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Wilderness Resources in Mammoth Cave National Park : A Regional Approach

WILDERNESS RESOURCES

IN

MAMMOTH CAVE NATIONAL PARK

A Regional Approach

A Cave Research Foundation Study

CAVE RESEARCH FOUNDATION

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MAMMOTH CAVE NATIONAL PARK

A Regional Approach

by

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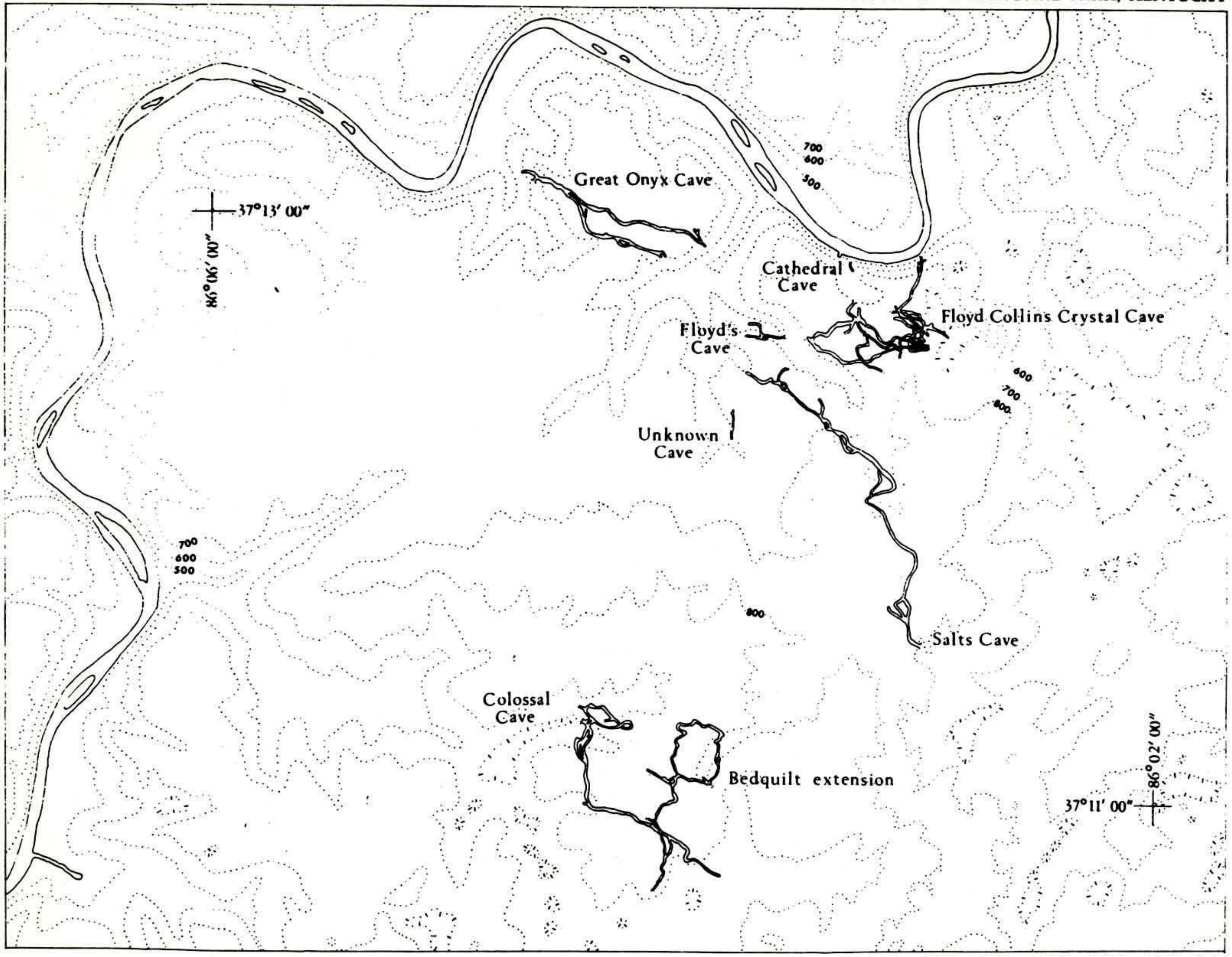

SURFACE TOPOGRAPHY FROM U.S. GEOLOGICAL SURVEY
7.5 MINUTE MAMMOTH CAVE QUADRANGLE, 1954

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Scale

Surface Contour Interval 100 Feet Datum MSL

Figure 1. Flint Ridge Caves in 1947.

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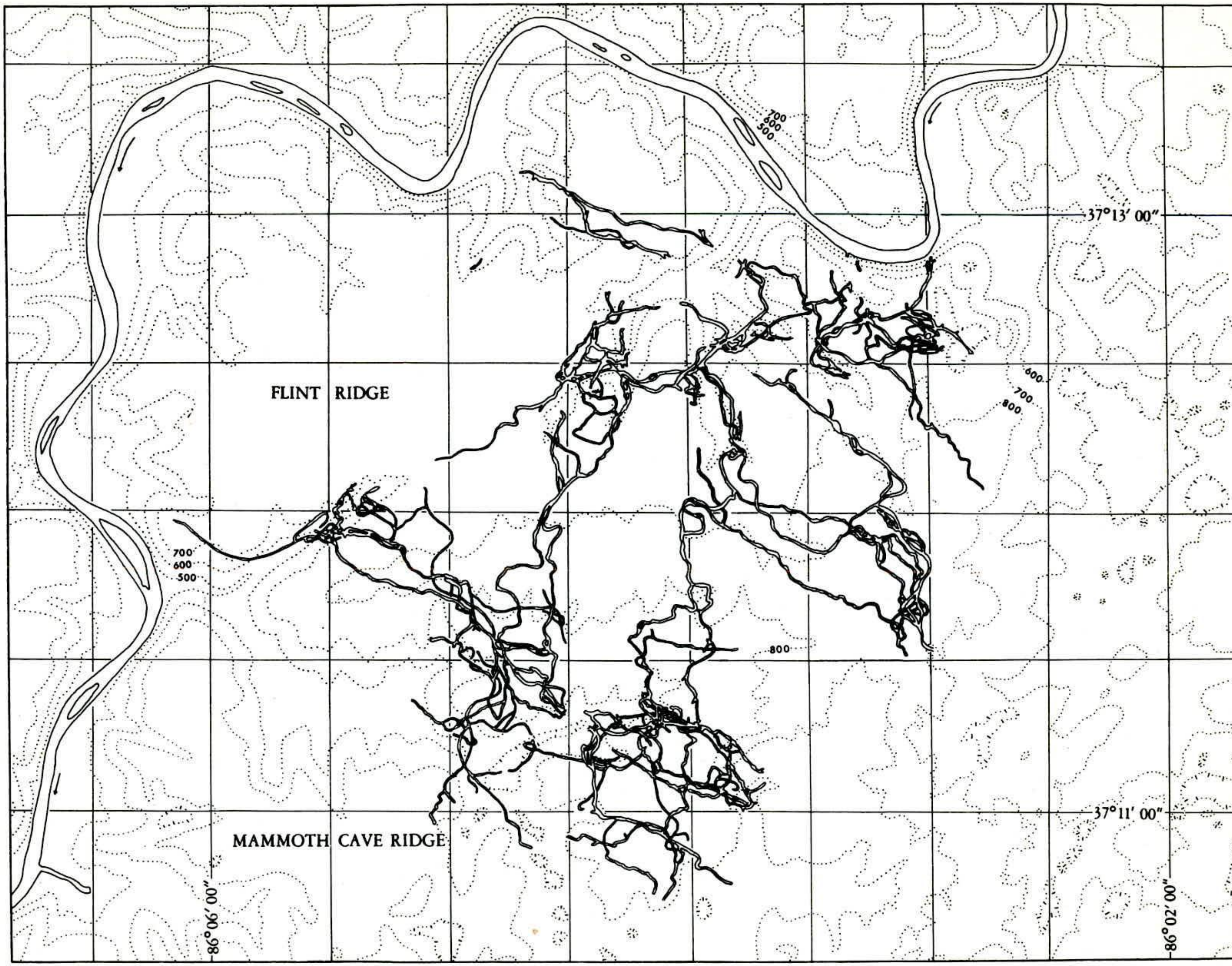
NATIONAL PARK SERVICE

THE FLINT RIDGE CAVE SYSTEM: 1971
MAMMOTH CAVE NATIONAL PARK, KENTUCKY



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Scale
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Figure 2. Flint Ridge Cave System in April, 1971.

THE CAVE RESEARCH FOUNDATION IN MAMMOTH CAVE NATIONAL PARK

Cave Research Foundation membership includes individuals whose scientific work in the Central Kentucky Karst began more than 35 years ago with geologic surveys being made for the then-proposed Mammoth Cave National Park. Other members began in 1947 when the modern era of cave exploration began. This phase culminated with the 1954 expedition in Crystal Cave within the boundaries of the park. During the next several years a cartography program was developed for Mammoth Cave National Park with the goal of understanding the geomorphologically integrated ecological and hydrological underground systems. One result has been the discovery that several large caves in the park form the Flint Ridge Cave System, the longest cave in the world with more than 85 miles surveyed as of April, 1971 (Figures 1 and 2).

In 1957 the Cave Research Foundation was incorporated to further research in cave-related sciences. In 1959 a research agreement was effected between the Foundation and the National Park Service for the purpose of providing scientific knowledge for service management and interpretive programs. Since that time members of the Foundation have contributed 200,000 man-hours of work in the park. More than 100 contributions in the form of books, theses, professional papers, and special reports have resulted. Although the Foundation does not restrict its work to the Central Kentucky Karst, one of its primary purposes is the continuing study of this region. Mammoth Cave National Park occupies the heart of this fascinating Kentucky Cave Country, and thus provides a unique opportunity for the study and appreciation of the most extensive cave systems in the world.

INTRODUCTION

This report was prepared at the request of the National Park Service to provide three things: 1) A general review of the natural features in Mammoth Cave National Park for use in evaluating the park's wilderness potential under the provisions of the Wilderness Act of 1964. 2) A passage classification system for the caves of the park. 3) A consideration of the uses of wilderness in Mammoth Cave National Park from both internal and regional viewpoints.

We have done this as follows: In Chapter I we describe the geological, biological, and archeological features of the park. In each case we show that the value and uniqueness of the park's natural features far exceed the assumptions and anticipations of the original proposers. Mammoth Cave National Park was established because of the renown of Mammoth Cave. It is now known that park lands contain the most extensive networks of cave passages on earth. This is because of an unusual stratigraphic situation. A widespread impermeable caprock not only fosters the formation of spectacular caves and the growth of rare mineral crystals, but also protects these underground features from rapid erosional breakdown that is usual in other karst areas. The size of these cave systems and their long-term protection has led to the evolution of some of the more extensive and interesting communities of cave animals known. More than 50 species live in ecological balance in the caves of the park. Besides these natural features, the caves contain many artifactual and organic remains of preColumbian Indians who explored and mined minerals more than 3000 years ago. The dry atmosphere in the caves has preserved many usually perishable items so that Mammoth Cave National Park is a key area for understanding the Early Woodland peoples. This material has more than ordinary archeological significance because it documents one episode of the most important revolution in man's life on earth, the domestication of plants and the shift from hunting and gathering to a farming way of life.

Chapter II contains a cave passage classification system based on natural underground features. Active processes and a dynamic interaction with surface phenomena are stressed. Five zones are delineated: horizontal drainage, vertical drainage, gypsum, rare minerals, and extraordinary features. Examples of each in park caves are described.

Several concepts of wilderness, the positive management values of wilderness designation under the Wilderness Act, and uses of wilderness are discussed in Chapter III. Pure wilderness exists underground in Mammoth Cave National Park, but more manageable is wilderness conceived as land where man's activities are unnoticeable to most observers. In this view, a considerable portion of the surface and subsurface of the park is now wilderness. Because of ever-present pressures for development and shifts of viewpoint resulting from the rotation of National Park Service management personnel, we believe that designation of a fair proportion of the surface and of large segments of the underground as wilderness under the Wilderness Act is the best way to maintain the natural character of the park.

