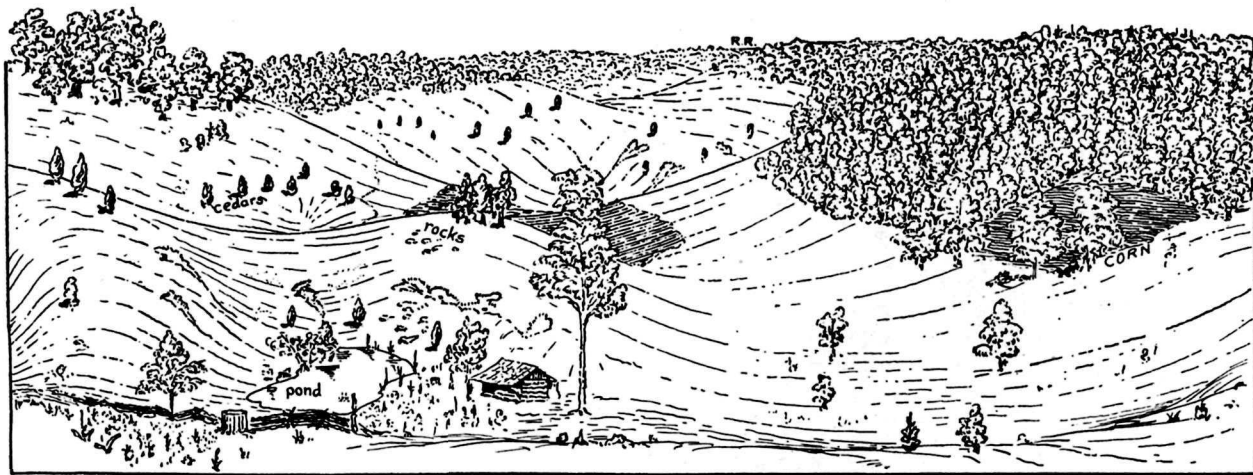


FIG. 6. LANDSCAPE SKETCH OF DEER PARK, A VALLEY SINK

This typical medium-sized valley sink, as a whole, has a branching system like most valleys. Its floor, however, is not a single depression. In the immediate foreground, for example, is a minor sink containing a pond. Many of the depressions are flat at the bottom, being covered with a layer of clay washed in from the sides, but there are many cases where this is not true and then the sink is cone-shaped. The bottoms of the sinks and many of the lower slopes are cultivated for corn and tobacco, these being the sole crops in the valley sinks. Where not cultivated there are open meadows with scattered trees and small shrubs. It is in this more or less open zone that cedars abound, and because of the park-like aspect thus produced gives the name Deer Park to this particular valley sink. The higher and steeper slopes which are in the upper limestone and in the sandstone horizons are invariably in forest which consists of oak and other deciduous trees including hickory, chestnut, tulip, sycamore, red bud, dogwood, and ironwood. Willows grow around the ponds occupying the sinks. There are no running streams in the area, but on top of the plateau above the sink, marshes and ponds may occur and these drain off in little rills which cascade over the sandstone ledges and then immediately disappear into the limestone. Few if any houses are found in the valley sinks, the farms being found on the plateau above which is extensively cultivated. Foxes, rabbits, raccoons, and many birds such as hawks, crows, owls, pileated and other woodpeckers, are commonly seen in these surroundings. No deer, however, live here.

THE MAMMOTH CAVE NATIONAL PARK REGION.

The region which it is proposed to include within the Mammoth Cave National Park embraces an area of over 100 square miles, some 70,000 acres, lying in a rugged plateau country (Figure 4) in south central Kentucky. It is just west of the Dripping Springs Escarpment and on the eastern margin of the Western Kentucky Coal Field. The area is cut into two approximately equal parts by the course of the Green River (Figures 15 and 5). These two parts are, in a general way, dissimilar, both physiographically and culturally. In the southern half lie all the caves of the region and here, too, sink holes and valley sinks abound (Figure 4). Flat-topped plateau remnants (Figures 7 and 8) make up a large fraction of the area although over one-half of the original plateau has given way to the sinks and depressions (Figures 9, 10, 11 and 12). It is under these flat-topped mesa-like pieces of country that the largest caves are found. The northern half is a rugged hilly country (Figures 13 and 14) with few or no sinks except along a belt near the Green River. In the part south of the river practically no streams are encountered even in the larger valleys. The temporary streams do not flow through continuously to the Green River but are interrupted and disappear into the ground. In the northern part the streams are frequent and follow well-defined valleys albeit during some seasons many of them are dry.

The difference between the two areas lies in the fact that a thick limestone formation makes up the southern half of the region (Figure 15) and is accountable for the caves and sinks which occur there. This limestone formation, however, dips gently toward the north and toward the west, and only a few miles north of the Green River it reaches so low a level as to have no effect on the topography. Other higher formations, largely shales and sandstones, overlie the limestone in this northern portion and make up the body of the country. In the most northern parts the limestone has entirely disappeared, even in

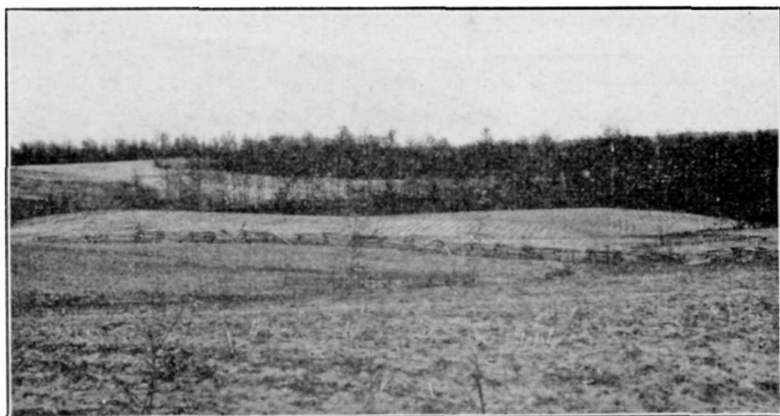


FIG. 7. TYPICAL CULTIVATED UPLAND SURFACE, NEAR CAVE

This landscape is characteristic of the region south of Green River and of a considerable belt just north of it. Corn is the chief crop but oats and hay are also grown. Rail fences are still to be seen but these are rapidly being replaced by wire fences which are much cheaper and more durable.



FIG. 8. POND ON SURFACE OF THE PLATEAU OVER MAMMOTH CAVE

This occupies a very shallow depression, undoubtedly formed by surface water draining through to the limestone cavities below. The outlet, however, has apparently become clogged and some of the water now drains off by a little stream to the plateau margin.

the bottoms of the valleys, and the massive sandstone produces cliffs and valley walls of striking charm and beauty.

Culturally, there is also a noticeable difference in the two areas. This is due largely to the fact that the northern part is distinctly isolated, owing to the presence of the Green River

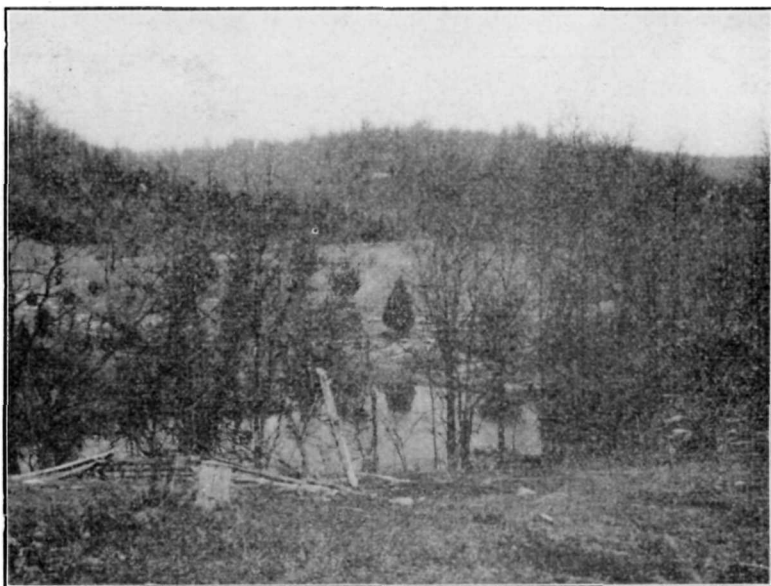


FIG. 9. POND OCCUPYING A MINOR DEPRESSION IN ONE OF THE VALLEY SINKS

Such small bodies of water are often very temporary, being most common in the springtime when the rainfall is abundant. When they dry up the floor of the sink is flat and usually no opening, well, or swallow hole is to be seen at the bottom.

gorge. It is true that there are frequent small ferries but nevertheless there is not that free and easy communication which is essential if a region is to be kept from having provincial characteristics.

Poor roads and a distinct dependence upon local resources characterize the northern areas (Figures 16 and 17). Automobiles are very infrequently used and travel is largely by horse back or by mules. Even wagons are not used unless necessary. The chief output or cash products of the region are cattle, pigs, and sheep, and these do not require good roads to get them to market. In the southern area, although by no means is the agricultural development to be compared with that in the

Pennyroyal Plateau, it is nevertheless more diversified than in the region across the Green River. The raising of vegetables and chickens for the hotels, and the growing of tobacco and the production of milk leads to a wider range of interests.

This isolation is observable also in the fact that no negroes live in the region north of the river. It is well known that

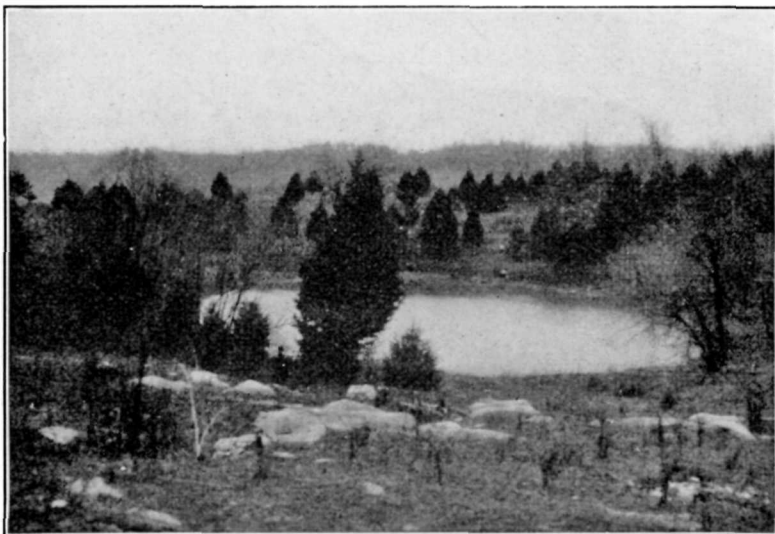


FIG 10. SINK HOLE WITH POND IN VALLEY SINK AREA NEAR NEW ENTRANCE CAVE

Many of the sinks contain small bodies of water because the outlet at the bottom has become clogged with silt washed down from the funnel-shaped sides. Outcrops of limestone are common throughout the valley sink area.

negroes are to a large extent dependent upon the initiative of the whites. In other words they tend to be parasitic. In localities where large farms and plantations can be maintained and where considerable labor is employed, the negro is at home, ready to work as a laborer for some one else. But he rarely makes a go of it when he has to match his wits against nature under adverse conditions.

The southern half of the area where the caves exist is more or less readily reached from the fertile plains of Kentucky only a few miles to the east. Railroads and roads make cultural influences more immediately felt. There are frequent opportunities for those who cannot succeed on their own account to

work as laborers or road builders, or to find employment in and around the hotels.

It is hoped in the course of the following pages to explain other facts of physiography and culture, but perhaps this bold characterization of the two parts of the Park area will provide the reader at the outset with something tangible upon which to fix his attention.

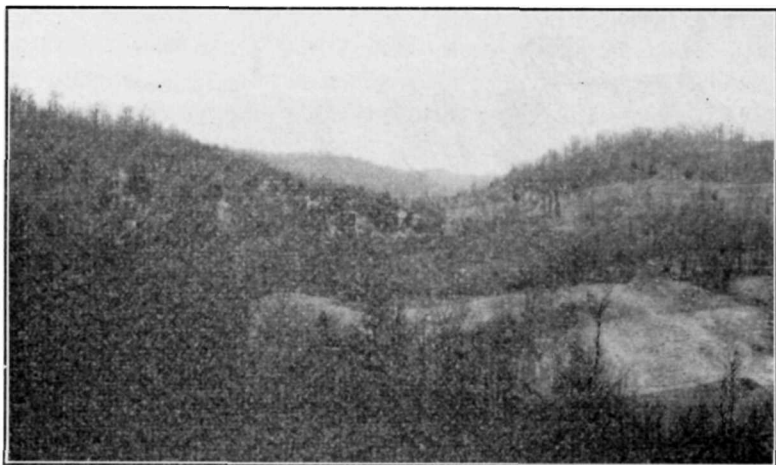


FIG. 11. A TYPICAL VALLEY SINK

The forested upper slopes, the cultivated lower slopes and the entire absence of habitations are all characteristic of the valley sinks.



FIG. 12. A CHAIN OF SINKS

These are of frequent occurrence and often occupy a narrow valley a mile or two in length. If not too small and steep-sided such sinks are usually cultivated, otherwise they are left in forest.

THE GEOLOGICAL STRUCTURE OF THE MAMMOTH CAVE NATIONAL PARK REGION.

The visitor to Mammoth Cave who knows nothing whatever about geology can, nevertheless, in a few moments grasp the essential facts which are necessary to a real appreciation of the region. Very few places of scenic interest have so simple a design.

Like all the rest of Kentucky, and like many of the adjacent states, this is a part of the vast Interior Lowlands of North America which stood at one time under the sea, and thus received deposits of lime, clay, and silt which accumulated on the sea floor to a thickness of hundreds and indeed of thousands of feet. When the continent was uplifted and the sea drained away to the south, where it still forms the Gulf of Mexico, these layers of rock piled one above the other were raised to form dry land. At first, having the aspect of a flat plain, the appearance of the region gradually changed because of the valleys which were cut into it by the many streams which developed there. Figure 15 shows this in an extremely simple and diagrammatic manner. The upper block portrays the appearance of the region immediately after uplift, and in the lower block may be noted its present configuration.

It will be observed that in this particular locality, when the layers of rock appeared above the sea they were not lying in a strictly horizontal position but were sloping or dipping very slightly toward the north or northwest. This is clearly to be seen in the upper block of Figure 15. In other words, although all of Kentucky is made up of sedimentary rocks such as limestone, sandstone, and shale, these rocks throughout the state do not everywhere lie in a strictly horizontal position but dip slightly in one direction or another. This may perhaps be more clearly understood by glancing again at Figure 1 which shows diagrammatically the physical features of the state of Kentucky together with a cross-section of the underground structure. Examine the cross-section and note that there are essentially four different structural units which make up the state of Kentucky.



FIG. 13. LANDSCAPE SKETCH OF UPLAND NORTH OF GREEN RIVER

This is a rolling, submaturely dissected plateau with well developed drainage pattern. Considerable flat-topped summit areas remain, usually deeply covered with sandy loam, but residual limestone soils also occur. The roads invariably follow the divides, and here are to be found all the houses of the region. Practically all of the upland is in farms as well as many of the slopes which are quite gentle. The valley sides and bottoms are always wooded.

Named from west to east they are the Gulf Coastal Plain, the Western Coal Basin, the Cincinnati Arch (or Blue Grass Region), and the Cumberland Plateau. The Gulf Coastal Plain and the Cumberland Plateau need not in this connection detain us any longer.

In the Western Coal Basin the rock formations have been warped or bent down slightly in the central part. In the Cincinnati Arch, on the other hand, they have been bent up, as the term arch implies. Geologists speak of the basin area as having the structure of a gentle "syncline," and the arch area as a gentle "anticline." Now it will further be observed when the cross-section and the map are studied together that in the Blue Grass Region where the strata have been up-arched, the top-most formations are no longer present, due to the erosive work of streams, and to the profound weathering and the decay of the rocks during the long time which has elapsed since the region appeared above the sea. The Blue Grass Region, therefore, shows in its central part, which is known as the Lexington Plain, the bottom-most or the oldest rocks to be observed anywhere within the state of Kentucky. This region reminds us very much of an onion with its different layers, the outer ones being cut away at one place so that the inner ones are visible. The rocks of course slope or dip away in all directions from the central or most elevated part of the arch or dome.

In contrast with the Blue Grass Region the Western Coal Basin still exhibits the complete sequence of formations, the upper-most ones being present in the center of the basin. Indeed it is more than likely that the coal-bearing formations of the Western Coal Basin at first continued eastward over what is now the Blue Grass Region and joined on with those of the Cumberland Plateau. The plateau, like the Western Coal Basin, is also a gentle basin in structure.

The next point to be noted is the fact that with the removal of the upper-most formations from the Cincinnati Arch, a series of escarpments was formed. Looked at through the perspective of geological time, the present position of these escarpments is only temporary. Each escarpment retreats or wears back, thus exposing more and more of the lower strata. The several escarpments differ considerably among each other. Some of them



FIG. 14. LANDSCAPE SKETCH OF TYPICAL GORGE IN NORTHERNMOST PART OF THE PARK AREA

Head of Bylew Creek, a young gorge cut into Pottsville sandstone and conglomerate which stands up in many places as vertical cliffs. The floor of the valley has occasional little flat patches. These are cultivated, but are subject to flooding. All moderately gentle slopes are cultivated, but people do not live here because of the inaccessibility. There are no good roads in the valleys but the plateau above is to a large extent developed. Springs issue at frequent intervals from the base of the valley walls.

are so much dissected by streams and ravines as to have a very irregular appearance. Thus the Knobs around the margin of the Blue Grass Region are to be explained. Most of the escarpments, too, are not simple and sharply defined, but frequently hills or outliers stand out in front of the escarpment, the last remnants of the formation which at one time extended continuously to that point.

Between the successive escarpments there stretch broad expanses of country usually called plateaus. The Pennyroyal Plateau is one of the most extensive of these. Some of these plateaus are flat or gently rolling, this being true of the Pennyroyal again, but elsewhere the plateaus are very hilly and rugged because of the many valleys which ramify through them. The Cumberland Plateau is so rugged on this account as to be called "mountains." The reason that a succession of plateaus develops is because the successive formations do not all react to erosion in the same manner. Certain layers like sandstone weather less readily than others and these often cap the plateau surfaces. In Kentucky, however, several of the plateaus are made up of limestone formations.

With these general observations it will now be advisable to turn again to Figure 1 and to note the relationship the Mammoth Cave Region bears to the rest of Kentucky. It is seen to lie on the eastern margin of the Western Coal Field, in the plateau area lying just to the west of the Dripping Springs Escarpment. The formations dip in general northwest toward the center of the coal basin.

We are now ready to examine with a little greater care the details of Figure 15. Five geological formations are shown in the series which make up the area.* Let us note the relationships which these formations bear to the topography. The lowest member of the series is called the St. Louis limestone. It outcrops in the southern part of the area and forms the surface of the Pennyroyal Plateau at Cave City and Glasgow Junction. Next comes the Mammoth Cave limestone followed by the Cypress sandstone. These together make up the plateau area north and west of the Dripping Springs Escarpment. The main mass of

* These formations are further subdivided and additional names are used in detailed geological consideration of the region. See J. M. Weller, *Geology of Edmonson County, Kentucky Geological Survey, 1927.*

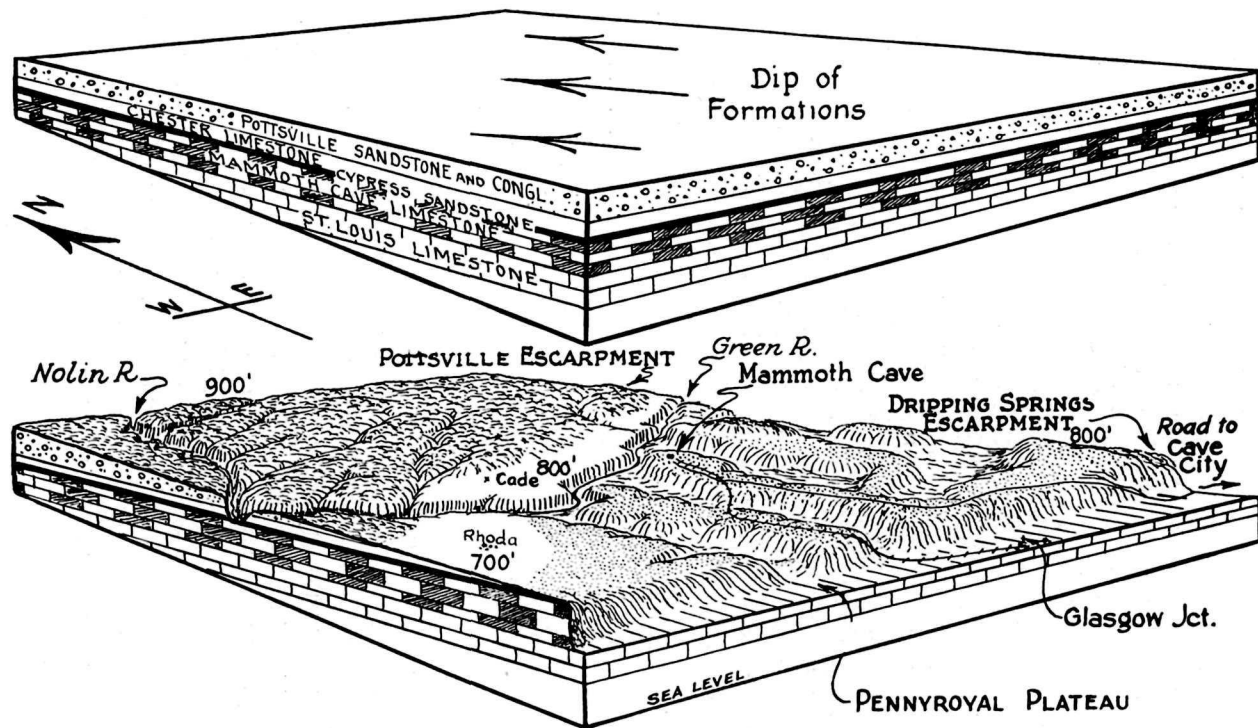


FIG 15. BLOCK DIAGRAMS SHOWING TWO STAGES IN THE DEVELOPMENT OF THE MAMMOTH CAVE REGION. The upper block illustrates the original conditions before dissection has taken place. The formations dip toward the northwest. The lower block illustrates the present configuration of the country.

the plateau is made up of the Mammoth Cave limestone formation which all told is almost 300 feet in thickness. The top of the plateau, however, is capped with the Cypress sandstone. This formation is less than 50 feet thick. In many places it has been worn away so as to reveal the limestone beneath.

At such places as well as along the margin of the plateau, that is, along the front of the Dripping Springs Escarpment, the limestone quickly weathers away. In other words, the Cypress sandstone formation is apt to be undermined more or less. The result is that the Dripping Springs Escarpment retreats or works back in the direction of the dip of the formations, that is toward the north and west; and also that the valleys that form in the plateau widen very rapidly. In consequence of this the plateau has lost its simple plateau-like aspect and is made up of a number of units or tablelands, somewhat like mesas in other parts of the country. It is under one of these mesas that Mammoth Cave is found.

Next above comes the Chester limestone, with some associated sandstones and shales. This series, in places 200 feet in thickness, is as a whole not very resistant to weathering and is apt to be removed from most of the hill tops. Finally, as we get into the hilly area north of the Green River, we find the Pottsville formation making up much of the country. This formation is a sandstone and conglomerate. It has a thickness of several hundred feet in places, depending of course upon the amount that has been eroded. Owing to the fact that all the formations lie deeper and deeper as one goes farther and farther north, it is evident that in the northern-most part of the region only the highest or the Pottsville formation may be observed, even in the deepest stream valleys.

So in the gorge of the Nolin River, in the northern part of the Park area we observe only the bold cliffs of sandstone where that stream has cut its narrow valley through the Pottsville formation. Farther south, in the vicinity of the Green River the Pottsville formation is to be found only on the tops of the hills. In the floor of the valleys may be seen the underlying formations such as the Chester limestone, the Cypress sandstone, or even the uppermost portion of the Mammoth Cave limestone.



FIG. 16. LOG BUILDING USED FOR STORING CORN AND SHELTER-
ING LIVE STOCK

All the material used in the construction of this building has come from the immediate locality.



FIG. 17. AN OLD HOMESTEAD

Several buildings of this type are still to be seen in the region north of the Green River. Practically every part of this building has been produced on the premises. This is still true of buildings more recently constructed, except that the introduction of portable saw mills has made it possible to use finished boards more extensively.

THE PHYSIOGRAPHY OF THE MAMMOTH CAVE NATIONAL PARK REGION.

The area to be embraced in the Mammoth Cave National Park is transected by the gorge of the Green River which, from the standpoint of physiography, divides it into two contrasting sections. The contrast in the physical appearance of the two regions is due largely to the fact that in the portion north of the Green River the present configuration of the country has been produced by the erosive activity of streams of water flowing on the surface of the ground, whereas in the portion south of Green River the present forms of the land have to a large degree been affected by the fact that most of the drainage of the region sinks below the surface and flows off through underground channels. Figures 18 and 20 are designed to show diagrammatically the contrast that results from these two opposing conditions. Each of the figures depicts four stages in the life history of the kind of region which it illustrates.

Life history of plateaus having surface drainage. Figure 18 has to do with a region made up of sedimentary rocks that lie in an approximately horizontal position. These rocks include sandstones, shales, conglomerates, and limestones. The limestone layers, however, are not anywhere of very great thickness, nor of exceptional purity. In other words, this illustrates a typical part of the extensive plateau area which is embraced in the eastern United States. The Western Coal Basin of Kentucky is a plateau of that type. Observe now the appearance of such a region during the successive stages of its development.

Youth.—In the top-most block we note two streams flowing across the area which has the aspect of a plain. The valleys have not yet cut very deeply, nor are they very numerous. Much of the surface is as yet unaffected by the activities of erosion. Such a region is said to be young.

Late youth or submaturity.—In the second block we note that there are more streams, that the streams are longer because they have, after the manner of gullies, worked headward into

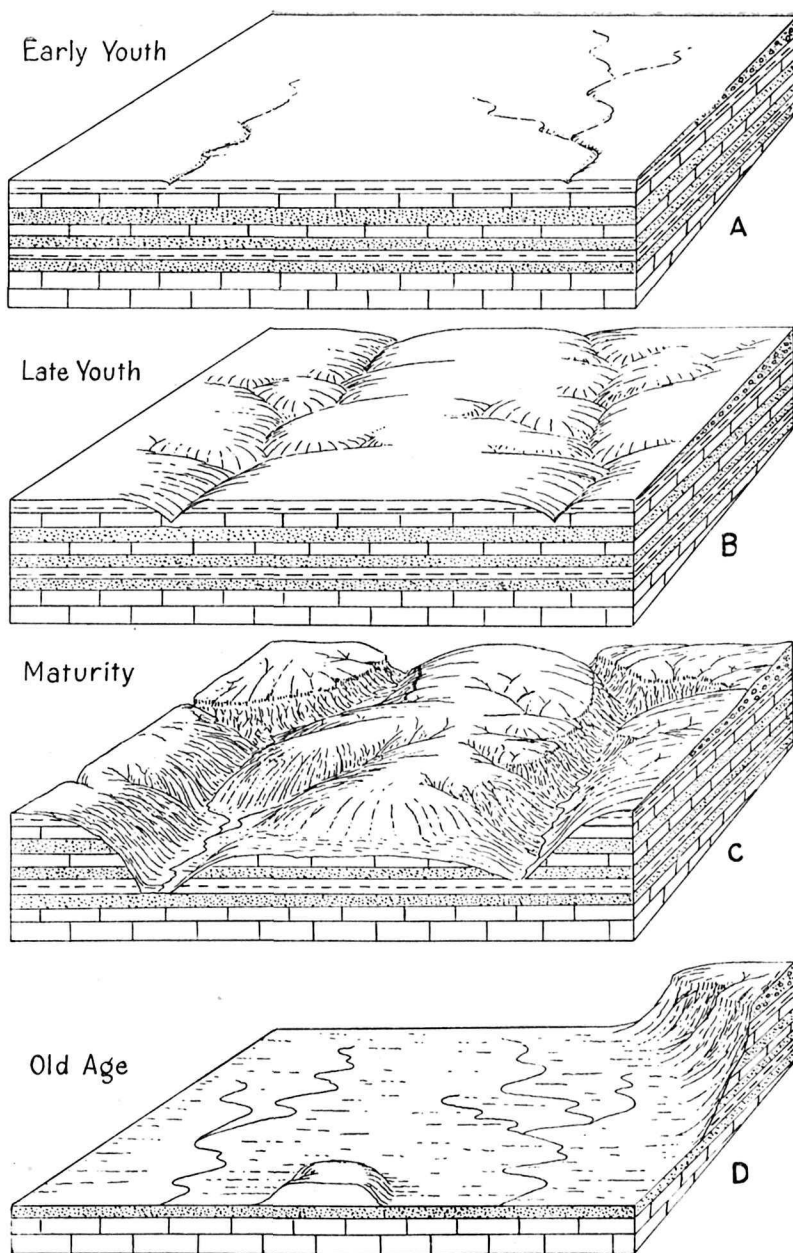


FIG. 18. FOUR STAGES IN THE NORMAL LIFE CYCLE OF A PLATEAU

The plateau here represented is made up of sedimentary rocks of several types. Surface drainage prevails throughout the region during the entire life cycle. The features illustrated here are discussed in detail in the text.

the plateau in all directions, and in addition we note that the valleys are deeper. There are still, however, broad spaces between the streams which are flat and undissected; that is to say some of the original surface of the plateau still remains. Such a region is said to be submature, that is, not quite mature. Some of the Allegheny Plateau in northern Pennsylvania is in this stage, but most of the plateau areas in Kentucky have advanced to maturity.