In Chapter III we also outline three uses of wilderness in Mammoth Cave National Park. Foremost of these in the eyes of the public and the Service is recreation. The Service's interpretive programs are designed so that visitors can use their leisure to recreate themselves in new appreciation and understanding of nature. The park offers a wide spectrum of opportunities to enjoy the natural scene, from hikes in the woods, through guided tours in Mammoth Cave, to true wilderness exploration underground. A second use of wilderness in the park is as a natural laboratory for scientific study of geologic and biologic phenomena. Without disturbing natural conditions, scientists can learn an immense amount by observing and describing. The information gained can be used for the park's interpretive recreational programs. It is also important to the third use of wilderness in the park as an environmental benchmark and management baseline for comparison with the developed portions of the park. Developments of land and caves in the park are in effect experiments that can be controlled only through observation of undeveloped areas kept in as natural a state as possible.

Mammoth Cave National Park wilderness in a regional context is the subject of Chapter IV. The uses of wilderness in the park are multiple, but the value of park wilderness extends far beyond park boundaries. Visitors come to the

park primarily to see the natural landscape and to tour Mammoth Cave. This superlative karst environment in the heart of the Kentucky Cave Country thus acts as a lure to tourists nationwide. Maintenance of natural conditions within this small park provides opportunities for considerable private development outside the park to market services for tourists in the surrounding region. Some of these opportunities are described in Chapter IV.

ACKNOWLEDGEMENTS

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CHAPTER I

NATURAL FEATURES IN MAMMOTH CAVE NATIONAL PARK

In the sections below we discuss the geological, biological, and archeological features of Mammoth Cave National Park in their geographic integration with the Central Kentucky Karst. In each case we move from regional considerations to more specific descriptions of features in the park.

1.1. Geology.

1.1.1. The Drainage Basin.

The Central Kentucky Karst (Figure 3) consists of about 700 square miles of limestone terrain in which drainage is almost entirely underground. It is bounded on the north by Green River, on the west by Barren River which is a tributary of the Green, and on the south and east by a line of sinking creeks. The north-south trending Chester Escarpment, about 200 feet high, divides the area into the Chester Cuesta to the north and the Sinkhole Plain to the south. Mammoth Cave National Park is located in the center of and along the northern boundary of the Central Kentucky Karst, just northwest of Park City and Cave City. Locally, the cuesta is known as the Mammoth Cave Plateau and the divide as the Dripping Springs Escarpment.

All drainage flows to Green River. On the Chester Cuesta beginning about 5 miles west of Park City and extending west to Barren River there are normal, perennial, dendritic surface tributaries to Green River. Even here, however, there is a considerable component of underground drainage shown by sinking creeks. East of this area, the Chester Cuesta has been dissected into five major northwest-southeast trending ridges. These make up the so-called Mammoth Cave Plateau that extends from about 5 miles west of Park City to the town of Horse Cave where the Chester Escarpment makes a sharp local bend to the north across Green River.

There is no surface drainage to Green River from the Mammoth Cave Plateau. Here water sinks underground quickly through sinkholes in the karst valleys separating the ridges, or flows in perched groundwater bodies in the ridges to the edges of the valleys where valley wall intersections of the impermeable caprock allow the water to descend hundreds of underground vertical shafts.

Rainfall on the Sinkhole Plain sinks quickly underground through thousands of sinkholes to join the water from the Mammoth Cave Plateau to emerge in big springs at or below the surface level of Green River.

A fourth component to this immense quantity of water that flows beneath the breadth of the Mammoth Cave Plateau to Green River is from at least 50 sinking creeks that terminate in swallow holes at the southern and eastern borders of the Central Kentucky Karst. Water from some of these sinking creeks flows 15 miles underground on a straight line to the big spring outlets on Green River.

A fifth and very important input to this underground drainage system comes from Green River itself. Seasonal flooding of up to 60 feet in the narrow, deeply entrenched Green River gorge backfloods an immense amount of water far into the system through its normal outlets.

It is important to note that there are two kinds of springs in the Central Kentucky Karst. The dripping springs that provide the local name for the Chester Escarpment flow from a perched water table on the impermeable caprock of the Chester Cuesta. Water emerges where the caprock is intersected, and commonly flows on the surface for only a few tens or hundreds of feet before sinking underground again. The other kind of spring is a major outlet to Green River, the big spring. At least seven big springs emerge from beneath the Mammoth Cave Plateau, carrying water from the widespread sources described above.

The picture of the Central Kentucky Karst drainage basin that emerges here is one of extensive underground drainage networks extending from their big spring outlets at Green River, south under the Chester Cuesta where water enters from vertical shafts and karst valley sinkholes, on under the Sinkhole Plain with its thousands of inputs, as far as 15 miles on to the line of sinking creeks (Figure 4).

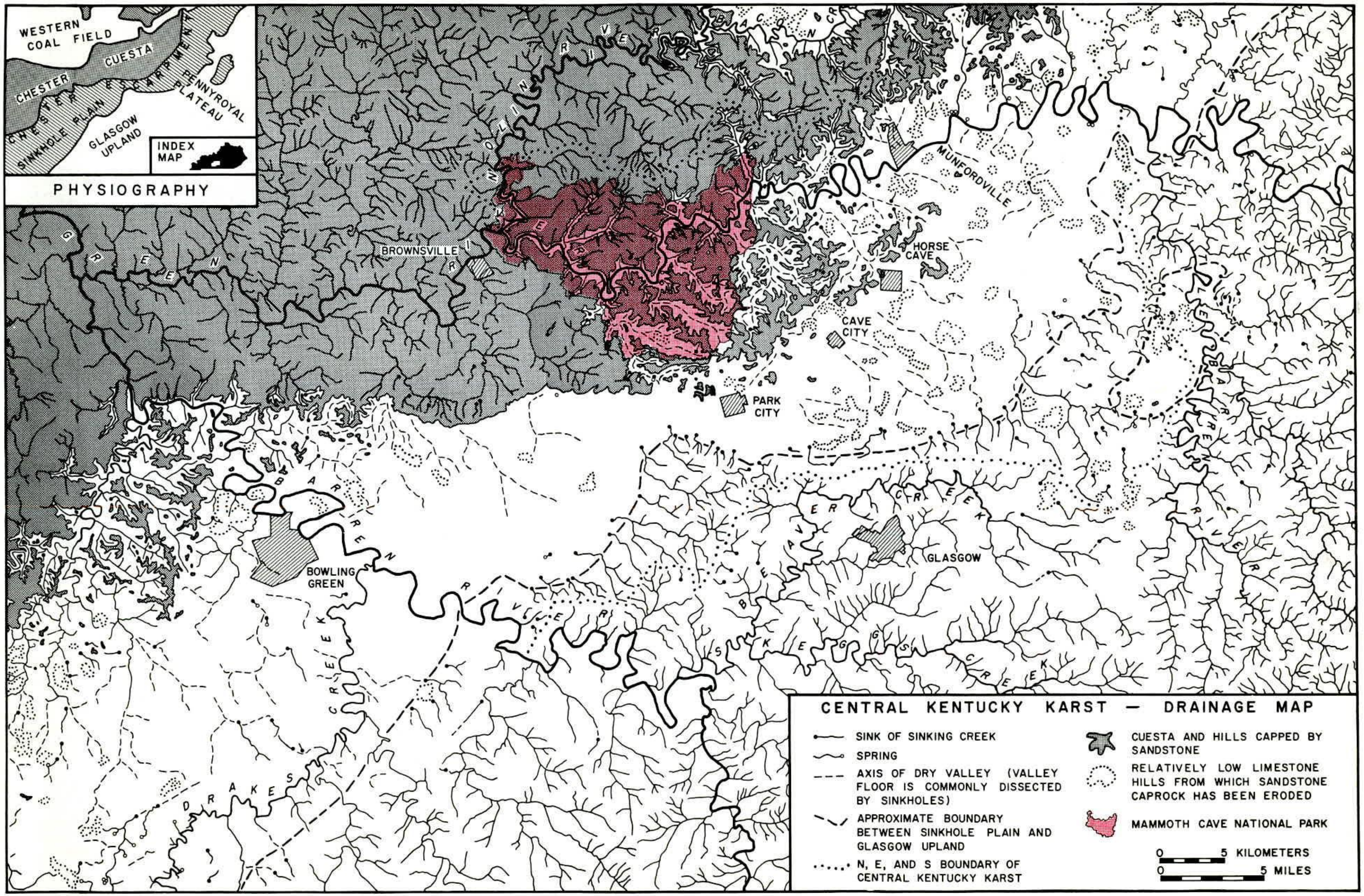

Figure 3. The Central Kentucky Karst. (Compiled from U.S. Geological Survey topographic and geologic maps by James F. Quinlan. Reprinted with revisions from *Mediteranee,* 1970.)

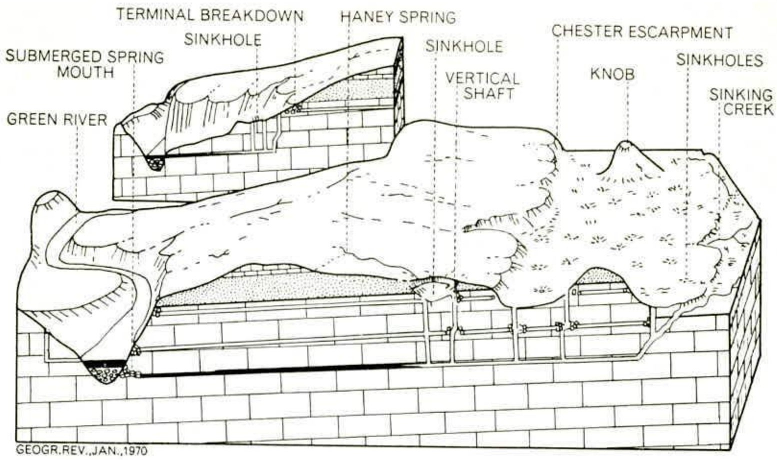

Figure 4. Karst Features of the Central Kentucky Karst. Five sources of water to the underground hydrologic system are shown, from right to left: sinking creeks, sinkholes on the Sinkhole Plain, vertical shafts, sinkholes in dry karst valleys on the Mammoth Cave Plateau, and backup water from Green River. Blacked in passages are below baselevel and thus are filled with water. (Reprinted from *The Geographical Review*, 1970.)

There are big underground rivers implied here; they are described in more detail in the next two sections.

1.1.2. Caves.

Great volumes of limestone have been and are being removed underground in the Central Kentucky Karst to form thousands of miles of horizontal and vertical voids. The major processes involved are solutional and mechanical erosion by flowing water. When such openings reach dimensions that a man can penetrate, they are called cave passages. Nearly 200 miles of cave passages are known under the Central Kentucky Karst, about 150 of which are under the Mammoth Cave Plateau. Geological relations strongly suggest that there are at least 150 more miles of cave passages in unexplored portions of the Mammoth Cave Plateau, and another 50 under the Sinkhole Plain.

Caves under the sinkholes and beyond the swallow holes on the Sinkhole Plain seldom extend more than a few hundred feet to a mile in length. They are generally canyon shaped, a few feet wide and up to 10 or more feet high. Usually they are so small that exploration involves crawling and squirming through the muddy passages of active water courses. An exceptional case is Hidden River Cave under the town of Horse Cave. Hidden River is a perennial stream that flows for more than a mile through passages with dimensions up to tens of feet.

Few caves are known in the undissected portion of the Chester Cuesta. On the cuesta north of Green River in Mammoth Cave National Park, however, there are five or six caves with lengths up to several thousand feet. These caves originate in sinkholes that breach the caprock, and they conduct water through canyon passages and elliptical tubes to Green River.