Maturity.—In maturity, the region reaches its most rugged condition. Streams ramify into all parts so that the divides between the valleys are comparatively narrow. There may be gently rolling upland areas but they are by no means extensive. The valleys are deep, even gorge-like, and in many places the valley walls may exhibit vertical cliffs of rock where harder formations like sandstone have been cut through by the streams. At this time, too, one may note a tendency for the larger streams to widen the floors of their valley and thus occasionally to provide here and there small stretches of bottom land which can be cultivated. Different kinds of rocks may appear in different places on the uplands between the streams. This may be due to the fact that the formations dip slightly in one direction as shown on the right hand side of block C in Figure 18. The region north of Green River in the Mammoth Cave National Park area presents all of the aspects just enumerated for the mature stage.

Old age.—After maturity is passed the streams develop still wider valley floors, the hills become much smaller, and eventually we find the conditions represented in block D. This is practically the state of affairs found in the heart of the Blue Grass district and to the east and south of the Park area. The Pennyroyal Plateau represents an area from which the overlying formations have been stripped. The Dripping Springs Escarpment represents the edge of those higher formations, that is, the margin of the plateau. Outliers of this plateau stand as isolated hills out on the Pennyroyal (Figure 2.) A region, then, which has by a long period of erosion been worn down to an extensive plain, like the Pennyroyal, is said to be in old age. The Pennyroyal, however, has started another period of devel-

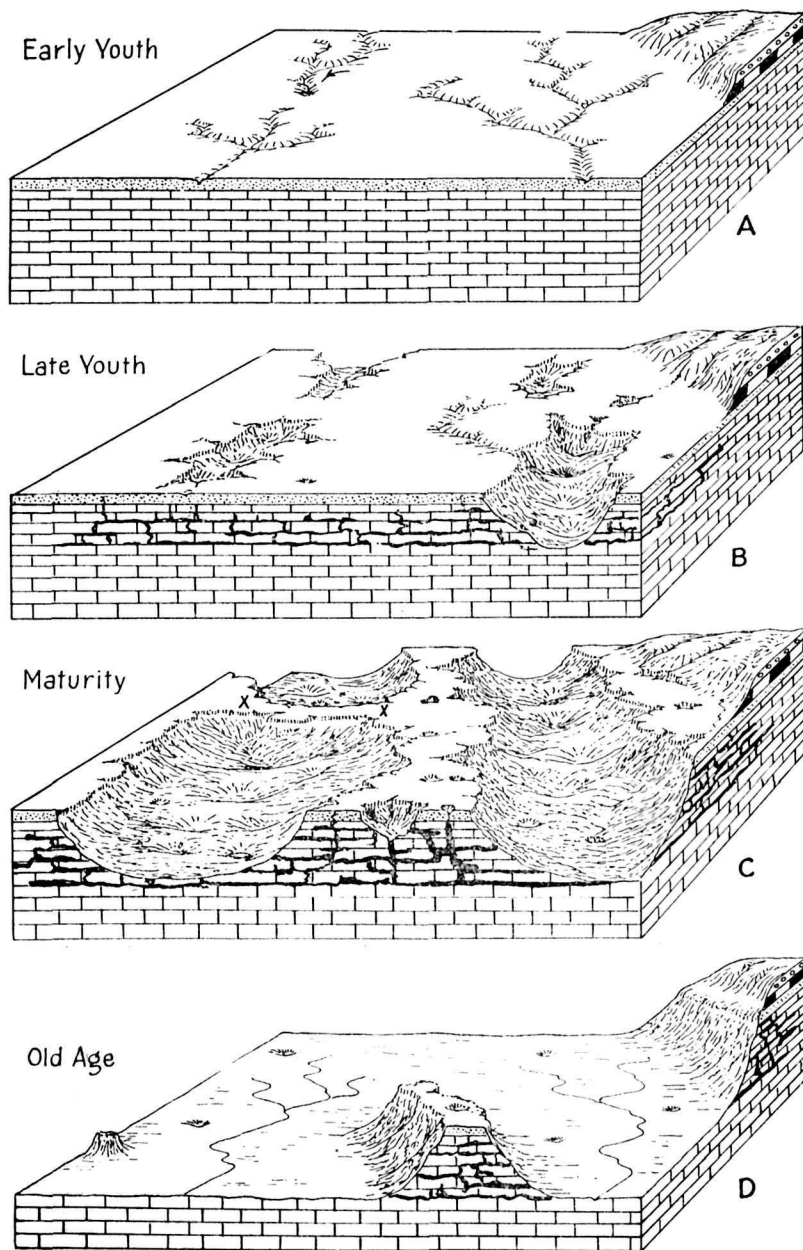


FIG. 20. FOUR STAGES IN THE LIFE CYCLE OF A PLATEAU
HAVING UNDERGROUND DRAINAGE

The plateau here represented is made up largely of limestone. Except for the earliest and latest stages surface drainage is almost entirely absent. See text for detailed description.

due to the much more extensive level topography, in contrast with the region lying still farther north, as well as to the much better soil, this being a sandy loam derived from the decay of sandstone and limestone, whereas the soils of the northern area, derived from the decay of the Pottsville formation, are sandy and gravelly, very open, and on that account so dry as not to yield good crops.

North from this point the tops of all the hills are capped with formations overlying those to which reference has just been made. The hills are much bolder, the valleys are deep, often gorge-like, and the uplands, although still constituting the chief inhabited parts of the area, are narrow and often very irregular and knobby.

Some of the most charming scenery is to be found in the northern-most part of the district where Nolin River, one of the affluents of the Green River, together with its tributary Bylew Creek have cut sharp-walled gorges below the upland surface (Figure 14). The sharp, vertical, rock cliffs of these gorges are due to the massive sandstone layers which make up the Pottsville formation. In some places the gorges have flat bottoms and here little cultivated patches of land are occasionally to be found. The numerous side ravines often head in steep-walled coves or amphitheatres, wild and picturesque in the extreme. Dismal Rock on Nolin River (Figure 19) is a part of the valley wall projecting a bit more than usual. On the side nearest the river a tall chimney-like portion is almost entirely detached from the main ledge, this being due to a joint or fracture, a feature common in all massive formations.

Life history of plateaus having underground drainage. Figure 20 has to do with a region made up of sedimentary rocks that lie in an approximately horizontal position. The great body of the plateau is made up of a massive, relatively pure limestone with a little capping of sandstone at the surface. This thin layer of sandstone is introduced into the drawing in order to simulate as closely as possible the conditions in the Mammoth Cave region. As a matter of fact there might be several layers of shale and sandstone and perhaps interbedded limestones, overlying the massive limestone. It is essential, however, that there

be a thick soluble limestone formation in order that subterranean drainage may bring about the usual succession of events.

Youth.—In youth, exactly as in Figure 18, we find streams coursing across the region. The valleys are shallow and the tributaries infrequent. This results in extensive flat areas or

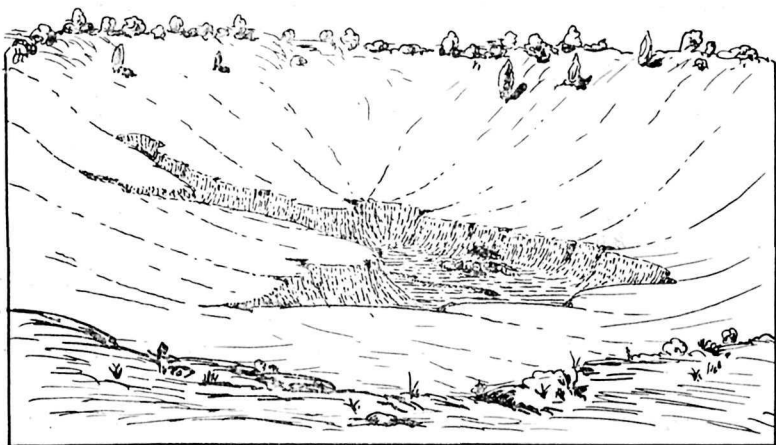


FIG. 21. SMALL SINK HOLE WITH SWALLOW HOLE AT THE BOTTOM

Many sink holes, instead of containing ponds at the bottom, show channels of erosion and an opening or well through which the water disappears underground. Sometimes these openings or swallow holes become clogged and a pond results.

plains. One or two departures from the normal process of erosion, however, may be noticed. The stream at the right in block A Figure 20 is exactly like the corresponding stream in Figure 18. But the stream at the left is commencing to be dismembered and to be broken into detached segments. This is due to the fact that it has in several places cut through the capping sandstone layer and this has permitted the water to penetrate immediately into the joints and bedding planes of the underlying limestone. In other words underground drainage is being inaugurated. In its earliest stages there are still some streams on the surface of the ground, and the sinks or swallow holes through which they find a way to underground cavities are neither large nor numerous.

Late youth or submaturity.—As youth advances, more and more of the drainage goes underground almost as soon as it

falls on the surface. The sink holes rapidly enlarge. At first they are small and funnel-shaped. Often at this stage they contain little ponds either permanent or temporary (Figures 9 and 10). That is due to the fact that the underground cavities at first are small and easily become clogged with the soil washed in from above. This may cause an accumulation several feet in thickness on the floor of the sink. In time, however, the water which seeps through the bottom of the sink dissolves away a larger channel underground and a real swallow hole is formed in the bottom of the sink. Such a feature is clearly illustrated in Figure 21. The accumulated silt in the floor of the sink is rapidly being carried underground, and in this manner a gaping hole or well is produced. In fact, the entrance to the underground channels can sometimes actually be seen in the layers of limestone rock which are thus exposed.

Maturity.—In full maturity the region has lost practically all of its surface streams. Underground passageways have become very extensive. The whole region is honeycombed with a great network and labyrinth of channels and passageways which constitute the caves. The various forms assumed by these features deserve special treatment and will be taken up in the next chapter. The numerous small sinks have been replaced by a few depressions of large size. These are usually called valley sinks or hollows. They may be several miles long and of great depth. The floor of these large hollows is not yet flat but is undulating and is interrupted by frequent sinks and swallow holes. The drainage of the entire area finds its way into these holes, though occasionally there is a certain amount of gullying of the slopes leading thereto. These large depressions are formed by a gradual enlargement of the smaller ones through solution at the bottom and by the washing of material down the funnel-like sides. Different sinks in that way come to be united. It is sometimes stated that sink holes or depressions like those just described have been formed by the collapse of huge caverns, but it is now known that this is practically never the case; at least collapse does not occur over any appreciable area. Sometimes just beneath a sink where the water has been concentrated an exceptionally large passageway may be formed, usually a

vertical channelway. There the floor of the sink may break through and the sink thus enlarged and its walls made somewhat more precipitous. But this, of course, is only of very local importance. Occasionally natural bridges may be formed in this manner but as a matter of fact in the Mammoth



FIG. 22. ENTRANCE TO MAMMOTH CAVE

This entrance is in a ravine leading down to Green River. Many cave entrances are on the sides of the valley sinks.

Cave Region no natural bridges of this kind are to be found. There are, however, certain archways and passageways in the caves which are designated as natural bridges.

It will also be noted that the valley sinks usually have a branching form like any valley. This is due to the fact that small rivulets from the adjacent uplands that still remain are constantly cutting into the upper ends of the ravines and causing them to advance headward. These little rivulets usually appear as springs on the top of the plateau areas, as shown in block C Figure 20, and, after plunging over the steep valley wall, which in its upper part is capped by sandstone, disappear immediately underground upon striking the underlying limestone beds. Large springs are occasionally found near the base

of the cliffs around the margins of the valley sinks at places where the subterranean streams emerge for a moment before again plunging underground in the bottom of the sink.

Practically all of the entrances to the different caverns of the Mammoth Cave Region are to be found along the margin of



FIG. 23. ENTRANCE TO GREAT SALTS CAVE

This entrance is in the bottom of a large sink, not in the center but over at one side. Horse Cave at Horse Cave city is entered in the same way but this means of entrance is uncommon.

the plateaus where the underground drainage channels make their appearance in the walls of the valley sinks or along the valley of the Green River (Figure 22). Sometimes caves are entered through sink holes (Figure 23), never in the very bottom

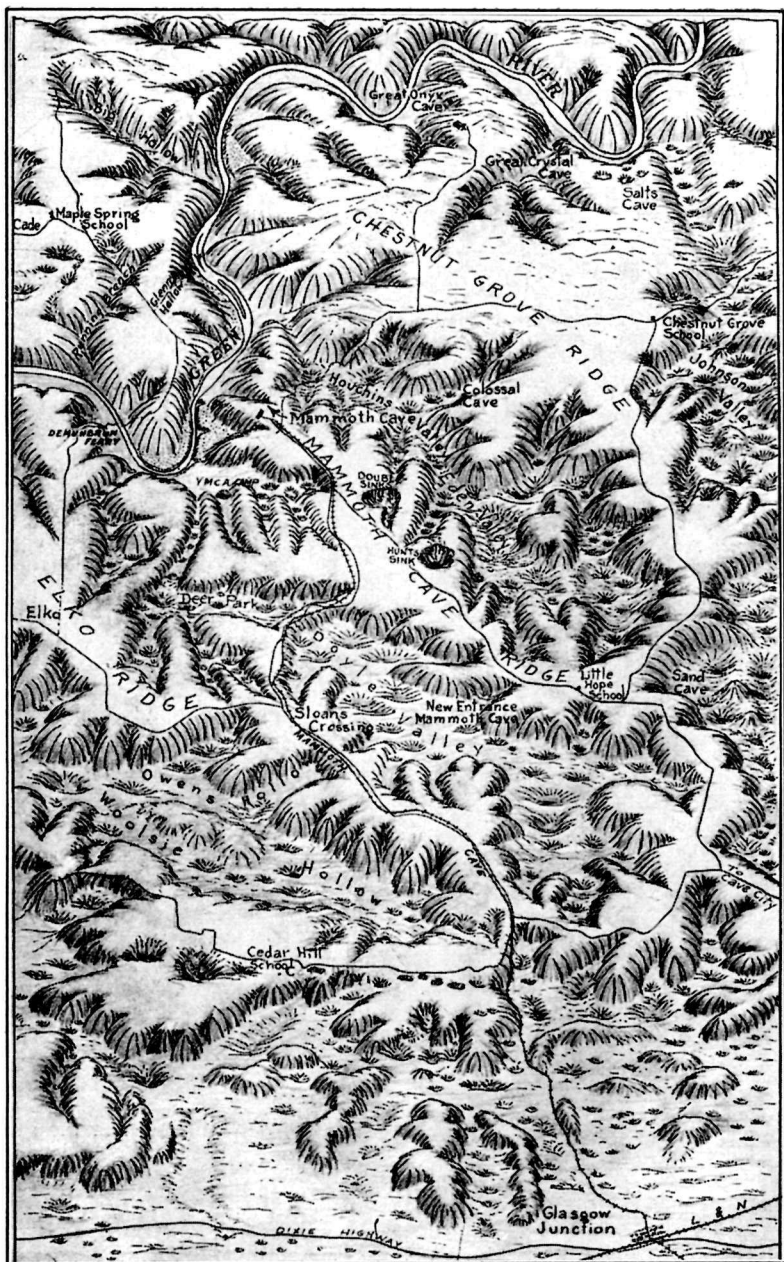


FIG. 24. THE MAMMOTH CAVE REGION IN DETAIL

This is a modification of the Mammoth Cave topographic map on which the features are shown by contour lines.

of the sink but over at one side because the bottom is usually filled with debris washed down from the surrounding rim.

Old age.—As a region having underground drainage advances from maturity to old age the valley sinks increase still further in size. The plateau remnants between the sinks at the same time become smaller and smaller until only occasional knobs remain above the more or less level country which now prevails throughout the region. These knobs are often flat-topped like those near Glasgow Junction, but in some parts of the world they assume more or less a conical shape and are known as haystack or pepino hills, this being the case in some of the limestone tracts of the West Indies.

With the increase in size of the valley sinks and a gradual dissolving away of the limestone hills which still cover the floor of the sink there comes a time when the underground drainage lines are exposed to view. That is to say, surface drainage is again gradually introduced. This condition may result either because the massive limestone layer has been entirely removed and the underlying beds are impervious in character, as suggested by the cross-section in the front part of block D Figure 20, or on the other hand, even if all the limestone is not dissolved away, nevertheless it may be that no more can be removed because the region has now been brought down to the level of the major streams of that area. With the complete development of old age with its surface streams the region resembles very closely one in old age whose development has been attended by surface streams throughout its whole history.

The country may now be rejuvenated, perhaps by the deeper cutting of the major streams of the region, and the consequent lowering of ground water level. This means then, that if limestones are still present new sink holes will form and the life history of the region will start over again. That portion of the Pennyroyal Plateau near Glasgow Junction displays exactly these phenomena, and for that reason is best classified here as a region that has reached old age during the subterranean cycle of erosion but shows evidences of rejuvenation in its present pitted surface. Other parts of the Pennyroyal, however, are of the more normal type previously described.

Description of the National Park area south of Green River.

This section of the Park is of course the part that holds most of the features of interest. Figure 24 shows part of the area in detail. It will be noted that the region consists of several long plateau-like ridges, trending in a northwest-southeast direction, separated from each other by extensive valley sinks or hollows. No streams are to be seen in the area except on the flanks of Chestnut Grove ridge north of Mammoth Cave, and that is because this hill still retains its thick capping of the higher impervious formations overlying the limestone. Most of this region, in other words, is a plateau where underground drainage has brought about the present features, and where the mature stage of development has been reached. It is like block C in Figure 20.

The plateau ridges.—Three ridges in particular deserve to be noticed. In the center is Mammoth Cave ridge which throughout its entire length is followed by the highway from Cave City. North of this is Chestnut Grove ridge, somewhat higher than Mammoth Cave ridge in its northern part because of the capping of higher formations, but it is quite flat farther south and joins onto Mammoth Cave ridge near Little Hope School. The third or Elko ridge extends south and east from Elko toward Glasgow Junction. It is followed by the Mammoth Cave Railroad from Glasgow Junction to Sloans Crossing, at which point the railroad crosses over a narrow divide to the Mammoth Cave ridge. This divide corresponds with the feature marked X in block C of Figure 20. Several others of similar character are to be noted. Perhaps in time, ages from now, a natural bridge will develop at that point as the sinks on either side are deepened and the underground drainage lines come to view.

Beneath each of the plateau areas there is an extensive system of channels and passageways which constitute the caves for which the region is famous. Mammoth Cave extends for many miles beneath Mammoth Cave ridge. It can be entered from several points around the margin of the plateau. Various entrances known and used at earlier dates have been filled in and obliterated to prevent intrusion. There are undoubtedly many places where one could, with the removal of some of the talus material, gain entrance to some part of Mammoth Cave in this

manner. The presence of bats, and of insects which spend part of the time each year on the surface of the ground, and also accumulations of debris, leaves, and other parts of plants in remote sections of the cave suggest the proximity of small openings through which these animals and this material have gained access to the underground channels. The New Entrance to Mammoth Cave was developed by removing material from the surface at a point near a known part of the cave. It is several miles distant from the main entrance to Mammoth Cave and visitors through either entrance never explore those portions of the cave tributary to the other entrance. The statement is frequently made that Mammoth Cave has over 150 miles of explored passageways. As a matter of fact it probably contains hundreds if not thousands of miles of channels of all sizes, for this limestone mass is literally honeycombed with openings.

Beneath Chestnut Grove Ridge there is undoubtedly a maze of caverns perhaps even more extensive than that under Mammoth Cave ridge, because of its greater size. Several well-known caves have been opened up around its margin. Colossal Cavern just across Houchins Valley from Mammoth Cave is entered from the side of the valley sink under conditions very much like those at the New Entrance Cave. Mammoth Cave, however, gains its entrance in a little ravine which descends toward Green River from the western end of Mammoth Cave ridge. Great Onyx Cave on the north side of Chestnut Grove ridge is like Mammoth Cave in that respect. The entrance to Great Onyx Cave overlooks the immediate gorge of Green River. It was discovered by the presence of cave deposits, that is, the so-called onyx of stalactite formations on the surface of the ground, and this was believed to indicate the nearby presence of a cavern which had slumped in along this steep valley wall.

Great Crystal Cave has a similar entrance along the side of Green River gorge. Great Salts Cave, unlike most of the caves of the region, is entered through the side of a steep-walled sink. This sink, however, really represents the upper portion of a valley of a stream which flowed at one time toward Green River, but whose headward part has already become detached by the development of a sink hole. There are several other similar

sinks in this immediate region. There are several other caves too. These are undoubtedly all parts of a vast system of underground openings. Salts Cave vies with Mammoth Cave in the size and extent of its many passageways.

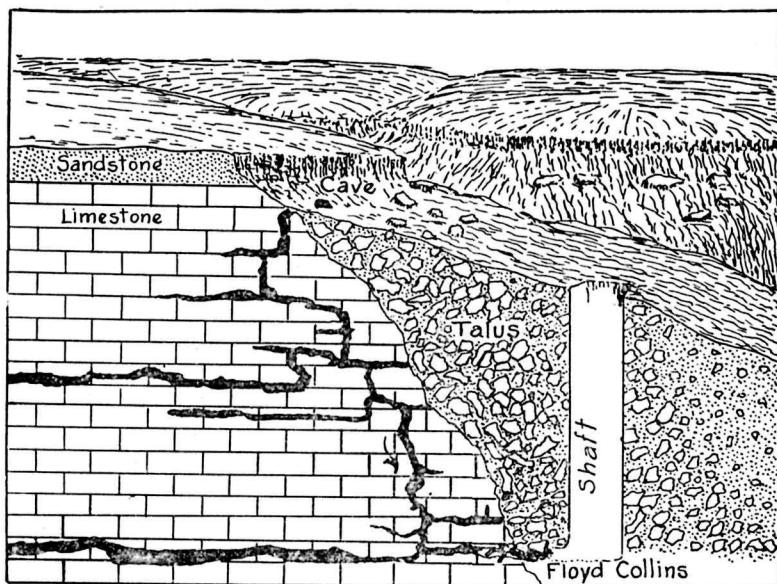


FIG. 25. GEOLOGICAL CONDITIONS AT SAND CAVE.

This diagram shows that Floyd Collins was trapped not in the cave but in the loose talus material on the side of the hill through which he was trying to work his way. The shaft by which his body was later removed was put down through this loose debris.

Sand Cave, in which Floyd Collins lost his life, is entered on the north side of Mammoth Cave ridge not far from Little Hope School. As yet it hardly deserves to be called a cave inasmuch as the passageways are so small and tortuous as to preclude its visitation by tourists. An explanation may here be given as to the reason Floyd Collins was trapped underground at this point, and also why it was possible to construct a shaft from the surface to the vicinity of his body. Figure 25 shows diagrammatically a section of this part of the plateau. There is nothing peculiar about the region. It is like miles and miles of plateau margin. Underground passageways abound. Some of them are horizontal, following the bedding planes, others are more or

less vertical, following joints which have been enlarged by the solvent action of water.

The slope of the plateau toward the valley sink is made up of loose fragments broken from the plateau margin. This is common everywhere. It is the way the plateaus are destroyed and the valley sinks increase their area. Floyd Collins penetrated to a depth of over a hundred feet through some of the small passageways. Then, losing his direction for some reason, instead of going on beneath the plateau he advanced toward the valley sink area and encountered the mass of disordered fragments. For a short distance he was able to find crevices through which he could crawl feet first, but his movements dislodged some of the loose blocks which fell upon him and pinned him there.

The valley sinks.—The extensive sinks and hollows may now be pointed out. To the south of Mammoth Cave ridge are Deer Park and Doyle Valley (Figure 24). The general aspect of Deer Park is shown in Figures 6 and 11. Doyle Valley is much larger. It ramifies in all directions into the surrounding plateaus, and on its floor there are numerous pits and sinks, several of them containing permanent ponds. To the south of Elko ridge is a magnificent series of hollows separated from each other by bits of plateau that have been almost entirely consumed through the development of the numerous sinks. Owens Hollow and Woolsie Hollow constitute the eastern end of this system. Just west of Cedar Hill School we may note several large sinks which presumably represent the position of earlier drainage lines now dismembered by the development of sinks along the course of the stream, somewhat like the condition represented in block B of Figure 20. Hunts Sink and Double Sinks on the northeast side of Mammoth Cave ridge are of similar type. The finest example in the entire area of a valley whose headward portion has been replaced by a sink is to be seen on the northwest slope of Chestnut Grove ridge, just a mile southwest of Great Onyx Cave.

Near Cedar Hill School, too, there are many hollows which open out toward the Pennyroyal Plain at the south. These undoubtedly occupy the position of drainage lines formerly flow-

ing southward. In several cases these valleys in advancing headward have encroached upon other streams which flow to the north. It is impossible to state in every case whether this diversion or capture preceded or followed the development of the sinks.

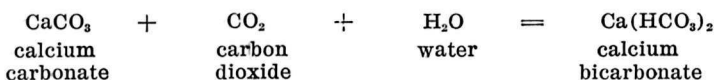
North of Mammoth Cave ridge is another splendid valley sink or hollow known as Houchins or Eden Valley. Like all of the others it contains great depressions which head back into the bordering plateaus. East of Chestnut Grove ridge there is a vast area of sinks and depressions with an occasional mesa-like remnant of the former plateau standing out conspicuously above the lower pitted country. Part of this is known as Johnson Valley. This region has passed beyond the mature stage, for over wide areas all evidence of the plateau which at one time occupied this region has disappeared. The term late maturity may be applied to the stage of development here represented. Figure 24 shows only the margin of this tract of country. On the Mammoth Cave topographic sheet, however, much more of it may be seen.

THE CAVES AND THEIR DEPOSITS.

The development of caves. Caves are by no means found only in limestone regions. Lava flows, for example, often have extensive underground openings resulting from the fact that the surface of the lava cooled and hardened and the part still fluid beneath ran out, leaving a tunnel covered by a roof. Waves frequently produce caves along the coast by their constant pounding and washing away the weaker rocks. Sandstones and other types of sedimentary formations often have vertical cracks or joints which gradually widen through weathering or by slight movement of rock masses and these spaces may then be entered. Bears often have their dens in just such places.

The most extensive caves occur in regions of thick and comparatively pure limestone formations. The solubility of the limestone is of course the prime reason for the presence of the caves. Dense and massive limestones tend to a maximum development of caves because such beds are practically impervious to water except along fissures and bedding planes, and by the concentration of solution in certain places much larger cavities result. Comparatively porous limestones, on the other hand, which offer free passage for the water in all directions do not usually develop caves, nor sink holes, except where the circulation of the water is concentrated locally.