The largest, longest, and most spectacular caves in this Kentucky Cave Country are in Mammoth Cave National Park. It contains the third longest cave in the world, Mammoth Cave with about 46 miles surveyed as of 1971, and the longest cave in the world, the Flint Ridge Cave System with more than 85 miles surveyed as of 1971. The length and size of cave passages in the park, plus their displays of gypsum and rare mineral crystals, make them a major attraction for tourists and scientists from all over the world.

The major features of park caves are very large horizontal passages of two sorts, elliptical and canyon. An example of a passage with an elliptical cross section in Mammoth Cave is Cleaveland Avenue. It is 1.5 miles long with an average width of 40 feet and an average height of 15 feet. Canyon passages with rectangular cross sections are often quite spectacular. The height and width of the main passage in Salts Cave exceeds 40 feet for distances of 1000 feet, and in some places both dimensions are nearly 100 feet. Throughout the cave systems and in all dimensions, combinations of elliptical and canyon passages form complex passages that join and diverge at different levels.

At the intersections of passages very large rooms sometimes form by solution and collapse. Grand Canyon in Crystal Cave is more than 90 feet high with a floor area of several thousand square feet.

Distinctive in Mammoth Cave Plateau caves are vertical shafts, formed by the solutional action of vertically seeping

water. They typically have flat floors and roofs, and circular cross sections, often looking like the interior of a silo. They are of all sizes, up to dimensions exceeding 40 feet in diameter and 130 feet in height. Bottomless Pit in Mammoth Cave is an easily accessible example. Lines of vertical shafts sometimes coalesce to form solution canyons such as are found in Colossal Cave in the park. Because the location of vertical shafts is determined by intersections of the caprock and is independent of conditions that form horizontal passages, vertical shafts often occur in isolation from horizontal caves. Where shafts intersect horizontal passages on several levels, they provide convenient routes of access.

Throughout the cave systems flutes, scallops, ceiling and floor channels, cusps, pendants, hollows, pits, and other minor solutional features are found. Ceiling collapse also modifies passage shapes, one of the most spectacular being in the Rotunda in Mammoth Cave where a limestone bed several feet thick has fallen to leave a nearly circular ceiling dome 80 feet in diameter.

Cave passages are most often terminated by clastic deposits. From within the cave, breakdown blocks sometimes reach dimensions of 50x30x20 feet and pile up as high as 100 feet. Clay, silt, sand, and gravel carried in by water from the surface also fill cave passages in many places making them inaccessible to man.

Mineral deposits in the caves include complicated suites of carbonate and sulfate minerals and minor quantities of nitrates and manganese coatings. A great variety of calcite and aragonite dripstone deposits in the form of stalactites, stalagmites, helectites, curtains, rimstone dams, etc. can be seen near the Frozen Niagara entrance of Mammoth Cave and in Great Onyx Cave. However, dripstone deposits are rare in Mammoth Cave National Park because the major portions of the cave systems lie under the impermeable caprock. In these dry portions of the caves, however, gypsum is sometimes abundant, and mirabilite, epsomite, and other sulfates occur. Gypsum flowers are found in Cleaveland Avenue of Mammoth Cave and in Floyd's Lost Passage in Crystal Cave. Rare mirabilite flowers three feet long occur in some portions of Crystal Cave. Nitrate is found in the fill of many of the caves, and that from Mammoth Cave was commercially important during the War of 1812. Thin coatings of black manganese form on some of the pebbles and floors of streams in the lower levels of the caves.

One result of widespread mineralization in the dry passages is a distinctive interior weathering process. The walls, floors, and ceilings of the passages are invaded by sulfate crystals whose growth spalls off chips, breaks up the rock, and often wedges out great blocks of stone. Since this process is highly unusual in temperate karst regions, it adds to the uniqueness of the caves of the Mammoth Cave Plateau.

Major horizontal passages under the Mammoth Cave Plateau exist on at least five levels with segments up to four miles long. All are easily accessible underground through vertical shafts and breakdown intersections. These passages exist as integrated cave systems under the three main ridges in the park: Flint Ridge, Mammoth Cave Ridge, and Joppa Ridge. The description above does not show the systematic interrelations of the cave passages. For this we now turn to the next section on the evolution of the major karst features.

1.1.3. Evolution of Major Karst Features.

The topography of the Central Kentucky Karst has been formed very largely by the solutional activity of water. Immense quantities of limestone have been dissolved by the 45 or so inches of yearly rain that has fallen on the area over the millenia. In terms of volume, the most spectacular voids left by limestone removal are not the caves, but the huge karst valleys of the Mammoth Cave Plateau and the Sinkhole Plain itself which is a gigantic solutional depression. The amount of limestone being removed in cave making processes operating now as they have in the past is large, but this removal is a small fraction of the total dissolution and removal of limestone taking place beneath the soil on the bedrock surfaces of the karst valleys and the Sinkhole Plain.

The unique form of this particular karst topography is the result of water acting on a particular stratigraphic and structural expression of rocks (Figure 5). In Figure 5 there are three important elements of the cross sections to keep in mind for the discussion below: First, in the rock sequence the impermeable Big Clifty sandstone overlies the caverniferous Girkin and Ste. Genevieve limestones. Second, the deeply entrenched Green River determines the northern boundary of the karst topography. And third, the dip of the rock structure is to the northwest.

The evolution of the Central Kentucky Karst can now be described as follows: Hundreds of thousands or more years ago the Big Clifty sandstone covered the limestone of the whole area. This impermeable caprock kept water from seeping through so that there was very little solution of the underlying Girkin and Ste. Genevieve limestones. Drainage was entirely on the surface with dendritic tributaries to Green River. What this topography looked like can be seen by examining the southwest third of the Central Kentucky Karst shown in Figure 3, and the northern third of the Brownsville cross section in Figure 5.

Over the years Green River entrenched itself through the Big Clifty sandstone into the caverniferous limestones, as shown in the Mammoth Cave cross section of Figure 5. At the same time, some of the major tributaries also cut through the sandstone into the limestone. When this happened, drainage quickly began to be established underground, so that the tributary valleys were soon left high and dry. Such karst valleys, with sandstone capped ridges between them, now exist on the Mammoth Cave Plateau, as illustrated in the north central third of the Central Kentucky Karst in Figure 3. Outlying sandstone capped hills isolated by the solution of the exposed limestone are known as knobs, many of which are shown in Figure 3.

Much deeper entrenchment of the Green River and further erosion of the sandstone capped ridges and knobs eventually results in the complete removal of the sandstone. This leaves a limestone surface sinkhole plain, as illustrated in the Munfordville cross section of Figure 5 and in the eastern third of the Central Kentucky Karst shown in Figure 3. The erosion of the sandstone ridges and knobs is

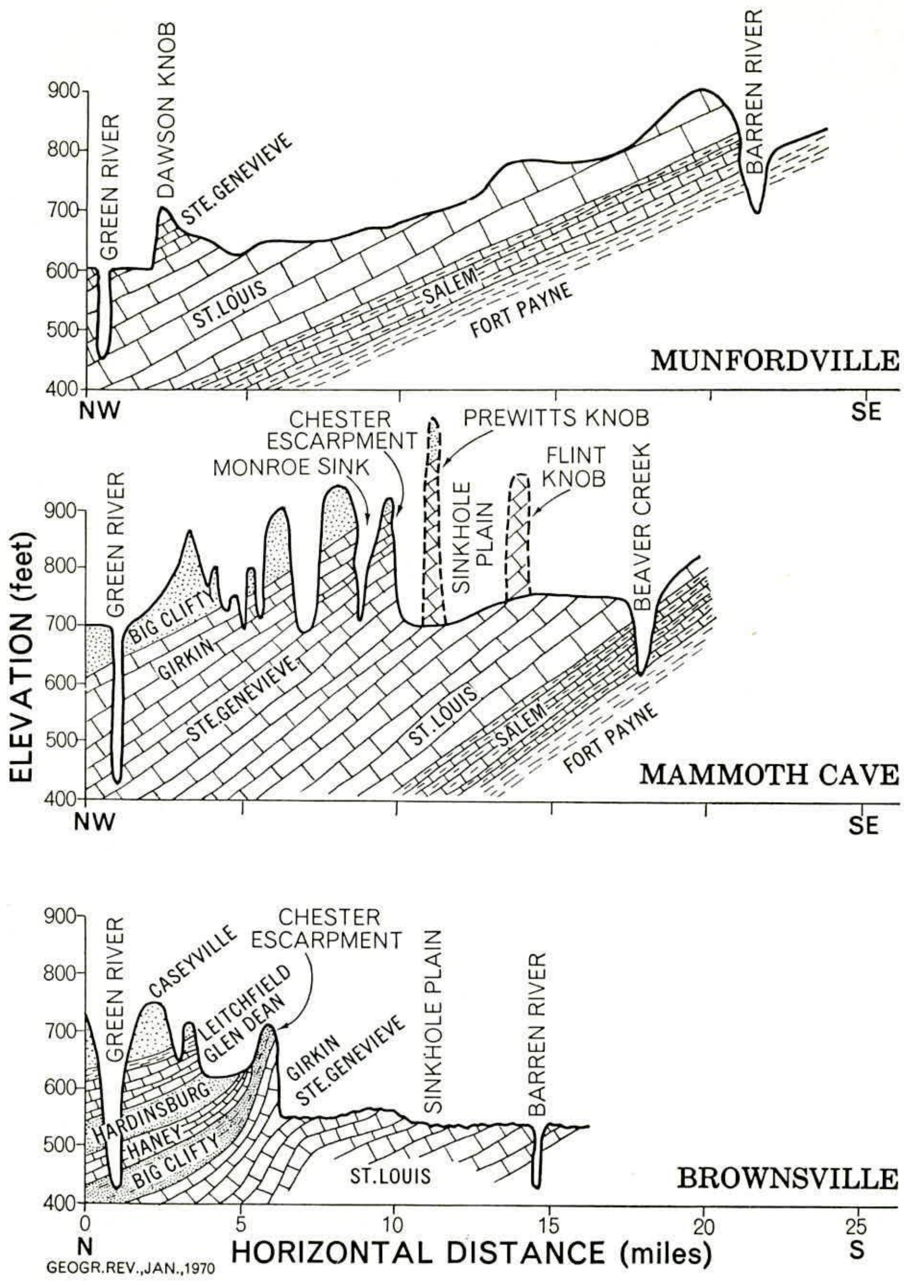

Figure 5. Cross sections through the Central Kentucky Karst. Sections are somewhat generalized to show regional relationships. Irregularities in structure make the dips less uniform than they appear here. These cross-sections also show simplified stratigraphic columns for the Central Kentucky Karst. (Prepared from U.S. Geological Survey topographic and geologic maps. Reprinted from *The Geographical Review,* 1970.)

accomplished in part by local surface runoff, but the major factor is the collapse of vertical shafts. These shafts form underground where the valley wall intersections of the sandstone caprock allow groundwater that was flowing on the impermeable caprock to seep vertically through the limestone. Enlargement and eventual collapse of vertical shafts causes further retreat of the walls of ridges and knobs until they disappear.

Overall, looking at Figures 3 and 5, one can see the Brownsville area west of Park City as representing a topographic expression that was found over the entire region at the initiation of the evolution of the Central Kentucky Karst. The Munfordville sinkhole plain represents the final stage of this evolution. And the ridges and valleys of the Mammoth Cave Plateau show a transitional stage. Erosion through the Big Clifty sandstone to expose the Girkin and Ste. Genevieve limestones has proceeded further in the eastern than in the western portions of the Central Kentucky Karst because the rock structure dips to the northwest. This allowed the entrenching Green River to cut through the sandstone where it lies at a higher elevation in the east sooner than it has toward the west where the sandstone is at a structurally lower elevation (see Figure 5). It also means that in the dynamic evolutionary processes still in progress, continuing entrenchment of Green River will encourage the erosional destruction of the ridges and knobs of the Mammoth Cave Plateau. At the same time, the now continuous portion of the Chester Cuesta in the western third of the Central Kentucky Karst will be cut into sandstone capped ridges and knobs separated by dry karst valleys. The culmination of this process will come when all the sandstone has been removed and nothing remains but a huge sinkhole plain on a limestone surface.

The importance of this evolutionary scheme to the understanding of natural features in Mammoth Cave National Park is as follows: First, of course, the park is seen to encompass only one portion of the Central Kentucky Karst – the ridge and karst valley part of the dissected Chester Cuesta. To understand and appreciate the park, one must see it in relation to the whole evolutionary process. And most important to this regional view are the great cave systems that have made the Mammoth Cave Plateau famous. The huge, dry, horizontal passages that lie on several levels beneath the ridges of the park are the downstream trunks of former underground rivers that drained the Sinkhole Plain to the south. They lie at different levels corresponding to the successively deeper entrenchment levels of Green River in the past. Canyon passages were formed by free air surface underground streams; elliptical passages were formed by flowing water that completely filled them.

These great cave systems are accessible to man today for three main reasons. First, they have been abandoned as water courses as Green River entrenched itself deeper into the limestone. At or just below base level today there are huge underground rivers, probably mostly filled with water, carving out new cave systems as they actively carry present day drainage from the Central Kentucky Karst. Second, the sandstone caprock of the ridges prevents the abandoned cave passages from being destroyed rapidly by ordinary processes of erosion. But the third reason is of most practical importance. The dissection of the Mammoth Cave Plateau to form ridges and karst valleys has destroyed some of the cave systems, but in doing so the valley walls formed have intersected cave passages to make entrances. Without such access we could not study and enjoy these caves, and would know of them only by conjecture. Thus, Mammoth Cave National Park exhibits remnants of once much greater cave systems that have been completely destroyed to the east toward Munfordville, and which may exist but are inaccessible to man to the west toward Brownsville.

1.1.4. Man as a Geologic Agent.

Local tradition in the Central Kentucky Karst is that the treeless area or barrens of the Sinkhole Plain is the result of fires set by Indians. However, if this area was relatively treeless before European settlers cleared it, this was probably the result of rapid erosion on the limestone surface. Certainly since modern cultivation began something over 200 years ago a tremendous amount of soil has been eroded to disappear down sinkholes. There it enters the underground drainage network to travel to Green River which transports it from the region. Pollen analytic studies have shown that some of the plugged sinkholes on the Sinkhole Plain have accumulated as much as 30 feet of sediment in recent times.

Intensive agriculture and deforestation expose the soil and rock to the direct effects of rainfall. The lack of vegetation permits rapid surface runoff. Thus the farmer and the logger have an immense effect on the physical geography of the region. In much of Eastern Europe and the Near East on similar limestone terrains man has been instrumental in stripping the soil to leave widespread rock deserts. Without knowledgeable forest and soil conservation practices, this could also be the eventual fate of the Central Kentucky Karst.

In Mammoth Cave National Park, deforestation and agriculture resulted in soil erosion and a noticeable silt input to the cave systems. However, reforestation since 1941 has slowed this process. In fact, the forest is now so thick that it conceals the number and magnitude of such features as karst valleys, karst saddles, sinkholes, and blind valleys. The park actually contains some of the most spectacular surface karst in the world, but it has remained largely unknown both because of the prominence of Mammoth Cave, and because it is hard to see for the trees.

Besides the laying out of agricultural fields, modern alterations of the surface of Mammoth Cave National Park include roads, building sites, cemetaries, wells, quarries, trash dumps, and power lines. There has been some excavation and closing of cave entrances. More recent alterations include large paved parking lots, a Job Corps Camp with two large open sewage basins, and the capping of several springs on Flint Ridge to provide a water supply. Probably the most significant geological effect man is having on park lands today comes through his removal of a considerable amount of water from the natural systems, with the related return to the systems of polluted water.

Underground, man's activities have caused only minor geological alterations. These, however, are often highly visible. Most obvious is the breaking off and removal of

such features as stalactites, stalagmites, helectites, gypsum flowers, and flowstone. There has been a steady tourist trade for these items for well over 100 years. It is still difficult to prevent an occasional visitor from breaking off a souvenir in Mammoth Cave. Another item removed by the ton from Mammoth Cave during the War of 1812 was saltpetre. Cave earth was dug up and leached in the cave and then tossed back into the excavations. The effects of this activity must be pointed out to most casual observers today.

A total of perhaps 20 miles of trails have been built in the caves of the park. Only about 7 miles are used for visitors in Mammoth Cave today. These trails, with attendant lighting systems, dining room, and toilets constitute the major alteration of the caves by man. However, in those caves no longer exhibited to the public such as Crystal, Great Onyx, Colossal, Salts, Proctor, and Long's, concentrated efforts have been made to remove signs of human activity. Today in these caves the casual visitor would only occasionally notice obvious signs of construction. This is because most of the trails were made be rearranging rocks and filling in with cave earth. Over the years they have taken on the patina of age, and often appear to be simply the natural lines along which people would walk.

There are some signs of man in the caves that are of great historical and human interest. Archeological remains are discussed below. Historical remains include saltpetre mining equipment and stone huts once used for tuberculosis patients in Mammoth Cave. In Crystal Cave there is Floyd Collins' wheelbarrow, a few clay masks made by Floyd's father, some of Floyd's bean cans in Lost Passage, not to mention the tombstone, casket, and remains of this great cave explorer in Grand Canyon of the cave. Bottles and old newspapers are sometimes found (and left *in situ*) by explorers far back in the cave systems. Of even more interest are the names and dates of early explorers scratched on walls in most of the caves. They provide a historical documentation of such early explorers as Edmund Turner, Pike Chapman, T. E. Lee, C. E. Lee, Floyd Collins, Leo Hunt, C. Puckett, Elkanah Kline, Lyman Cutliff, Ellis Jones, and others.

More recent items left in the caves record two now more or less abandoned ideas. There are some remains of the 1954 National Speleological Society camp in Crystal Cave. Explorers lived in the cave for a week, amply demonstrating that the most efficient work can be done from surface rather than underground camps. Also now of primarily historical interest is the installation of Civil Defense supplies in caves of the park. It is quite clear that with the free circulation of water and air between the underground and the surface, caves are far from ideal as fallout shelters.

Man's effects on the great cave systems of Mammoth Cave National Park from a geological viewpoint have so far been minimal. It is quite probable that they will remain so in the future. The most extensive effects actually are apt to come from outside the park. As described above, water drains through the park from a very extensive drainage basin. A change in this regime could affect the caves. Upstream from the park oil wells have released brine and oil scum into Green River, and this has backflooded into the caves. And downstream the Brownsville dam has raised base level in parts of Mammoth Cave around 9 feet, submerging some passages, and, incidentally, making it possible to provide visitors with boat rides in other passages. It is its central geological integration with the surrounding region that makes it necessary to be concerned with man's activities in a wide area outside the park if we are concerned with preserving the natural features within the park.

1.2. Biology.

1.2.1. Surface Flora and Fauna.

The surface of Mammoth Cave National Park is typical of eastern deciduous forests. An average annual rainfall of 45 to 50 inches supports a temperate deciduous forest of oak-hickory and southern hardwoods. Along the river bottoms are stands of mature trees with sycamore very noticeable. Almost impenetrable canebrakes as high as 15 feet formerly grew on islands in Green River.

Mammoth Cave National Park contains most of the fauna known in the Central Kentucky Karst. The larger animals include white-tailed deer, fox, raccoon, opossum, woodchuck, rabbits, and squirrels. There are numerous species of bats, mice, and lesser mammals. In earlier days there were beaver, bobcat, wolf, otter, and black bear. There are numerous reptiles, including several species of snakes and turtles; timber rattlesnakes and copperheads are not uncommon. There are many species of birds, mourning dove, yellow-billed cuckoo, whippoorwill, screech owl, nighthawk, and several species of woodpeckers, warblers, and sparrows being among the most common. Green River contains a rich and varied fish and crayfish fauna, with major fish being primarily carp, suckers, catfish, and bass. The mussel fauna of Green River is one of the most diverse known, and contains many unique species.

1.2.2 Cave Fauna.

The caves of the park have a rich fauna of 50 species that live all or part of their lives underground. These animals are representative of cave life in the Central Kentucky Karst. Of these, 27 species can live only in caves (troglobites), 11 can live in caves or other cave-like habitats (troglophiles), and 12 live primarily outside caves but visit them often enough to be considered as cave guests (trogloxenes). Several species are unique in the caves of the Mammoth Cave Plateau, including a shrimp, a beetle, a pseduscorpion, and perhaps a booklouse and one of the millipedes. In addition, another one-third of the underground fauna in the park is found only in the Central Kentucky Karst. Table 1 is a list of important kinds of animals in this cave fauna:

Flatworms	Spiders	Crickets
Segmented worms	Phalangids	Book lice
Snails	Mites	Flies and Gnats
Isopods	Pseudoscorpions	Beetles
Amphipods	Millipedes	Fish
Shrimp	Diplurans	Amphibians
Crayfish	Collembola	Reptiles, Birds, Mammals

Table 1. Important Cave Animals in Mammoth Cave National Park.

This large variety of cave animals is grouped into ecological cave communities. These are less complicated than

surface communities, both in numbers of individuals and of species and in their interrelations. Green plants cannot photosynthesize in the darkness of caves, thus eliminating one source of nutrition. Cave animals in general must live on other cave animals or on organic debris washed into the caves. The most important aspect of the cave communities in the park is that some contain closely related species. Several contain related pairs, one contains a triad, and another contains five potentially competing species. In these communities an important element of community organization, the dynamics of competition, is sharply delineated.

Terrestrial underground communities in the park are composed of from 2 to 13 species. The degree of complexity is caused by subtle differences in habitats, with different combinations of animals resulting from differences in food supply, moisture, climatic fluctuations, and other disturbances. These communities inhabit areas above base level. The most complex terrestrial communities, however, depend on food import from the quiet backwaters of flooding streams. Communities with very few species occur in areas that are disturbed, have very little food, or have a rigorous microclimate. In general, the terrestrial communities appear to be more fragile than aquatic communities.

Aquatic communities in the park are quite simple, having 6 species at most. There are two types. One lives in vertical shafts and shaft drains below the edges of the sandstone caprock where it is truncated by valley walls. These communities depend on groundwater that has been captured by the impermeable caprock. This water sometimes flows out as springs at the caprock truncations, or it stays underground. In either case it very soon seeps down into the vertical shaft complexes and flows out their drains. Shaft communities are precarious, depending as they do on a constant flow of water that may be interrupted by dry years or the capping of springs to provide water for human users. Such disturbances tend to simplify the communities by decreasing the number of individuals and species. The simpler the community the larger its population fluctuates, so that vertical shaft communities are often in danger of local extinction.

The other type of aquatic community lives in streams in trunk passages of the underground drainage systems, or in backflooded passages near Green River. An excellent and accessible example is in the Styx-Echo-Roaring River complex of Mammoth Cave lying mostly under Jim Lee Ridge. The large base level streams that contain these communities bring food not only from the surface overhead and from Green River backwater, but also from the Sinkhole Plain. These communities seem to have been unchanged in historical times, and thus show a relatively high survival capacity despite varied disturbances.

It is to be stressed, however, that in comparison with the more adaptable surface species, underground animals and their communities are quite easy to destroy. This is because they have evolved in very specialized forms to live in the narrow environmental limits of caves. Their evolution is discussed in the next section. Here we repeat that the total variety of species and the community organization of cave life in Mammoth Cave National Park is unique. These animals depend for their stability and survival on inputs of food and water from the surface. Because of the geological integration of park caves with a large area outside the park, concern with preservation of rare and delicate cave animals is yet another reason for keeping both local and regional perspectives on park affairs.