The chief constituent of limestone is calcium carbonate which is only slightly soluble in pure water, that is, chemically pure H_2O . Approximately 75,000 parts of water are required to take into solution one part of calcium carbonate. Rain water, however, is not strictly pure but contains some carbon dioxide which it absorbed from the air. These carbonated waters act upon the limestone and produce calcium bicarbonate, thus:



The resulting bicarbonate is 30 times as soluble as the calcium carbonate, even in pure water. But if the water still con-

tains some carbon dioxide it is even more effective as a solvent. We see, therefore, that the presence of carbon dioxide in the water, absorbed either from the air or from the soil renders it highly capable of dissolving away the limestone. In fact, the amount of water which falls as rain upon one acre of land in the Mammoth Cave region in the course of a single year is capable of dissolving some 25 or more cubic feet of rock. Or expressed

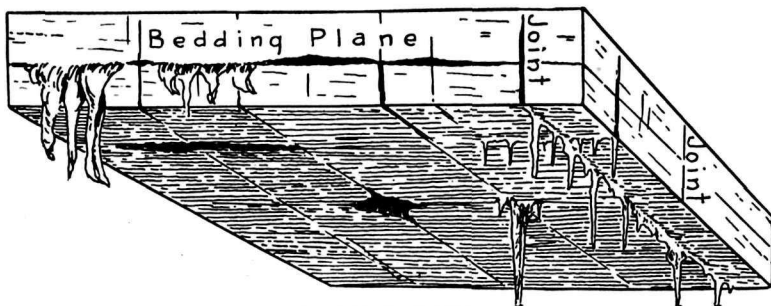


FIG. 26. DIAGRAM SHOWING BEDDING PLANES AND JOINTS

The bedding planes of the rocks in the Mammoth Cave region are practically horizontal, the joints are practically vertical. Both bedding planes and joints provide means by which water can work its way through the rock and hence bring about solution. Stalactites are here shown concentrated along the different planes.

differently, the rain falling on this region is easily capable of removing in solution one foot thickness of limestone from the entire region every 2000 years. Inasmuch as this solvent activity is concentrated so definitely in certain places it is not difficult to appreciate the method by which so many caves of such large size have been formed.

Concentration of water in massive limestones is effected in two ways, first along the joints or fissures, and second along the bedding planes. Nearly all stratified rocks are cut by cracks or joints, roughly vertical. These often occur in two sets or systems which intersect each other at nearly right angles (Figure 26). Such joints offer avenues whereby the water which has soaked into the soil may penetrate downward to greater depths. As the water descends along the joints, solution takes place, the joints are enlarged and crevices are formed. The intersection of two joints which cross each other is a particularly favorable spot for the penetration of water into the limestone. In such situations more or less circular openings are dissolved instead of the long narrow crevices produced along single joints.

Water which finds its way into the joints of the rock descends until its downward progress is brought to a stop. This may be the result of one of two causes: first, a bed, such as shale or a massive limestone layer which is impervious to water may be encountered; or second, the ground water table, or the depth at which all the openings in the rock are filled with water, may be reached. In either case, when the downward movement of the water is brought to a stop, lateral movement begins and channels are dissolved out along the bedding planes or in porous layers in the limestone.

Figure 27 depicts several stages in the development of caves and shows the relationship between the underground and surface features. In section A the drainage is practically all on the surface of the ground. Green River is shown in a valley but little below the surrounding country. The illustration simulates the Mammoth Cave region in showing a layer of sandstone capping the massive Mammoth Cave limestone formation. The sandstone does not readily permit surface drainage to seep through except at occasional places where joints occur. In section B we note that Green River has cut a deeper valley. This has lowered the ground water level and has enabled the water that seeps into the ground to penetrate deeper into the limestone mass. Several of the surface streams have been diverted to subterranean courses, and sink holes have thus begun to make their appearance. The position of sink holes has undoubtedly been determined by the presence of joints in the sandstone layer, whereby the surface water readily gained access to the limestone, or possibly by the fact that in places the sandstone was entirely removed by erosion.

Section C shows further advance. The river has cut to a lower level. The sink holes have been greatly enlarged. Surface streams have almost disappeared, except for the smaller rills, almost all of which find their way soon into the depressions. The cave system has now become more elaborate. Different "levels" may now be detected in the caves. These levels may be due to the presence of especially pervious or soluble beds in the limestone or to the fact that the river halted temporarily at different levels during the time that it was cutting down

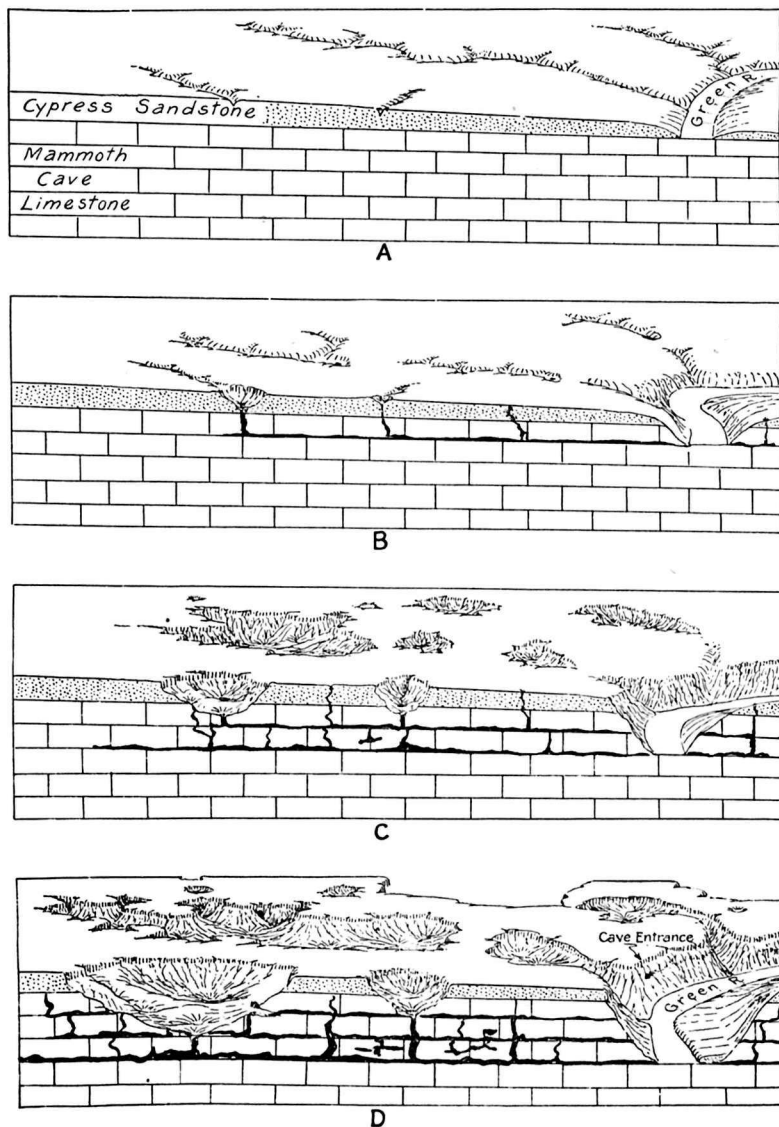


FIG. 27. FOUR STAGES IN THE DEVELOPMENT OF THE MAMMOTH CAVE REGION

These drawings show the conditions which result from the gradual cutting down of the Green River. A detailed discussion is given in the text.

its valley. It seems likely that the greatest activity in cave formation takes place along the joints down which the surface water is making its way into the caves, and in the bottom level where most of the surface water is concentrated. Some of the upper levels may of course at the same time still function as channels.

Section D shows by no means the final stage but only the conditions approximately as they exist in the Mammoth Cave region at the present time. Extensive valley sinks break the plateau up into different parts. The cave system is highly developed. The vertical channels have been greatly enlarged by running water so as to produce large underground cavities of great height. When viewed from the lower levels of the cave with which they communicate they are known as "domes," though rarely are they dome shaped. In fact they are usually narrower at the top and flare out at the bottom. The frontispiece gives the general aspect of such a dome. The walls, fluted and channeled by running water, rise majestically to great heights into a realm of darkness, like the walls and columns in the interior of a Gothic cathedral. From an upper level a view down into one of these great wells is equally impressive. The lower portion is called a pit.

In section D the sinks have increased in area through the weathering back of their walls. Sinks occasionally are enlarged by the collapse of the cavernous passageways beneath them. When this occurs they are apt to have steep sides. However, it is not believed that this occurs very commonly, nor is it believed, as is occasionally stated in text books, that natural bridges are generally formed by the collapse of the roof of a cave, one portion of which still remains intact. Not that this is impossible but that the general collapse of a cave almost never occurs. In fact no natural bridges are known in the Mammoth Cave area.

The sandstone capping at the top of the plateau (Figure 27, section D) causes the upper portion of the walls to have a vertical form but the lower slopes are more gentle. It is here that cave openings may occasionally be discovered. Were it not for the accumulation of talus and debris washed from above many more cave openings around the valley walls would be visible.

Cave channels and passageways are developed not only by the solvent action of water but also by its erosive force, in the same manner as on the surface of the ground. This is aided by the fact that the underground streams often contain a great deal of silt which has been carried into them from the surface of the region above. When it is realized that all the material which formerly filled the spaces now occupied by the sinks and depressions has been carried underground through various swallow holes in the floors of the sinks it is easy to understand that much sand and silt must thus be carried into the caves. This sand and silt comes in part from the disintegration of the capping sandstone layer, and in part is the residual soil left after the limestone is dissolved away. This residual limestone soil is usually red or orange in color. Accumulations of it may be seen in practically all the caves of the region.

This silt is the source of the nitrate deposits for which Mammoth Cave was exploited during the War of 1812. Nitrates of calcium, sodium, and potassium are present in this earth and are probably derived from the excretions of bats which formerly lived here in great numbers. In some of the caves many bats are still found. In some of the halls of Colossal Cavern hundreds if not thousands of bats are to be seen hanging in groups of dozens from the rough ceiling. The nitrates were leached out from this "peter dirt" as it was called and the resulting saltpeter was used in the manufacture of gunpowder. During the Civil War many of the caves of Tennessee provided a similar source. Water was conducted into the cave through a wooden pipe and the concentrated solution pumped back to be evaporated outside of the cave. These pipe lines and leaching vats are still seen by all visitors to the cave.

Cave passageways in general are of two types, those which follow the joints and those which follow the bedding planes. The former are apt to be high and comparatively narrow. The latter are apt to be wide and comparatively low. However, both types, after they have been produced, are much modified by the constant cracking off of fragments from the walls and roof. This material, falling on the floor of the cave, is ground up and washed away by streams of water. Sometimes gigantic "halls" result, having a height of 100 feet or more, and encompassing

an area of an acre or so. When the ceiling of a cave consists of a firm and massive layer of limestone it is less subject to destruction in this manner. Some such ceilings extend over thousands of square feet of cave, as flat and uniform as an artificial structure.

The natural tendency, however, is to develop the form of an arch inasmuch as this provides the greatest strength. Sometimes the material which has broken from the ceiling accumulates in such quantities on the floor of the cave as to close it off entirely, though usually there are little openings between the top of the pile and the ceiling through which a person can crawl. Explorers in caves are rarely daunted in following a large passageway, to find it interrupted in this manner, knowing that beyond the obstruction it will open out again.

Cave Deposits. To most visitors the deposits of calcium carbonate in the form of stalactites, stalagmites, and other fantastic shapes constitute one of the chief features of interest in caves. The deposition of this material is due to the fact that water containing carbon dioxide seeping through the limestone takes into solution appreciable quantities of calcium carbonate. If the water moves through the rock quickly and finds its way promptly to an underground stream it will be able to carry off all that it has had opportunity to dissolve. But if it is delayed in its progress due to the fact that it goes through very small cracks, and also if it comes through in relatively small quantities so that its flow is not rapid, it has opportunity to become saturated with mineral matter in solution. Then as it drips slowly from the ceiling or flows in an extremely thin film over rock surfaces, it evaporates and the material in solution is deposited. Another reason for the deposition of mineral matter is the fact that it loses its carbon dioxide due to agitation as it trickles over rough rock surfaces. And as we have noted before, the presence of carbon dioxide makes the water many times as effective a solvent of limestone as if it were strictly pure water.

Stalactites. Figure 28 shows in the upper-most view several of the forms commonly assumed by deposits of calcium carbonate. On the ceiling of the cave are to be seen the stalactites, hanging like icicles, but having greater variety of form than icicles do. Beneath the stalactites, and rising from the floor of

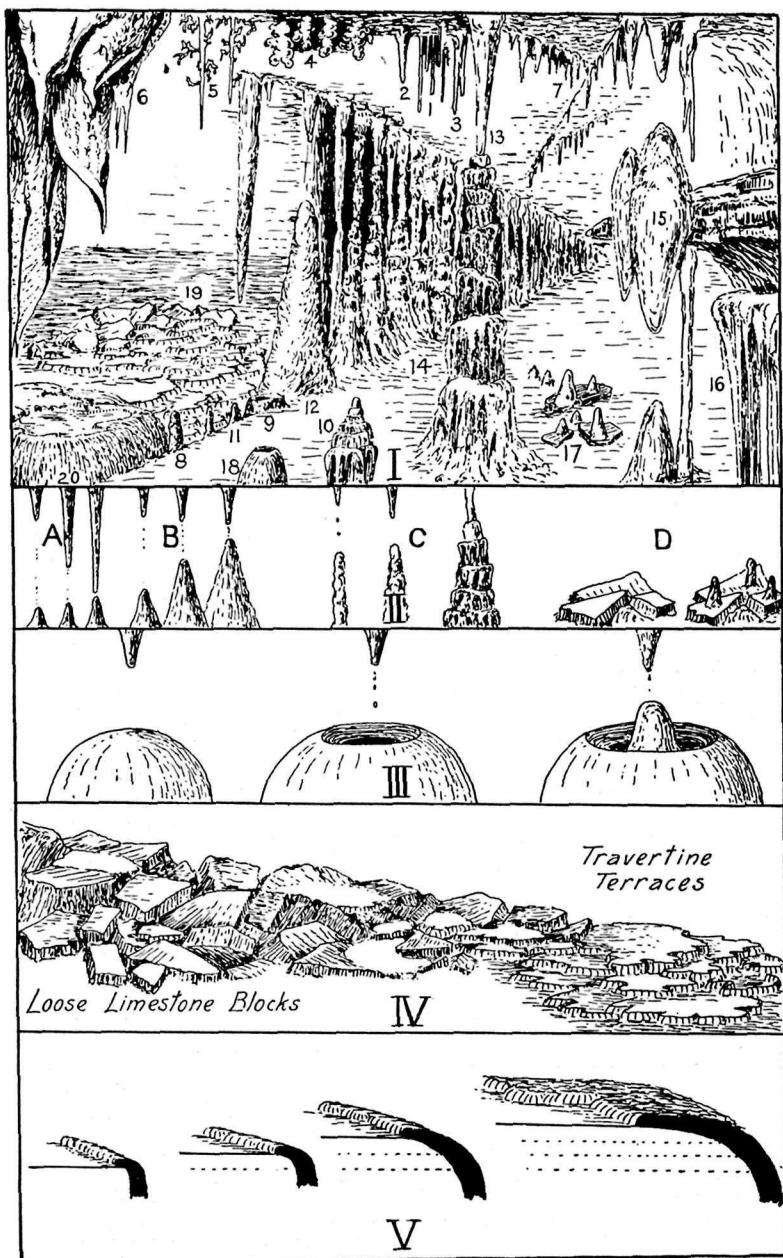


FIG. 28. CAVE DEPOSITS

I. Twenty kinds of cave formations are illustrated. II. A shows relation between stalactite and stalagmite when the dripping is slow. B shows relation when dripping is fast. C shows development of columns. D shows how stalagmites sometimes form on loose blocks. III. Stalagmite formed and then cut through at the top by a renewal of the dripping from above; this followed by development of new stalagmite in the center of the old one. IV. Development of terraces. V. Development of bowls or cauldrons, shown in No. 20 above. All of these forms are discussed in the text.