1.2.3. Evolution of Cave Fauna.

The number and variety of species and communities that live beneath the Mammoth Cave Plateau is a result of local evolution and the adaptation of species that have immigrated to the area from three separate cave regions. Animals have immigrated along the Chester Escarpment from the north through the caves of the Pennyroyal Plateau, from the southwest through other caves of the Pennyroyal Plateau, and from the southeast through caves over the Cumberland Saddle. Only the great cave systems under Flint Ridge, Mammoth Cave Ridge, and Joppa Ridge in Mammoth Cave National Park are large enough and diverse enough in kinds of habitat to contain all these species in one cave system.

As discussed in the section on geology, great cave systems have existed in the Central Kentucky Karst for at least hundreds of thousands and perhaps for millions of years. During this time evolution has proceeded so that species and communities are adapted to very specialized underground conditions. Typical of these animals are blind fish that prosper in the darkness and constant temperature of underground streams. Their survival depends, however, on highly evolved physiological constitutions. Removed to the sunlit and variable temperatured waters of Green River, they would soon perish. The uniqueness of cave animals is that they have evolved into extremely specialized forms in order to survive in the inhospitably restricted environments of caves.

1.2.4. The Influence of Human Activities.

It is obvious that human activities have radically altered the biological complex of the Central Kentucky Karst. Forests and grasslands have been replaced by corn and tobacco fields; deer and bear have given way to cattle and domestic cats. Except possibly for the Big Woods in Mammoth Cave National Park, all the original timber has been cut in historic times. Where this land has been allowed to reforest naturally, different species have grown up than were there before. And where brushlands have burned, other sequences of second-growth have followed. As for the grasslands, plowing for farming has created disturbances that favor the plants we call weeds, plants that are not particularly abundant under natural conditions. Besides inducing readjustments of local species, men have also introduced many exotic trees and plants along with those they raise for crops.

A similar situation exists with respect to animals. The major predators are extinct in the Central Kentucky Karst, as are valuable fur animals such as otter and beaver. Mice and rats have multiplied with the advent of grain crops, as have birds that feed on farm produce. More recently the use of insecticides, pesticides, and herbicides has made yet another alteration in both plant and animal communities. The effects of modern man on the biological complexion of

the region are far reaching and ubiquitous.

This is true also for Mammoth Cave National Park despite its protection as a natural area since 1941. Some efforts have been made to remove non-native plants from the park. However, because the park is so small (around 52,000 acres) and because its boundaries with surrounding areas are arbitrary so do not constitute natural barriers, it is impossible to remove exotic species entirely from the park. For example, there are always numbers of domestic dogs and cats that have gone wild to find a good living hunting within the boundaries of the park.

The park situation itself has led to imbalances. For example, local grass and forest fires are natural, but are not allowed to persist in the park. As for animals, the deer herd is overpopulated. This leads to stunted growth and disease within the herd, but it has other widespread effects as well. The superabundance of ticks and chiggers is well-known to most visitors who venture off paved roads and sidewalks; deer flies are everywhere. The presence of these annoying parasites is in part due to the large deer herds. The deer also overgraze their brouse, endangering the survival of many species of plants. They are then led to crop other trees and shrubs, hindering the maturation of these plants and fostering the continuation of scrub land growth. Deer are the only animals without natural predators in the park, so they are the ones most obviously out of ecologic balance. (The same might be said for people in the park on some occasions.) The situation is probably less severe for other animals. The only animals other than insects that are wantonly killed by tourists in the park are rattlesnakes and copperheads. These snakes seem, nevertheless, to be holding their own.

Besides introducing exotic plants and animals, the residents of the area prior to its becoming a national park also selectively removed certain species. Bear and other animals have been mentioned. The wood of native walnut trees was quite valuable so that most of these trees were removed. A few years ago we were puzzled by a strange series of small pits a few feet across and deep scattered in the forests of the park. We though perhaps that they had been dug by Indians until an old-time resident told us that they were merely the holes left by people who had gone back to dig up walnut stumps to sell after all the trees themselves had been logged. Also removed in quantity were ginseng plants and other medicinal herbs. Besides watching for deer poachers in the park, Rangers have still occasionally to be on the lookout for ginseng diggers.

In general, however, surface plants and animals will survive. As National Park Service Director, George B. Hartzog, Jr., said in a speech in 1967, "where other uses have impaired past wilderness values, the National Parks are managed to restore the wilderness characteristics by the removal of adverse uses." This undoubtedly can be done at Mammoth Cave National Park.

Underground, it is another matter. If the rare forms of cave life are destroyed by man's activities, it wil! not be possible to replace them. At the present time some of these species and communities are in jeopardy, but so far none is known to have been totally destroyed. Where the most disturbance has occurred is in the heavily developed and visited portions of Mammoth Cave. Here some species and communities have vanished, while others have prospered on augmented food supplies from litter and debris. Crickets, for example, seem to dislike trails with many people walking by, but they multiply explosively where garbage is stored or dumped. Blind fish often avoid lighted portions of the caves, but exotic plants and animals such as algae and house flies adapt quickly to conditions of artificial light.

The most endangered species and communities in the park today are not in the visited portions of Mammoth Cave, but in the more remote wilderness areas of the Flint Ridge Cave System. Springs are capped on Flint Ridge to provide a water supply for park visitors. These springs ordinarily supplied water and food for large areas containing shaft drain communities. Another danger comes from the faulty sewage basins of the Job Corps Camp on Flint Ridge that allow sewage to pollute the water of underground stream communities. So far these adverse uses have not seemed to have disastrous effects. However, in combination with a very dry year, the taking of water from springs could destroy many vertical shaft communities. And a heavy dose of sewage could have extremely adverse effects on underground stream communities.

Alterations of a different order have affected the bat communities of the park. Some artificial entrances have been dug, and some natural entrances have been closed by doors or blasting. The bat population of the park has evidently diminished during historical times, but whether this is because of tampering with cave entrances or because of regional conditions is unknown. It is known, however, that use of insecticides in the Central Kentucky Karst has not favored the health of bats.

Some of the most profound effects on cave life in the park stem from human activities outside the park. As mentioned above, the Brownsville dam has flooded the lower levels of Mammoth Cave, creating a much larger aquatic environment there than is natural. This environment has been polluted in the past by Green River backup water containing effluents from upstream oil wells. Not yet noticeable but potentially dangerous is the possibility of sewerage, fertilizer, insecticides, and pesticides flowing into the cave systems along the drainage lines that come underground from the farmlands of the Sinkhole Plain. However, the outside event that might have the most profound effect on cave life in the park would be a dam upstream on Green River, pooling the water in the gorge through the park. The breeding cycles of many underground species are triggered by seasonal floods that bring new quantities of food into the cave on backup waters. If these floods were controlled too strictly, the possible effect on cave life could be disastrous.

In general, human activities have simplified the ecologic situation in the Central Kentucky Karst by substituting a few domestic plants and animals in the place of many wild ones. Simple communities, particularly those favored by man's disturbing influence, are less stable than complex ones, but are least subject to alteration or destruction by the activities of man. In this context the ecologic communities of Mammoth Cave National Park, particularly in the cave, are relatively complex and stable. The complex cave

communities are most subject to simplification, and thus to destruction, by extreme environmental fluctuations and disturbance by man. Nevertheless, with imaginative and careful management, natural conditions in the park can be restored and maintained.

1.3. Archeology.

There are many evidences of the activities of Indians in the Central Kentucky Karst. Archeological remains left by prehistoric explorers and miners are present in some abundance in Mammoth Cave, in the Flint Ridge Cave System (Salts Cave and one passage in Crystal Cave), and in Lee and Bluff Caves of Joppa Ridge. According to radiocarbon dates, the Salts Cave and Mammoth Cave remains are 2000 to 3000 years old. Materials in Salts and Mammoth Caves are the most abundant and are so similar to one another that it seems clear that they were left by the same general prehistoric group. These remains consist of torch and campfire fuel fragments, torch-ties (grass, vine, and bark), nut shells and husks, gourd and squash fragments, dried human feces, clam shells, fragments of textile (including pieces of woven slippers), rare pieces of wooden vessels, mining tools, and footprints. The feces contain seeds and other remains of wild and domestic plants as well as bits of bone, insect fragments, and meat debris. In addition, animal and human bones have been found in both caves.

Some of the aboriginal material has been recovered from excavation of sediments in the entrance chambers of Mammoth and Salts Caves, but many fragile items (for example, textile and gourd fragments and paleofecal specimens) lie on the floors of the cave passages and could be crushed or disturbed by casual visitors. The preColumbian Indian remains in Upper Salts and Mammoth Caves have been known for more than 100 years and early visitors removed large quantities of them. However, the material in Lower Salts Cave was not discovered until some 15 years ago, hence has not been disturbed by souvenir collectors. Especially important and unique are the prints of naked feet in the dust of one Lower Salts passage, Indian Avenue.

The remains in Lee and Bluff Caves are much less comprehensive and abundant, consisting almost exclusively of torch and campfire fuel. However, the finds in Lee Cave are important in that the main passages were discovered very recently (1969), so that the aboriginal torch debris is undisturbed.

Two major points should be made concerning archeological remains in the caves of Mammoth Cave National Park: First, most of them are very fragile. Second, most of them are of types that are non-existent or extremely rare elsewhere. Preservation in the unvarying atmosphere of these caves is excellent, and therefore organic material never found in open sites is abundant. The plant remains (especially those in the paleofeces) are particularly important. They are of great value to the study of prehistoric diet in this region, and to investigation of the change from hunting and gathering wild species to use of domestic plants.

In sum, the aboriginal remains in the caves of Mammoth Cave National Park not only document an unusual prehistoric activity (mining cave minerals), but also comprise unique and valuable material of great significance to the investigation of early food-production in the eastern United States. There is undoubtedly a considerable quantity of material still undiscovered in park caves that will tell us more about the way of life of these early cave explorers.

CHAPTER II

CAVE PASSAGE CLASSIFICATION FOR MAMMOTH CAVE NATIONAL PARK

The cave passage classification system given below is based on the physical characteristics of caves in Mammoth Cave National Park. It is purely descriptive, and is applicable exclusively to the caves of the Mammoth Cave Plateau. Although the separations of zones are made primarily on geological and hydrological criteria, they clearly block out biological provinces as well. Thus for cave passages in each zone we describe their main characteristics, indicate their relations with cave passages in other zones, suggest how they can be maintained in natural conditions, and name a few examples in the park.

The classification system leaves open the question whether cave passages were once, are now, or will be developed. Collaterally, the system does not designate any passages as wilderness. This is because all passages could be either wilderness or developed. Those now developed could be returned to wilderness conditions, and those that are now wilderness could be developed. We believe that a good land classification system for National Park Service purposes should not preclude questions of development, but instead should provide a neutral descriptive basis for making decisions about park management. Consequently, we have not used as a model the Outdoor Recreation Resources Review Commission's proposed land classification system – although it is sometimes preferred by the National Park Service – because it is not based on the permanent physical characteristics of land, but on its changing and variable past and present use.

Five zones are defined below. The first four are mutually exclusive, and cover the entire geographical extent of the Mammoth Cave Plateau. These designations cover zones of horizontal drainage, vertical drainage, gypsum, and rare minerals. The fifth zone is based on rareness and fragility of extraordinary features, and is an adjunct to the other four zones. All cave passages, therefore, fit in only one of the first four zones, whereas any cave passage can additionally be classified as Zone 5. The five zones are schematically represented in Figure 6.

2.1. Zone 1: Horizontal Drainage Zone.

Passages located below an elevation of 475 feet in the Ste. Genevieve limestone are conduits for horizontal drainage. The base level of Zone 1 is influenced by Green River. The top of the zone represents the upward limit of severe flooding such as occurred in 1962 when the water rose 59 feet. The bottom limit, estimated at an elevation of 390 feet, is the approximate floor of present-day, water-filled, trunk drain passages that are actually draining the Central Kentucky Karst. Thus, the defining characteristics of Zone

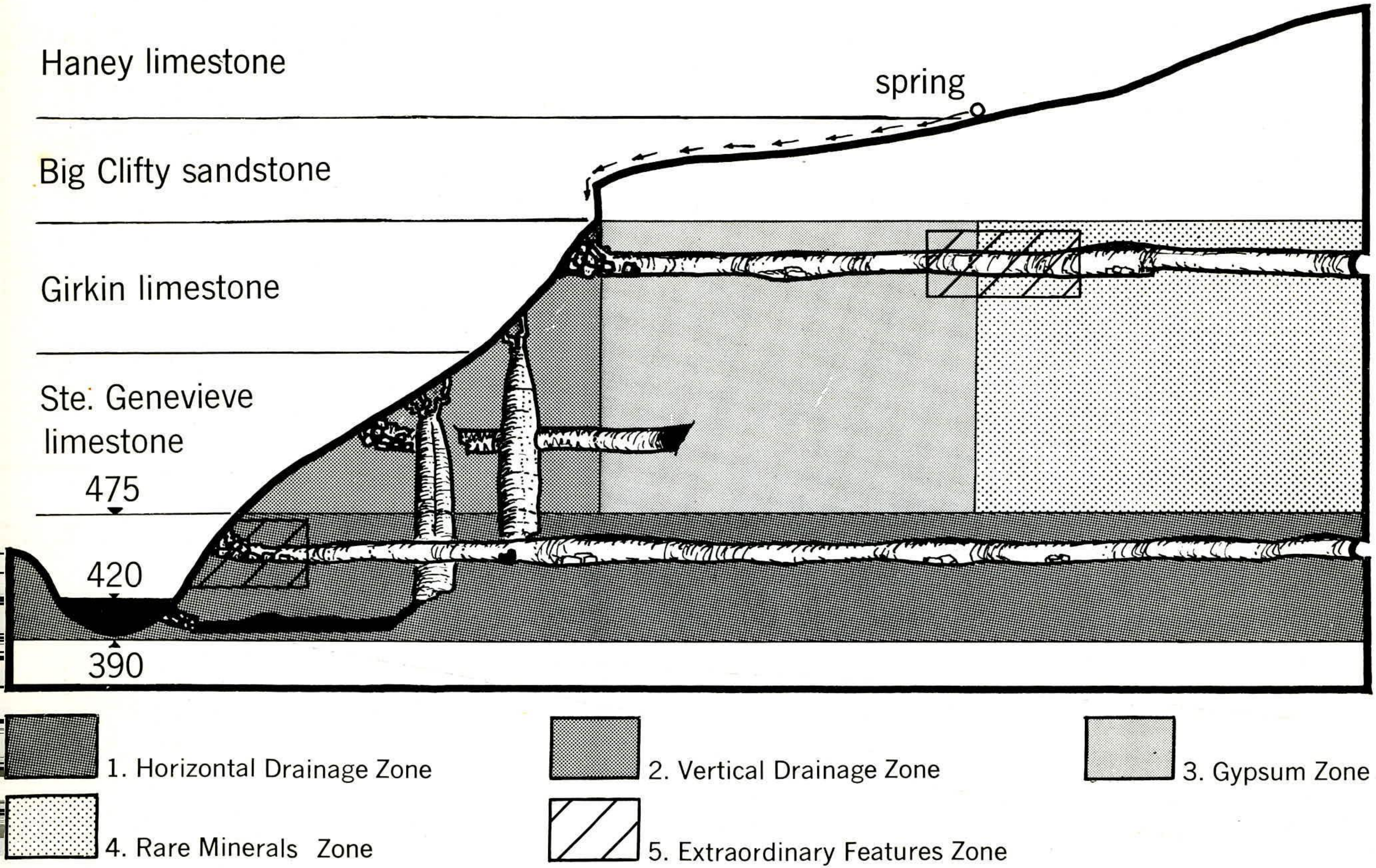

Figure 6. Schematic Diagram of Cave Passage Classification for Mammoth Cave National Park.

1 are horizontal passages that lie within the limits of the perennially and occasionally flooded lower areas of the cave systems. Passages in the Horizontal Drainage Zone extend beneath the three major cave-bearing ridges in the park and underlie Zones 2, 3, and 4.

Passages in the Horizontal Drainage Zone are invariably damp and usually wet and muddy. When Green River floods, flood water and entrained silt rush into the cave. This flooding tends to dilute and to distribute both food and pollution over wide regions. When the river recedes, the flow reverses and water drains out. The flooding also tends to prevent secondary mineralization in passages of Zone 1. Consequently, formations if present at all occur near the top of the zone.

The streams and pools in passages of the Horizontal Drainage Zone contain most of the underground aquatic life, as well as the largest variety and populations of terrestrial cave animals. Because the uppermost areas of the zone are flooded only occasionally (a few times each century), the life there is very similar to that in overlying zones. For example, in areas of Zone 1 overlain by the Vertical Drainage Zone, the upper passages support shaft-drain stream communities. The lower passages are either permanently pooled or undergo annual flooding, so support trunk drain stream communities. The upper passages throughout the Horizontal Drainage Zone support terrestrial communities. The life content of this zone thus changes with elevation.

Passages in Zone 1 range from tight crawlways to trunk drains 50 feet wide and 50 feet high. The elevation above base level of vertical shaft floors varies considerably, and the lowermost are in the Horizontal Drainage Zone. Even those with floors high above base level have shaft drains with flooded downstream portions in Zone 1. The tops of all vertical shafts are never flooded and thus are in the Vertical Drainage Zone.

Passages in the Horizontal Drainage Zone in the Flint Ridge Cave System include Pohl Avenue, Columbian Avenue, Eyeless Fish Trail, and Northwest Passage. The river passages in Mammoth Cave are easily accessible examples of this zone.

Preservation of natural processes and features in the Horizontal Drainage Zone requires that water inputs to the cave systems do not change substantially either in quantity or in quality. This depends on surface circumstances, as described above.

2.2. Zone 2: Vertical Drainage Zone.

All passages and vertical shafts located beneath surface outcrops of the Girkin and Ste. Genevieve limestones and above the elevation of 475 feet exhibit features related to vertically moving water. The passages within this zone are wet from seeping water throughout the year. They generally increase in wetness immediately after rains, but they are never flooded. As noted above, portions of vertical shafts below 475 feet are in the Horizontal Drainage Zone. Thus the defining characteristics of Zone 2 are predominantly vertical drainage passages in perennially vadose (free air surface) conditions. Carbonate dripstone formations, such as stalactites, stalagmites, helectites, and drapery, are primarily confined to passages in the Vertical Drainage Zone in the large cave systems of Mammoth Cave National Park. This is because the impermeable Big Clifty sandstone caprock that prevents downward percolation of water into Zones 3 and 4 has been eroded from the surface overlying Zone 2. The result is that surface runoff and groundwater move rapidly downward throughout Zone 2. Near the edge of the capping bed – at surface elevations between about 750 to about 650 feet in the park – large quantities of groundwater channelled horizontally on the Big Clifty sandstone flow out to sink and drain downward. This water is a very weak carbonic acid, and thus dissolves the limestone. It does not deposit carbonate minerals, so active vertical shafts in this zone do not exhibit formations. Areas of the Vertical Drainage Zone farther from the edge of the caprock – in the park this is where the surface elevation is below about 600 feet – do exhibit carbonate dripstone and flowstone formations because the water recharge is from diffuse infiltration through a soil zone rather than from large upland watersheds. Water that percolates through a limestone soil becomes more alkaline than water that flows through the sandstone soil of the caprock, and thus has a tendency to deposit formations.

Vertical shafts are distinctive and universal features of the Vertical Drainage Zone. They vary in diameter from a few feet to over 40 feet, and range in height from a few feet to over 130 feet. Both single shafts and clusters of shafts are found. Beneath valley center lines can be found long chains of vertical shafts merged as underground solution canyons.

Vertical shafts are not only the principal water inputs to passages in the Vertical Drainage Zone, but they are also conduits for organic matter that is the primary element in the cave food chain. Quantities of organic debris sustain relatively abundant populations of cave animals in horizontal passages within the zone. The basic fragile feature of Zone 2 is the stream community of cave life that is dependent on the undisturbed continuity and purity of the groundwater flow.

Another feature of the Vertical Drainage Zone comes from the solutional and abrasive action of descending water. The rockscape is ever-changing under the action of flowing water, and loose rocks and breakdown are found in both vertical and horizontal passages. Rock dissolution causes continual structural weakening of bedrock. Advanced stages of structural weakness frequently are found adjacent to entrances. As described in the section on geology, vertical shaft formation and collapse is a major contributing factor to slope retreat.

Horizontal passages in the Vertical Drainage Zone are of three basic types: the terminal ends of trunk drain passages, either abandoned or active vertical shaft drains, and valley drains. Breakdown-terminated trunk passages have sizes ranging up to 60 feet wide and 30 feet high. Shaft drains vary from tight crawlways to passages 12 feet high by 6 feet wide. They usually follow a meandering course. Valley drains carry the localized runoff of the karst valleys and are similar to but larger than shaft drains.

Example vertical shafts in the Flint Ridge Cave System are Colossal Dome, Twin Domes, Overlook, Big Canyon, Jones Shaft, and Wow Shaft. In Mammoth Cave, Bottom-

less Pit is in this zone. Examples of shaft drains within the zone are Black Avenue and Elberfeld Breathing Trail in the Flint Ridge Cave System, and passages leading off of Mammoth Dome and Wyatt's Domes in Mammoth Cave. Examples of truncated trunk passages and entrance areas in the zone are the Colossal Entrance, Davis Hall at the Austin Entrance, and the Great Onyx Entrance. Sample flowstone areas are the south end of Grand Avenue, Davis Hall, and Mallot Avenue in the Flint Ridge Cave System, and in the Frozen Niagara section of Mammoth Cave. The entrance area of Great Onyx Cave contains fine deposits of flowstone and dripstone columns.

The maintenance of the natural processes in passages of the Vertical Drainage Zone depends on continuance of natural surface water flow patterns, both above the zone and above the caprock beyond it.

2.3. Zone 3: Gypsum Zone.

Dry passages located beneath surface outcrops of Big Clifty sandstone contain crystalline deposits of the common mineral, gypsum, which is often beautiful and generally fragile. Rare minerals are seldom found in these passages. Thus the definitive characteristic of Zone 3 is an abundance of gypsum crystals and an absence of rare minerals. It lies above 475 feet and below the Big Clifty sandstone where this caprock is exposed on the surface. Known passages in Zone 3 frequently contain one or more forms of gypsum crystals, from massive crusts and layers of crystals that penetrate the limestone to cause breakdown, to rare forms such as gypsum flowers, hair gypsum, needle gypsum, and occasionally cotton gypsum. Gypsum remains relatively stable and does not appear to be affected by variations of temperature and humidity. The sulfate ion originates, in some part, from the mineral pyrite contained in the overlying Big Clifty sandstone.

Passages in the Gypsum Zone are dry. They are primarily abandoned horizontal drainage passages that were active millenia ago when the ancient Green River determined a higher base level because it had not entrenched itself as deeply as it has today. Passages range in size from tight crawlways to large trunk passages occasionally reaching 60 feet wide by 30 feet high. Cave life is scarce in passages of Zone 3 and is predominantly composed of terrestrial beetle-cricket communities. It is more abundant at the outer edge of the zone, under the contact between the Girkin limestone and the overlying Big Clifty sandstone. Cave life becomes rare at the inner edge of the zone, just under the contact between the Big Clifty sandstone and the overlying Haney limestone.

Example passages in the Gypsum Zone include portions of Grand Avenue, Floyd's Lost Passage, and Storts Trail of the Flint Ridge Cave System.

Maintenance of natural processes in passages of the Gypsum Zone requires careful supervision of human traffic, particularly in especially fragil and beautiful areas. A special problem arises because attractive gypsum flowers and crystals are prized souvenirs of rockhounds and some tourists. Gypsum crystals do grow relatively rapidly in the caves, but return to a pristine state after vandalism would require at least hundreds of years. So long as visitors are careful and a natural vegetation protects the caprock from extensive erosion, this zone will probably undergo minimal alteration.