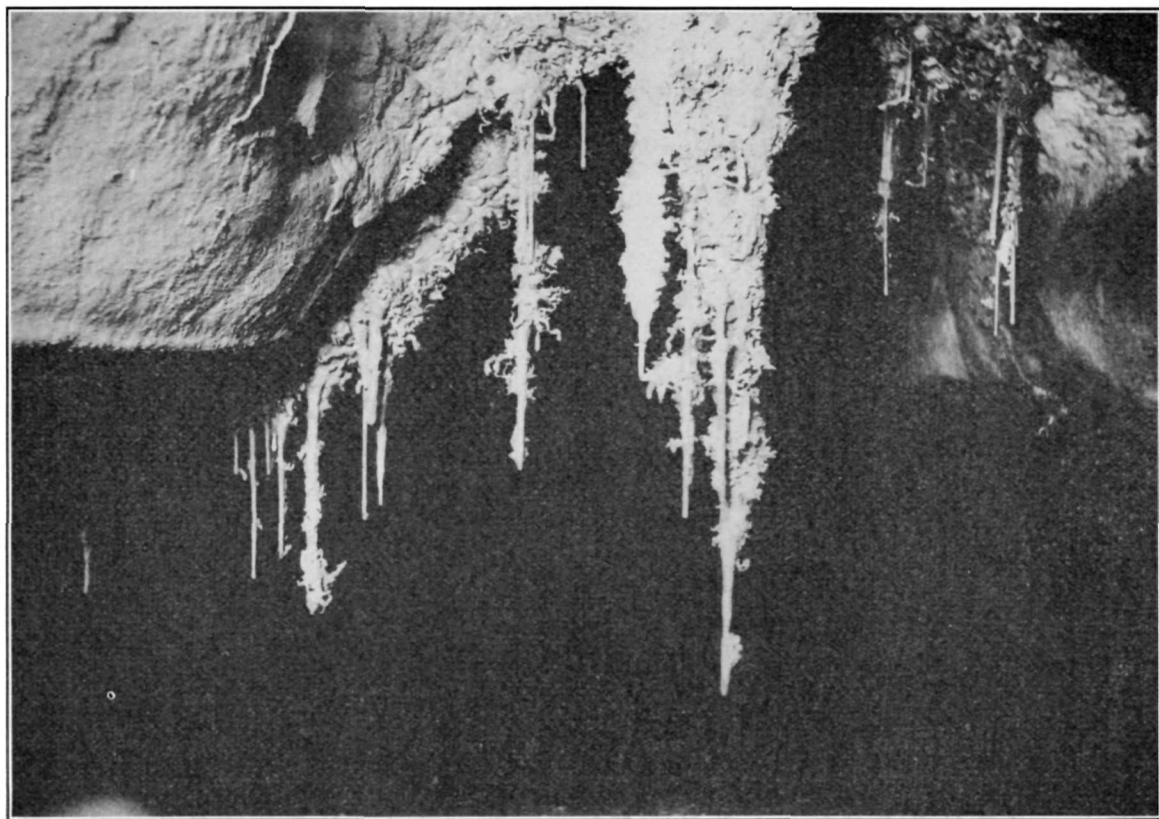


FIG. 29. STALACTITES COVERED WITH HELECTITES

These branching and twisted deposits result probably from impurities in the water which affect the direction of crystal growth. Most of the caves contain examples of this type. Those illustrated here are from the Great Onyx Cave.

the cavern, are the stalagmites, also very varied in their shape and size. Some of these different forms may now be considered, as to manner of origin. Form 1 is a long simple pendant. This results when the water seeping through the porous rock above flows relatively fast. Such forms are usually hollow. That is because a drop, first forming on the ceiling, evaporates most near its margin and this tends to build up a little rim which, as it increases in size, becomes a cylinder. The water flows through the tube thus formed and drops from its end. Such tubes are often extremely delicate, usually white or almost transparent, and quite uniform in thickness, having the diameter of a pencil for a length of a foot or more. In time, however, the opening in the center becomes so small by the deposition of mineral matter and perhaps also by becoming clogged with impurities, that the water starts to flow down the outside of the stalactite. This, as shown in No. 2, causes the stalactite to increase in thickness, especially at its upper end. Sometimes pronged forms appear, as at 3, where two stalactites become united. Grape-like clusters (4) result when the flow is less rapid, in fact when all the water evaporates without dripping off. Branching forms, known as helectites (5), (also Figure 29), result probably from the presence of impurities in the dripping water. These impurities, such as grains of sand or silt, accumulate on the outside of the stalactite and cause a change in the direction of crystal growth at those points. Sometimes great sheets or draperies are formed (6), (also Figure 30), frequently combined with other forms. These result probably from the fact that the water does not drip off from a single point but from a ledge. It also occurs when the water is highly charged with mineral matter and deposition takes place over a considerable area before the water has had time to concentrate in a single drop. Sometimes the draperies are colored with mineral matter, usually oxides of iron which give red, yellow, and orange tints to these translucent formations. Stalactites frequently follow the joint planes (7), (also Figure 31), in the ceiling because the water seeps most readily through those places.

Stalagmites. Stalagmites rise from the floor of the cave. They owe their position to the fact that water dripping from above lands on the floor and there evaporates, leaving its burden

of mineral matter. If the amount of water which drops down is relatively small so that it evaporates almost immediately the stalagmite is apt to rise rather pointedly from the floor. Its base will not be large (8). But if the amount of water which falls is considerable so that a little puddle is formed, then deposition will take place around the margin of the puddle and the resulting stalagmite will have a broad base (9) and usually a flat top or perhaps a slight depression at the summit. As the stalagmite grows up there may be a succession of flat disc-like parts and pointed columnar portions alternating with each other as shown at 10 in Figure 28. Around the margin of the discs are draperies and stalactites formed by water flowing down over the sides. Such forms are often extremely beautiful and frequently very elaborate in their make-up, especially if they are large.

The relation between stalactites and stalagmites may now be considered. If the stalactite drips very slowly so that most of the water is evaporated before it has a chance to fall off, then the stalactite will rapidly increase in length while the stalagmite rises very slowly, this being shown at 11 and at A in Figure 28. But, on the other hand, if the water remains suspended for only a short time, then the stalagmite instead of the stalactite shows the more rapid growth. This is shown at 12 and also at B in Figure 28. Other factors such as the concentration of the solution also play a part. When the stalactite and the stalagmite ultimately join a column is formed (13). Such columns, as might be imagined, assume every conceivable shape, dependent upon the various conditions above discussed.

Other interesting features shown in Part I of Figure 28 may also be pointed out. At 14 there is represented a row of pillars standing like a wall in the middle of the cave. These follow the course of a joint or crack. An example of this may be seen in Whites Cave near Mammoth Cave Hotel. A rather interesting combination of features is shown at 15 where a projecting ledge or shelf has intercepted the dripping from above and has caused the growth of a second set of stalagmites and stalactites. The flutings and columns shown at 16 are formed wherever water pours over a ledge or projection. Sometimes these reach magnificent proportions, as in the Corinthian Columns in Mammoth Dome of Mammoth Cave, or in the

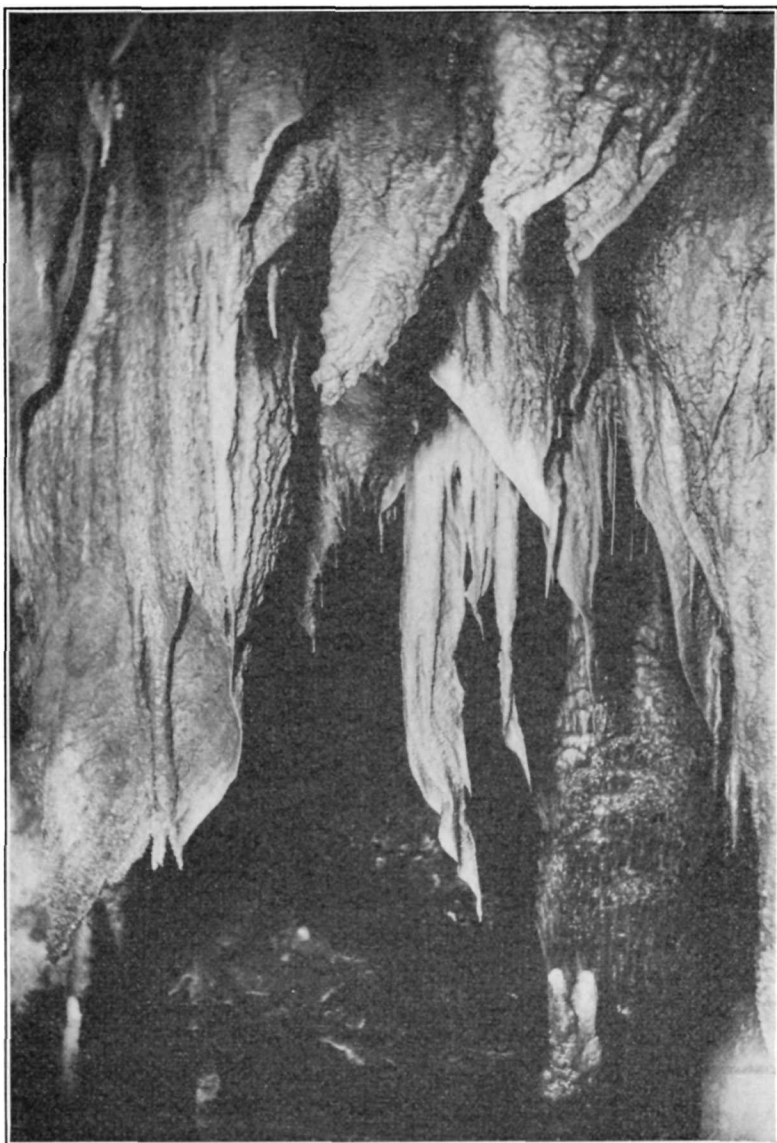


FIG. 30. DRAPERY DOME IN GREAT ONYX CAVE

Stalactites often assume the form of flat bands and sheets when the water flows over smooth surfaces and deposition takes place along an edge instead of at a single point.

Frozen Niagara of New Entrance Cave. This last mentioned feature is one of the most impressive sights in the whole Mammoth Cave region. At 17 and also at D just below, stalagmites are shown perched upon loose blocks which have fallen from the roof of the cave. Usually stalagmites are frozen so hard to the floor upon which they stand as to be quite immovable. Forms like those represented, however, can actually be carried around. In Violet City of Mammoth Cave there are several such blocks bearing stalagmites a foot or two in height.

The form shown at 18 in Figure 28, and also more clearly in Part III of the same illustration, is rather exceptional. It represents a stalagmite, more or less rounded at the top, as is frequently the case. After having assumed that form it apparently ceased growth for a time and became dry. This was followed by renewed dripping which, instead of adding to the deposit, actually wore through the top of the stalagmite, forming a kind of crater. This erosion was undoubtedly facilitated by the fact that when the stalagmite became dry it developed cracks and this made it a ready prey to the impact of water dropping from above. This may be followed, as shown in the same illustration, by the growth of another stalagmite in the center of the old one.

At 19 in Figure 28 we note the development of terraces. These resemble very closely the terraces of the Mammoth Hot Springs in Yellowstone Park. The mode of formation is suggested in Part IV of Figure 28. At first there is an irregular surface over which the water flows, accumulating here and there in pools. At the edges of the pools where it overflows calcium carbonate is deposited and this tends to build up a little rim. The water in consequence rises and the rim is further increased both in height and in length. Pool after pool develops in this fashion, at many different levels, until the whole irregular surface is covered over. At the far end of Whites Cave there is a fine display of this type.

Sometimes, as at 20, bowl-like or cauldron-shaped features are produced. The succession of events leading up to such a form is suggested in Part V of Figure 28. It is similar to the terraces in having a rim. This rim, however, not only grows in height but at the same time it advances inward over the surface of the water due to the deposition of material on its inner edge.