2.4. Zone 4: Rare Minerals Zone.

Dry passages located beneath surface outcrops of the Haney limestone and strata that overlie the Haney contain both gypsum and frequent deposits of rare metastable sulfate minerals such as mirabilite. Thus the defining characteristic of Zone 4 is the existence of rare minerals. The most spectacular gypsum deposits are also in this zone. The origin of the rare minerals is not yet known. There are pyrite concentrations in the Big Clifty sandstone, and probably other sources of the sulfate ion in clastic beds above the Haney limestone. Critical, stable atmospheric conditions in these passages also appear to play a role.

Passages in the Rare Minerals Zone are invariably dry, ranging in size from tight crawlways to large trunk passages, sometimes 80 feet wide by 60 feet high. Like those of the Gypsum Zone, they are long-abandoned horizontal drainage passages. Rare mineral crystals are often in the form of needles and hair, and occasionally appear as large crystals. They are found intermingled with gypsum crystals. Laboratory analyses are usually necessary to differentiate the rare minerals from each other and from gypsum. Some of the rare minerals remain stable only under conditions of constant temperature and low humidity, and decompose when removed from the cave.

Life is extremely rare in passages of the Rare Minerals Zone because these areas occupy locations farthest away from food inputs and because the relative humidity is often below 90%.

Ancient Indian use of the large cave systems in Mammoth Cave National Park appears to have occurred predominantly in passages of the Rare Minerals Zone, presumably because of the large dry passageways and the availability of mineral salts.

Passages in the Rare Minerals Zone include Benington Grotto, the nearby areas of Turner and Mather Avenues, Upper Salts Avenue, and Indian Avenue of the Flint Ridge Cave System.

Maintenance of natural conditions are clearly required for preservation of the Rare Minerals Zone. Human traffic should be minimized to avoid damage from breakage, humidity change, temperature change, and contamination. Surface conditions above passages of the Rare Minerals Zone play an important role in the processes that form the crystal displays. Thus overlying rock and sediment layers, such as the Caseyville gravel, should be left in a natural state.

2.5. Zone 5: Extraordinary Features Zone.

Extraordinary features may occur in any of the other four zones. Thus the defining characteristic of Zone 5 is the presence of features anywhere that are both unique and very easily damaged even by careful visitors. Such features may be natural or artificial, and organic or inorganic. Some, such as mineral deposits, are physically fragile. Others, such as Indian footprints and prehistoric feces, are both fragile and difficult to see. Table 2 contains a list of some of the

extraordinary features under Flint Ridge:

Feature	*Location*
Indian footprints, feces, artifacts.	Indian Avenue.
Indian footprints.	Upper Crouchway.
Extraordinary sulfate minerals.	Mather Avenue, Benington Grotto, White Way, Turner Avenue, Floyd's Lost Passage.
Extraordinary carbonate minerals.	Davis Hall, Northwest Passage.
Cave pearls.	Foundation Hall.

Table 2: Extraordinary Features in the Flint Ridge Cave System.

A similar table for Mammoth Cave would contain relics of early pioneer and saltpetre mining operations as well as items like those listed above. In Joppa Ridge, Indian artifact areas would qualify.

The Extraordinary Features Zone is an adjunct zone, being a classificatory designation superimposed on the general passage designations. For example, minerals in Benington Grotto (Zone 4) and the Indian footprint in the Upper Crouchway (Zone 2) warrant additional designation as Zone 5.

Protection of these features simply demands extraordinary care.

CHAPTER III

WILDERNESS IN MAMMOTH CAVE NATIONAL PARK

3.1 Concepts of Wilderness.

Three definitions of wilderness are pertinent to the analysis of the natural features of Mammoth Cave National Park:

1) Wilderness is land untouched by man.
2) Wilderness is land where the effects of man's activities are substantially unnoticeable.
3) Wilderness is land that gives one the psychological feeling of being remote from the activities of man.

All three kinds of wilderness now exist in Mammoth Cave National Park. Underground, particularly in the remote reaches of the Flint Ridge Cave System and in the unknown passages under Mammoth Cave Ridge and Joppa Ridge, there are scores of miles of passages that have not been touched by man. If one will allow the first definition to cover also those areas that have been visited by man, but not modified by him, then there are several hundred miles of wilderness cave passages in Mammoth Cave National Park. We believe that true wilderness need not be totally untouched by man. Thus we stress that a most extensive park resource is the immense area of true underground wilderness.

The second definition allows almost all of the surface and underground of Mammoth Cave National Park to be classified as wilderness. The tour passages of Mammoth Cave and the forest-covered surface of the park appear to most men to be wilderness. We believe, as indicated below, that more trails on the surface are in order to make this wilderness accessible to the general public. While it is contradictory to talk of opening up wilderness areas by putting automobile roads through them – for the existence of roads and automobiles destroys this kind of wilderness – a man walking along a trail is in harmony with wilderness where the effects of man's activities are substantially unnoticeable. Well-constructed trails in such wilderness are often indistinguishable from game trails. For people who want to commune with nature, observe birds or deer or other wildlife, or just to take a quiet walk, Mammoth Cave National Park has great potential. It combines small size with a great deal of relief and forest-cover, so that a man can soon find himself alone with nature.

This leads to the third definition of wilderness. There are few places where one can feel as remote from the activities of man as he can in the dark depths of a great cave. The psychological impact of the cave is often as strong on tourists in the exhibited portion of Mammoth Cave as it is on explorers in the absolute wilderness of the Flint Ridge Cave System. This third definition is the widest of the three given of wilderness here, for one can feel remote from the works of man even in the presence of an old log cabin collapsed on a Kentucky hillside and now grown over with vines and shrubs. For whatever reasons people come to the national parks, it is this experience of remoteness and the immensity of nature that most of them take away and remember the longest. It goes without saying that providing this experience is one of the finest services that the National Park Service can perform.

A significant feature of Mammoth Cave National Park is the large area of underground wilderness that it contains. In line with the three definitions given above, the vast underground world of the park is almost all wilderness. This is an underground land area of substantial acreage in its own right, and although it is geologically and biologically linked to the surface, its wilderness characteristics are largely independent of surface conditions. Underground wilderness is not unique to Mammoth Cave National Park. It exists also in Carlsbad Caverns National Park, in Wind Cave National Monument, and in most other caves in the National Park System. Mammoth Cave National Park simply contains the largest area of underground wilderness in the world. Thus it is both necessary and useful to employ the concept of underground wilderness when evaluating the natural environment of park caves.

3.2. Administration of Wilderness.

Wilderness of all types described above has been administered by the National Park Service in the past on the basis of administrative decision. Such a method is extremely flexible, and its advocates stress its value in meeting the contingencies and emergencies of day to day management. However, in such a system where any land at all might be developed according to the needs perceived by administrators, no land is perpetually safe from development. If administrators felt the need, virgin land could be developed anywhere in the National Park System according to the present administrative mandate. Wilderness in the national parks thus rests now in the hands of National Park Service Administrators. This is sometimes precarious. There are

many pressures on Service administrators to develop more land in the parks. We believe that wilderness lands must be protected from these pressures and sometimes even from the good intentions of sympathetic administrative advocates of wilderness.

It is our experience that the general administrative body of the National Park Service is of the highest integrity, and that Service concern to conserve and manage *natural areas properly* is honest and magnanimous. This is the more to be commended because Service work is often exasperating and inadequately appreciated. Nevertheless, disastrous mistakes have been made in the National Park System. For example, unless one is aware of political and other outside pressures on the National Park Service, it would be difficult to understand how the surface over the longest cave in the world – a cave very largely in a state of true wilderness – could have been the site in the last 10 years of the development of a system to supply water for visitors to Mammoth Cave National Park by capping natural springs, and of a Job Corps Camp where over 200 trainees are housed and engaged in a program that includes teaching the use of heavy road building equipment in the park. It is expediency, not public interest, that puts sewage basins in a national park where they can overflow to pollute the wilderness. The mere presence of open sewage basins in a national park, so far as that goes, is pollution of a higher aesthetic order.

These mistakes are the results of poor management decisions made by National Park Service administrators more under the influence of outside pressure than according to their own inclinations. Most of these mistakes can be rectified. Almost any developed land can be returned to wilderness, at least under the second definition given here, which states that wilderness is land where the effect of man's activities are substantially unnoticeable. The Job Corps boys themselves have contributed to this reconstitution of the wilderness in Mammoth Cave National Park in their efforts to remove the traces of roads, buildings, junk heaps, quarries, and fences of the former occupants of the area. When that work is done, a logical extension is to remove the Job Corps Camp itself, the roads and water supply system and sewage basins that service it, to return the entire surface of Flint Ridge to more natural conditions. It can be done; we have no doubt that eventually it will be done because the present development does not belong to any conception of a national park.

Our present concern, however, is not with the important question of returning lands to natural conditions, but with the problem of how in the future to avoid land management decisions that harm natural features. We believe that the solution is to declare selected portions of Mammoth Cave National Park as wilderness under the provisions of the Wilderness Act. George B. Hartzog, Jr., had this in mind when he spoke in the speech quoted above of restoring wilderness characteristics "as we now plan for specific areas within National Parks that will henceforth be identified legislatively as units of the Wilderness Preservation System."

> In the Wilderness Act, wilderness is defined as follows: /Wilderness is/ an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain . . . /wilderness is an area that/ generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable.

This definition is consistent with the second and third given above, because it does not deny man's presence, but only demands that the effects of his visits be substantially unnoticeable. It encompasses areas that give the general visitor a psychological feeling of being remote from the activities of man. It is clear, then, that all forms of wilderness described above as existing in Mammoth Cave National Park are appropriate for inclusion under the Wilderness Act.

Where cave systems have wilderness character below developed surface lands, they should be designated as underground wilderness, even if the overlying surface is given another designation. This is an appropriate application of the sense of the Wilderness Act, because the underground areas constitute a land regime of their own. It is an appropriate way to designate and to protect underground areas whose wilderness character does not derive from what lies on the surface overhead. For the absolute preservation of caves as natural features, it can be hoped that where the surface above is developed, it will eventually be returned to natural conditions. However desireable this is because of the geological and biological integration of surface and underground, it is obviously not necessary for the maintenance of underground wilderness values under the practical definitions given above.

The provisions of the Wilderness Act of 1964 are such that any land designated as wilderness can be administered under a broad range of management choices so long as the land is maintained in essentially natural conditions. Obviously, the designation of land as wilderness does not lock it up. We turn now to the multiple uses of wilderness in Mammoth Cave National Park.

3.3. Uses of Wilderness.

Wilderness has value because it can be used in at least three important ways: for recreation, as a natural laboratory for research, and as an environmental benchmark and management baseline. These uses are seldom mutually exclusive, so that wilderness almost always has multiple use. It is assumed in the following that all wilderness in Mammoth Cave National Park will be used in various ways, and that it will be used in ways compatible with keeping the land in a natural state.

3.3.1. Recreation.

3.3.1.1. General Nature of Wilderness Recreation.

Recreation in wilderness necessarily involves human contact with an undisturbed or unnoticeably disturbed natural environment. The recreative aspect of this interaction of man with nature results from the wonderment, enjoyment, understanding, and sometimes from the awe felt by the observer. Such wilderness experiences can be had wherever man observes or enters wild land.

One must approach the wilderness for recreation on its own terms. A tolerant bending to nature's ways is crucial to

the wilderness experience. Thus, in wilderness recreation one should behave as a harmonious part of nature, and the sense of this harmony is perhaps the most valuable thing one can get from wilderness.

The key to being only a visitor to wilderness that is left untrammeled is care for the natural environment. The land does not remain noticeably undisturbed if it is penetrated with motor vehicles or an excess of camping and survival equipment. Thus one enters on his own power, or at most on horseback. He secures his comforts by hand, and covers as best he can any sign of his passing.