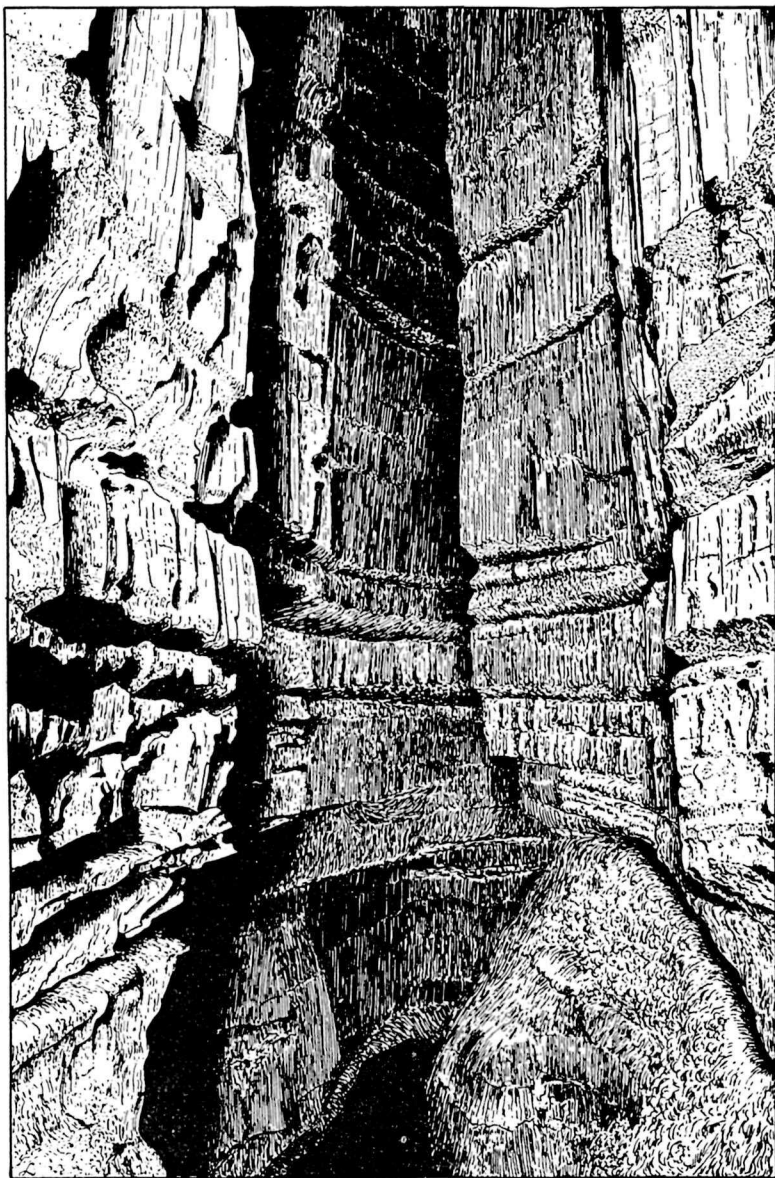


FIG. 31. VAUGHN'S DOME IN COLOSSAL CAVERN

The vertical lines are formed by running water which has come through from the surface of the ground above. The horizontal lines are due to the bedding planes of the limestone. The deep shadow, the absolute silence, and the magic beauty of the towering heights call to mind the interior of a Gothic cathedral. Domes of this type are found in several of the caves and are of special interest.

Sometimes the water level remains constant, in which case no increase in height takes place but the rim continues to encroach on the surface of the water, thus forming a flat shelf.

For most of the forms just described the term "onyx" is popularly used. Strictly speaking, however, onyx is a deposit of silica. Travertine is the correct name for these calcareous formations. The term "cave onyx" has also been suggested. Impurities of various kinds are always present. If in the form of iron oxide, the travertine assumes a reddish or yellowish hue, often very pleasing in tone. Sometimes manganese dioxide is present and this imparts a deep black color to the formations. The ceiling of many caves, as in Star Chamber, for example, of Mammoth Cave, is coated over with manganese dioxide which often takes the form of jet black patches. Crystals of calcite sparkling through the mass simulate the stars. The iron and the manganese in these instances have usually been leached from the formations overlying the limestone. Sometimes the iron oxide is deposited in cracks or joints of the limestone and there forms a very resistant vein which stands out like a ridge when the limestone is later dissolved away.

Crystal forms in caves.—Some caves exhibit beautiful sparkling surfaces coated entirely with calcite crystals. These deposits, unlike the travertine, were probably formed in the cave at a time when it was filled with water charged to a high degree with calcium carbonate in solution so that very slight changes in the conditions, as for example loss of carbon dioxide, caused some of the calcite to be deposited.

Gypsum or hydrated calcium sulphate is another common deposit on the walls of caves. The presence of sulphur is accounted for by the fact that pyrite is frequently found in the overlying shale through which the water seeps. Moreover, analyses of the limestone show considerable calcium sulphate to be present in the rock itself. Sometimes the gypsum deposits take the form of elaborate rosettes several inches in diameter, often of exquisite beauty (Figure 32). In other places the gypsum occurs as long hair-like fibrous crystals on the walls or in the silt filling the caves. Epsomite or magnesium sulphate occurs in some caves as masses of fine fibrous crystals coating

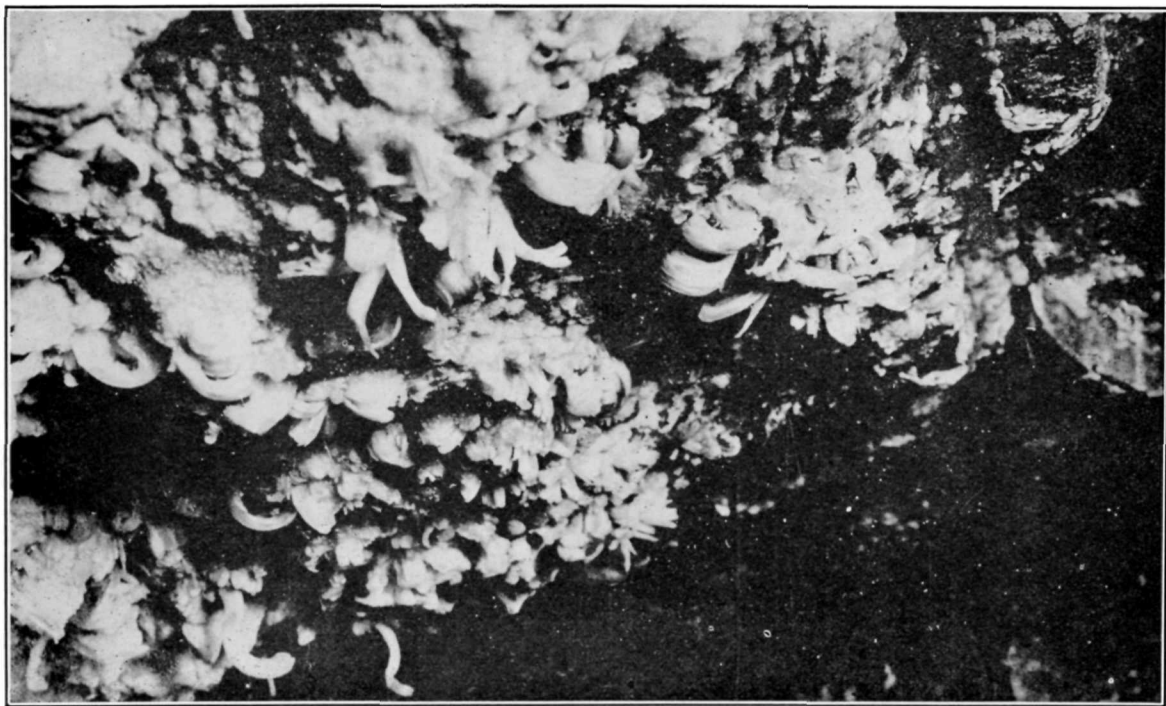


FIG. 32. GYPSUM CRYSTALS IN GREAT CRYSTAL CAVE.

The gypsum crystals assume the form of flowers or rosettes, curving out as long snowy white fibers from a central point.

the cave walls. It is found abundantly in Great Salts Cave and also in parts of Mammoth Cave.

Cave Life. The two commonest forms seen by all visitors to the caves are the small brown bats and the so-called cave cricket or Katydid, both illustrated in Figure 33. Some of the

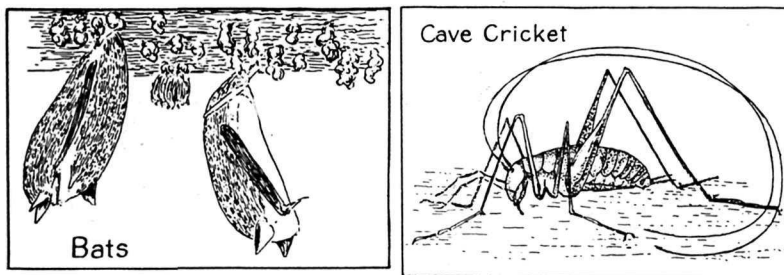


FIG. 33. EXAMPLES OF CAVE LIFE

The little brown bat is very abundant in some of the caves, notably in Colossal Cavern where thousands of them may be seen hanging in clusters from the ceiling. The cave cricket, really a katydid, is to be seen in every cave. Its very long antennae are extremely sensitive and compensate to some extent for its sightless eyes.

white or almost transparent blind crawfish are also to be seen in the pools. Numbers of small cave beetles abound in a few places. In the list of references citation is made to sources of information upon these interesting forms.

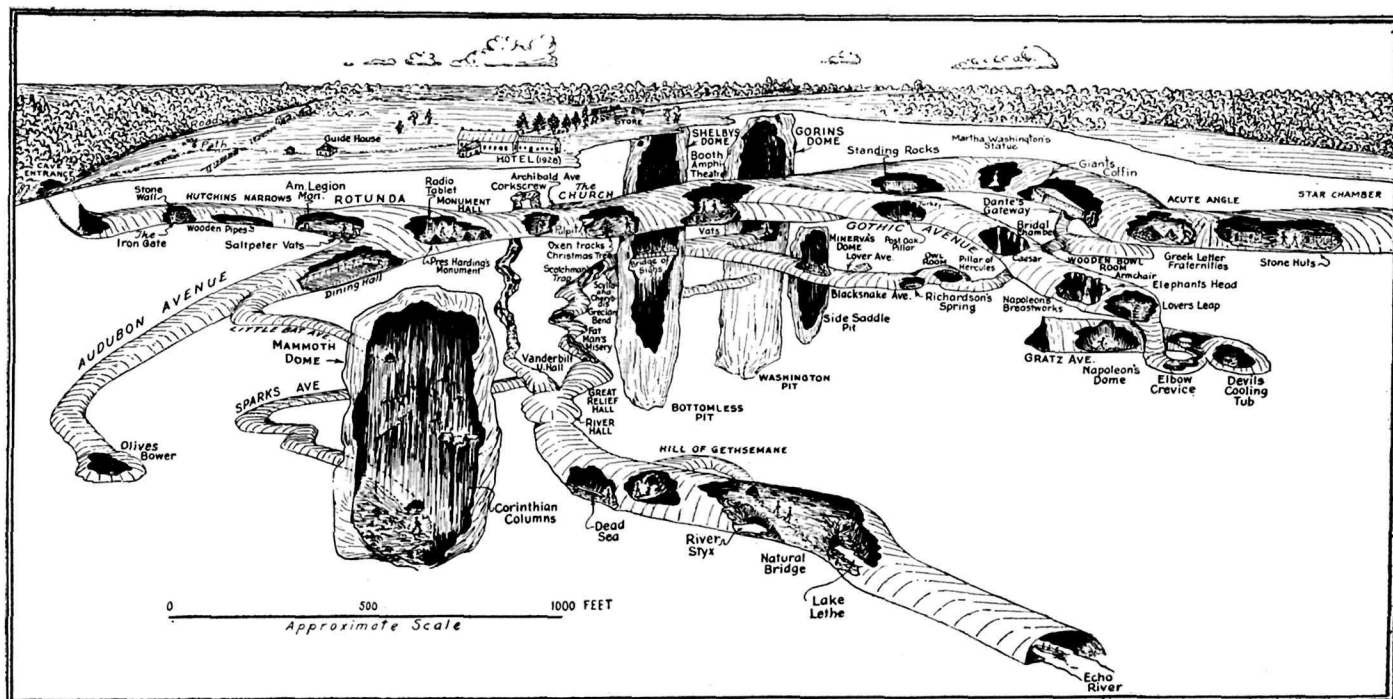


FIG. 34. DIAGRAM OF MAMMOTH CAVE

Showing graphically the passageways which are followed on Routes I and II. Described more fully in the text.

DESCRIPTION OF MAMMOTH CAVE

The average visitor, after a trip through Mammoth Cave, comes out above ground with little or no idea of the relative position of the various passageways he has traversed. The large diagram, Figure 34, of the cavern reproduced herewith attempts to portray in a graphic manner that portion of the cave which is most frequently visited. In fact, only those parts covered on the standard routes No. 1 and No. 2 are shown. Trip No. 3 takes us far beyond Star Chamber along the main avenue of the cave. Trip No. 4 goes down to Echo River and then four miles or so beyond, some of it by boat, and all of it along the lowest level of the cave. The various pasageways and domes illustrated in the diagram, intricate as they seem, represent only a portion of the many caverns and openings known to exist under that part of the plateau.

It is quite unnecessary to present here a detailed account of the features of interest to be seen on the trips through the cave inasmuch as several excellent guide books already render that service. The diagram can well be used in conjunction with any of the guide books. Most of the features mentioned therein are depicted on the drawing. A few facts of general interest may not be unwelcome, however.

The diagram shows more or less clearly a number of different cave levels. The main avenue of the cave, sometimes known as Broadway, represents the second level. The first level is a bit above it and is represented by Gothic Avenue, entered by a stairway from Booth Ampitheater. The third level lies beneath the second level. It is represented by Blacksnake Avenue which is entered by going through Dante's Gateway from the Main Avenue at Giant's Coffin. It is from this level that three domes are visited, namely Minerva's Dome, Gorin's Dome, and Shelby's Dome. Below each dome is a corresponding pit, known respectively as Side Saddle Pit, Washington Pit, and Bottomless Pit.

The fourth level is reached from the third level by going through the Scotchman's Trap and Fat Man's Misery to Great

Relief Hall. This hall, with Vanderbilt University Hall and Sparks Avenue, constitute parts of the fourth level. From this level Mammoth Dome is visited. Inasmuch as this level brings the visitor out near the bottom of the dome, the corresponding pit is not very deep and does not therefore receive any particular designation.

Mammoth Dome can also be visited through Little Bat Avenue from Audubon Avenue, representing part of the second level. This comes out near the top of the dome. It is not a part of any regular trip but it is used as a route through which lumber for bridges and boats can be taken to the river level without going through the various narrow and roundabout passages heretofore mentioned. The lumber is lowered from the mouth of Little Bat Avenue by a pulley to the bottom of Mammoth Dome whence it is but a short distance to River Hall.

The fifth level is that of Echo River and is reached by passing from the fourth level through River Hall. Practically all of Trip No. 4 follows this level, whereas all of Trip No. 3 follows the second level.

In addition to the levels mentioned there are many other intermediate levels. Moreover, any given "level" does not remain constantly level but may have a range in elevation as great as 40 feet. The various levels correspond with bedding planes of the limestone. Throughout the cave the horizontality of the rock is apparent. Sometimes, as in Gothic Avenue, beautiful flat ceilings may be noted, where the limestone is free from joints. It is on this ceiling that so many of the old names are to be seen, marked there with the smoke of candles as early as 1817. The departure from horizontality in the floor of many of the avenues, notably on the main avenue followed on Route No. 3 to Violet City, is due to the accumulation of tabular blocks that have fallen from the ceilings. Such fragments are apt to be abundant where the rock is most intersected with joints.

The domes and pits of the cave correspond with widened joint planes and have a vertical extent almost from the plateau surface to the river level. There is no doubt that these have been formed by water seeping through from above and finding an outlet below at the lowest level of the cave. In some places, as

at the Corinthian Columns in Mammoth Dome, part of the burden of limestone thus removed has been redeposited.

In addition to the avenues which correspond with the bedding planes and to the domes and pits which represent the vertical joints, there are occasional smaller and much more devious ways from one level to another, formed by currents of water. Such channels are often narrow and show clearly the scouring effect of the moving water. Elbow Crevice at the end of Gothic Avenue is the best example. Fat Man's Misery is somewhat similar. Still another type of passageway is that represented by the Corkscrew which provides a very direct means of getting from the main cave, second level, down to the river level. It owes its presence to the breaking away of a great mass of limestone. Numerous blocks of all shapes and sizes became dislodged and it is through this maze of disordered rock that the Corkscrew makes its way.

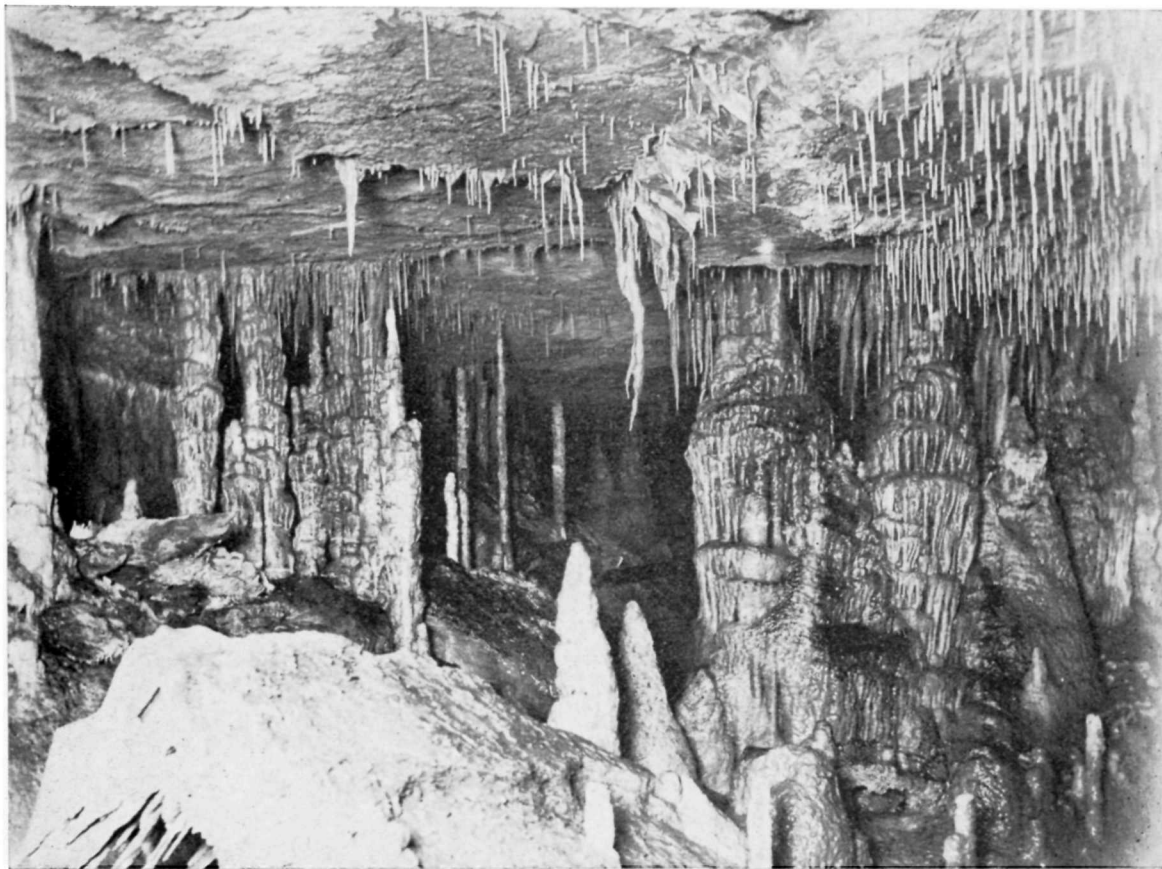


FIG. 35. TERRACE COLUMNS, GREAT ONYX CAVE

A typical cave interior showing stalactites, stalagmites, and columns of different shapes. The stalactites frequently follow the joints in the ceiling.

NOTES ON THE HUMAN GEOGRAPHY OF THE MAMMOTH CAVE NATIONAL PARK REGION

To the person interested in human geography the contrast between the sections north and south of Green River is of especial interest. In both sections, as in practically all other parts of the world, the local or smaller physical forms are influential primarily in the way they affect the location of cultural features such as roads and towns, and in the utilization of the land. Taken in a large way, the general tone or quality of the region is imparted by its accessibility to or remoteness from the driving forces of the world.

Thus viewed, we mark at the outset that the entire area is just off the great lane of travel which traverses the Pennyroyal Plateau from Louisville to Nashville. While relatively rugged the region offers no especial difficulty to penetration. The Dripping Springs Escarpment is by no means a barrier. And consequently we find the influence of the outside world reaching into this hilly belt with little interference for ten miles or more until the Green River gorge is encountered. This interposes a barrier to farther penetration and introduces an element of isolation to the region lying beyond. Moreover, the region lying between the Pennyroyal and Green River has its many caves to which annually thousands of tourists find their way. This helps to maintain a close contact with outside influences and to diversify the activities of the people who constantly live there.

As a whole, the region south of Green River is an agricultural one. The farms are located on top of the mesa-like plateau areas because there the land is level, and the soil derived from the capping sandstone is good and retains a large amount of moisture, whereas in the extensive sinks every drop of rain disappears immediately far underground. Occasionally the lower parts of the sinks are cultivated, but their inaccessibility, small extent, and inconvenient forms cause such patches to be of very little importance.

The character of the agriculture here is directly the result of the conditions mentioned. Tobacco constitutes an important

cash crop, readily sold on the Pennyroyal Plateau where the raising and marketing of tobacco is a staple industry. The production of garden vegetables and fruits, and the raising of chickens, all for the nearby hotels, is an important element in the agricultural life. But by no means do the people in this



FIG. 36. RAILROAD TIES READY FOR SHIPMENT BY BOAT ON GREEN RIVER

Practically every farmer derives some income from this source. The ties are of oak and sell for about thirty-five cents each. They are trimmed by hand with a large ax, the preparation of one tie taking about twelve to fifteen minutes.

region depend upon agriculture. There are numerous opportunities to work around the hotels and caves, to build roads, and to serve tourists in other ways, to say nothing of the ease of getting work in the nearby towns of the Pennyroyal. This accounts for the negroes found living in this region. With opportunities such as these they are able to survive with little need for initiative on their own part.

Besides farming there is also the cutting of timber and the making of railroad ties (Figure 35). Although this industry is no longer the great predominating activity it once was when thousands and thousands of ties might be seen on the river awaiting shipment by barge down stream to Evansville on the

Ohio, nevertheless it still constitutes a welcome source of income to practically every farmer.

Throughout this region one of the foremost problems is that of water supply for both animals and man. Figure 36 illustrates diagrammatically several of the devices used. At the right is

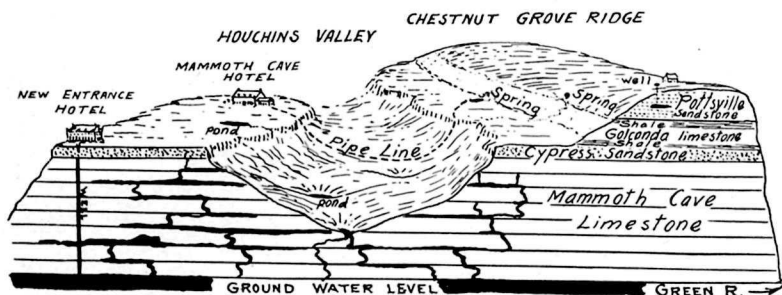


FIG. 37. DIAGRAM SHOWING VARIOUS SOURCES OF WATER SUPPLY

These include shallow wells in the Pottsville formation, deep wells reaching to the Green River ground water level, springs at various levels, and ponds in the sink holes.

Chestnut Grove ridge, capped with Pottsville sandstone. The farmers in this region put down shallow wells about fifteen feet deep until they strike small amounts of water held up by slightly impervious beds. These are known as perched water tables. Below the Pottsville are two pronounced shaly layers separated by the Golconda limestone. Each of these shaly beds is impervious and causes the water to seep along the bedding plane and appear on the hillsides in the form of springs. Several farms are thus supplied, especially those on the lower slopes. The water from such a spring is carried by pipe line to Mammoth Cave Hotel two miles away. The New Entrance Hotel, not having access to such a source, was obliged to drill a well several hundred feet deep until it reached ground water level below the plateau. For animals the ponds which occasionally are found in the bottom of sink holes constitute a very important source of water in the valley sink area.

The region lying north of Green River, and constituting about one-half of the proposed National Park, is not likely to be frequented very much by tourists. For many years its detached position forced the inhabitants to be dependent largely upon their own resources and ingenuity. Many of those who now

live there made their own clothes from the wool of their native sheep, and built their houses entirely from materials obtained right at hand. Indeed, some of these practices have not entirely disappeared. But gradually opportunities have provided contact with the outside world and now we find many of these people leaving their homes and securing employment in such places as the natural asphalt mines on the Nolin River near Brownsville. Farming, however, remains their chief occupation. Corn is a staple crop. Small mills run by gasoline power throughout the region provide corn meal for local use. Illicit stills are by no means unknown in this area.

NOTES ON READING MATERIAL

The most technical but at the same time readable description of the geology of this area is by Dr. James Marvin Weller in "The Geology of Edmonson County," published by the Kentucky Geological Survey in 1927. This presents in detail the chief facts relating to the geological formations and their characteristics and gives an account of the geological resources of the region from the economic standpoint, chief of which is rock asphalt. There is also a useful bibliography.

For Mammoth Cave in particular several interesting guides have been published, notably that by Horace Carter Hovey called "Mammoth Cave of Kentucky" and published in Louisville in 1912. This book gives an account of the things seen on the different trips through the cave as well as a description of Colossal Cavern. It includes, too, a chapter on the animal and plant life of the caves, and is well illustrated. Hovey's "Handbook of Mammoth Cave," published in 1909 is less elaborate.

Another similar guide by Helen F. Randolph is called "Mammoth Cave and the Cave Region of Kentucky." It was published 1924, at Louisville, and describes Great Onyx Cave, Crystal Cave, and several others. It includes an excellent bibliography of 96 titles on Mammoth Cave, prepared by Dr. Willard Rouse Jillson, State Geologist of Kentucky. Dr. Jillson has prepared another booklet called "Kentucky State Parks," published in 1924 by the Kentucky Geological Survey. This contains a brief description of Mammoth Cave as well as of a dozen other attractive regions of the state.

A description of the birds and mammals and other wild life of the region, including that found in the caves, is given by W. D. Funkhouser in "Wild Life in Kentucky," an illustrated report published in 1925 by the Kentucky Geological Survey.

Several articles relating to the physiographic development of features in limestone regions are worth attention by those interested in the scientific aspects of the subject. In 1910 J. W. Beede published a paper entitled "The Cycle of Subterranean Drainage as Illustrated in the Bloomington, Indiana,

Quadrangle," in the Proceedings of the Indiana Academy of Sciences. The principles evolved there apply equally to the Mammoth Cave area. A similar and more recent discussion by E. M. Sanders, entitled "The Cycle of Erosion in a Karst Region," appeared 1921 in Vol. 11, page 593 of the Geographical Review. This is a summation of a larger work in French by Jovan Cvijic, a Serbian well known for his investigations on the karst topography of the Adriatic area. This paper is illustrated with several very excellent diagrams. Other references to German and French literature are included. In the Geographical Review for 1924, Vol. 14, page 26, Cvijic contributed an article on "The Evolution of Lapies," the furrows so characteristic of some limestone regions, especially those having semi-arid conditions. Such features, however, are almost undeveloped in the Kentucky area.

A rather monumental work on caves in general is in French by E. A. Martel entitled "Nouveau traite des eaux souterraines," published in Paris in 1921, and reviewed in the Geographical Review, Vol. 11, page 630. In August, 1924, Dr. W. R. Jillson published in Vol. XLII of the Pan-American Geologist a very carefully prepared article entitled, "American Karst Country" which describes the unique sinkhole topography of this region in much detail.

An interesting account of the "Evolution of the Map of Mammoth Cave" up to 1896 is given by R. Ellsworth Call in the Proceedings of the Indiana Academy of Science for that year.

Attention should also be called to the splendid topographic sheets of the U. S. Geological Survey and Kentucky Geological Survey covering this area. The Mammoth Cave sheet is the most important. It shows all of the region lying between Glasgow Junction and Green River. North of this is the Cub Run sheet covering the northernmost part of the Park area. To the west of these sheets respectively are the Brownsville and the Leitchfield quadrangles. They include, however, hardly any of the Park area. These maps may be purchased from the U. S. Geological Survey, Washington, D. C., at 10 cents each, and are indispensable to anyone who wishes to have at hand an accurate representation of the topography.

Visitors interested in the human occupancy of this region will find two other reports of the Kentucky Geological Survey of the greatest interest. One by Carl Ortwin Sauer on the "Geography of the Pennyroyal Plateau" was published in 1927; the other by Wilbur Greeley Burroughs on the "Geography of the Western Coal Field" appeared in 1924. Both of these contain numerous maps, graphs, and illustrations, and explain the relation of the people and their culture to the landscape in which they live. A special report in this noteworthy geographical series is now being prepared for the Kentucky Geological Survey on "The Barrens" by Samuel N. Dicken. This will be published during the coming year and will add much to the literature of a detailed and specific character.



FIG. 38. AN OLD CEMETERY IN ONE OF THE VALLEY SINKS

On one of these stones is inscribed: "In memory of FRANCES JANE CHATFIELD, Born in Oneida, N. York, Sept. 20th, 1823, Died Nov. 22nd, 1849, aged 26 years 2 months and 2 days."