People often choose wilderness recreation for adventure. On one's own with a few companions, a person feels the demands of self-reliance and the bonds of camaraderie. Climbing a mountain in the wilderness, for example, gives one elemental satisfactions that are not ordinarily attainable in an urban society. The adventure is in the confrontation and accomodation with wild nature.

Cave wilderness is quite out of the ordinary. People entering caves are impressed by the world of stone, silence, and absolute darkness. Cave passages are often complex, so explorers must make special efforts to remember the way back. It is difficult to carry much equipment when one has to crawl and worm one's way through tight passages, so it is fortunate that caving equipment consists of little more than a lamp and hard hat, with a bag for food. More than a few companions often destroys the wild aspect of narrow passages, so wilderness recreation in caves is most attractive to small groups. In the larger passages of Mammoth Cave, however, even large groups of visitors can be made to feel the vastness of the caves. In these caves one can experience a remoteness as intense as if one were at the poles or in the depths of the ocean, despite the presence of crowds of tourists on the surface overhead. The possibility of having such experiences is the basic attraction and challenge of Mammoth Cave National Park.

Men first entered wilderness to explore it, to see what no other man had seen before. Wilderness recreation today often consists in retracing the routes and experiences of original explorers. So long as the land retains its natural aspect, the experiences one has in visiting it can be nearly as adventuresome as those of the first explorers. There are still places on the surface of the earth where no men or only a few men have set foot. There is such true wilderness in the National Park System. Its presence enhances the appreciation even of those visitors who do not leave their cars. In the great cave systems of Mammoth Cave National Park the certainty that there are tens of miles of unexplored passages just beyond the trails heightens the quality of every visitor's experience.

3.3.1.2. Types of Wilderness Recreation.

There are two primary types of wilderness recreation distinguished by the degree to which the visitor is an observer of or a participator in the wilderness scene. By far the majority of visitors to national parks are observers. Their appreciation of wilderness usually begins in the park museum. It extends along nature trails to the sites of great natural wonders. It is enhanced by the talk of Park Naturalists around campfires. And it may culminate in a quiet walk to a place where wilderness land can be seen stretching into the distance. This kind of wilderness experience is important to many people. It satisfies a yearning to see and to know that is also expressed every year in the purchase of hundreds of thousands of books on wilderness themes. In Mammoth Cave National Park, the desire for such low intensity wilderness recreation is what brought more than a million people to see the caves in 1970.

Mammoth Cave National Park is also ideal for short-term wilderness recreation of a more participatory nature. It is a small park, so that wilderness areas can be reached from central areas and roads by hiking for short distances along trails. Visitors in search of the solitude of nature, and those who wish to observe wildlife such as deer and birds, can do so easily. The park also lends itself to overnight hiking and canoeing along Green River.

Similar wilderness experience could be arranged for visitors to the underground. As in the mountain parks, day schools to train people in the elements of caving could be initiated, and then guides could take small groups into the remoter portions of the cave systems. Visitors could thus experience the adventure of wilderness cave exploration.

More intensive short-term recreation, such as climbing the great walls in Yosemite, is not available on the surface in Mammoth Cave National Park. Underground, however, the cave systems stretch out to frontiers of unexplored wilderness. Explorers in these regions can have intense wilderness experiences. Long-term, high intensity adventure has not been a feature of wilderness recreation in the park, but there is some potential for it. One could imagine small parties spending a month or more underground traversing from one great cave system to another. However, such trips would require camping gear and food more compact and lightweight than has yet been developed. For the present, intensive wilderness experiences in these caves will seldom exceed 36 hours.

3.3.1.3. Management of Wilderness Recreation.

Two problems of protection face managers of wilderness recreation. The wilderness must be protected from the visitors, and the visitors must be protected from the wilderness. Solutions to both must rest in large part on trust. It should be one goal of the interpretive programs in the national parks to educate the public so that people understand why and how the wilderness is to be protected. At the same time they should learn some of the rudiments of taking care of themselves in wilderness situations. A major proportion of wilderness management activity, then, should be concerned with the interpretive program for the majority of visitors who are seeking low intensity wilderness recreation. Museums, nature hikes, talks, booklets, etc. are essential.

In Mammoth Cave National Park, guides for large groups of visitors touring the main passages of Mammoth Cave are also a critical part of the management scheme. It is their business to take visitors comfortably and carefully through the cave, interpreting the features to give people a knowledgeable sense of the natural environment. An excellent program of self-guided tours was initiated a few years ago, and although this raises special problems in conserva-

tion, it provides such a superlative experience for visitors who want a quiet and relaxed tour of the cave that it certainly should be continued. It is the natural complement to self-guided nature trails on the surface.

Short-term, low intensity cave exploration for more venturesome visitors requires the establishment of a training school. Management here must evaluate and improve the capabilities of aspiring explorers. Equipment would have to be provided, and a much larger number of guides in relation to visitors would be necessary than in the main cave. The maximum size for a group exploring in wild portions of the caves would probably be six visitors accompanied by two guides. The small size is necessary to maintain the wilderness aspect of the trip. Two guides would be required as a safety measure. However, a well-organized program of trips through areas known perfectly to the guides could be managed in such a way that successive parties act as security for those that have gone on ahead. Because most participants would probably have never taken a wild cave trip before, their experiences can be made quite satisfying as they crawl through passages in undeveloped portions of the cave, even when these are quite close to paved trails. Obviously the guide force here would also constitute rescue teams in rare cases of need.

Exploration in the wilderness passages on the fringes of the known cave requires highly organized management. Most of this activity since 1957 has been managed by the Cave Research Foundation in a general geographic program of cartography and scientific research. Thus, the main purpose has not been wilderness recreation. Nevertheless, for some participants this work is also recreation, and in any case the general principles of management are the same. To field parties safely in the remotest portions of the cave systems, leaders must be trained who know the cave passages, who know how to lead parties, and who know how to make the right decisions both in routine exploration and in emergencies. A well-organized surface crew in contact with quickly mobilizable rescue crews must be maintained. Finally, the overall program must be under the direction of one person or a few people who know what is going on because they have done such exploration themselves.

Parties should be no larger than four or five people, for otherwise it is hard for a leader to keep track and control of them. The leader's word must be law, and no one should conceal fatigue or uneasiness. Despite the tight framework outlined in the paragraph above, explorers in this greatest of all cave wildernesses are very much on their own. The Cave Research Foundation requires a considerable amount of training and preliminary experience before allowing people to work in these regions. We are certain that any program of intensive wilderness cave recreation in similar areas should be managed in the same way.

3.3.2. Research.

3.3.2.1. The Natural Laboratory.

Because of the commitment of the National Park Service to maintain its lands in relatively natural conditions, most of its parks are ideal natural laboratories for scientific research. Natural laboratories are areas in which natural conditions prevail. These laboratories are not in buildings and do not contain large quantities of equipment. Instead, they contain natural features that can be observed and studied by scientists interested in natural processes. The importance of national parks in this context is first that they contain extremely interesting and sometimes unique features. Second, the parks have firm, perpetually protected boundaries so that studies of long duration can be undertaken with assurance that natural conditions will be maintained.

It has been remarked above that the surface of Mammoth Cave National Park contains perhaps the only stand of virgin timber in the Central Kentucky Karst. The park also contains animal and bird populations that can be observed in relatively natural states. In the caves below, there is an immense underground laboratory.

The natural cave laboratory of Mammoth Cave National Park has in effect been described in Chapter I on natural features. Here we need say only that much has been learned from this laboratory already, but that much more of considerable value remains to be learned. Thus this great laboratory should be maintained primarily as wilderness in the future as it has been in the past.

It is to be stressed that natural conditions can be maintained easily because study in natural laboratories is almost entirely observational. The most extensive equipment used for this is usually various remote sensing devices that report such parameters as temperature and humidity, but do not disrupt natural conditions by their presence. Experiments involving the manipulation of natural features or the environment are seldom undertaken in natural laboratories. When they are it is most often for mission-oriented purposes, and only under strictly controlled conditions. Experimental work is much better done in specially prepared formal underground laboratories outside the parks, such as the Ozark Underground Laboratory and the facilities maintained by the Institute of Speleology at the University of Kentucky. Formal analysis of materials and data is also invariably completed at the scientists' home institutions. After 10 years of examining the question, it is now the opinion of the Cave Research Foundation that only rudimentary formal laboratory facilities are needed in Mammoth Cave National Park. These can be housed economically in the already developed park headquarters complex. No formal facilities are needed in the natural laboratory.

3.3.2.2. Types of Research.

Classic natural history, the observation and recording of the behavior patterns of wildlife and the effects of natural processes, is the foundation for all studies in natural laboratories. In Mammoth Cave National Park the natural history of cave life and processes is far from being completely written. There are many aspects of the life cycles of cave fauna, and of the origin of cave features, that are not yet understood. Consequently, the primary type of research activity in the park will continue to be observational natural history for some time to come.

Observation, however, seldom involves simply going into the woods and caves to look around. Scientists enter the natural laboratory with specific questions in mind, and they have ingenious techniques for coaxing the answers out

of nature. Most people are familiar with the tagging of deer, bats, and birds to study their ranges and migrations. But what about catching all the insects of selected areas in a small cave to put tiny color-coded specks of paint on each? This was done by one scientist in Mammoth Cave National Park, who released the insects, and then caught them again to study their movements and migrations. Special equipment here, it goes without saying, included a microscope and magnifying glasses. And though some of the insects, like some of the deer, protested about being tagged, none seemed worse for wear.

Sedimentation has been studied in the caves by trenching and by leaving measuring devices to record increases and decreases from flooding. Mineralization and crystal growth are studied with similar techniques. Water chemistry and regimes change and are plotted throughout the year. Dye tests have demonstrated that water from the Sinkhole Plain flows under the Mammoth Cave Plateau to discharge out big springs into Green River. Remote sensing devices have been used to record micro-climates in parts of the cave systems.

Archeological excavations in the caves of Mammoth Cave National Park have provided a wealth of unique data about the activities of Early Woodland peoples. Much remains to be discovered about these prehistoric Indians, about the saltpetre miners of the Nineteenth Century, and about the early explorers and guides in Mammoth Cave. The special techniques of archeological recording and analysis represent another type of research in the natural laboratory.

The above provides illustrations of relatively simple types of research in the natural laboratory. However, they are parts of an interdisciplinary program designed to provide understanding of the larger biological, geological, and human geographical systems of the Central Kentucky Karst. In 1960 the Cave Research Foundation published a booklet – *Speleological Research in the Mammoth Cave Region, Kentucky: Elements of an Integrated Program* – in which the modern systems approach is outlined. The present research programs are designed not only to obtain specific data as outlined above, but also to understand the biological evolution and ecological interactions of the region. In the total geological system we are concerned to see how processes as diverse as erosion and crystal growth contribute to the evolution of the total karst landscape, and to understand the complete hydrological economy of the region. From the standpoint of human geography, a vast panorama of human relations is presented, from the prehistoric origins of agriculture, to the replacement of Indians by European settlers, to present-day economic interrelationships. All these dynamic systems are interrelated in a complex, evolving physical and social organism – The Central Kentucky Karst. A high level type of research in the natural laboratory of Mammoth Cave National Park, therefore, is this integrated program of study of biology, geology, and people.

3.3.2.3. Value of Research.

One result of value from the systems approach is the analysis of regional economic relations in Chapter IV below. An understanding of the big picture is essential for all varieties of planning, not only for activities within Mammoth Cave National Park, but also for regional development and the national interest. The practical value of wilderness research thus stems from the common need to know as much as possible about a situation before making decisions about what to do.

A second general value of information derived from wilderness research is that it is a commodity sought after by millions of visitors to the National Park System. The complete story of the insect study mentioned above, or explanations of how caves form, and so on, are things that many people find delight in knowing, if for no other purpose than to satisfy their curiosity about the natural world. Of course this desire to know is what makes us human, and we mention only in passing that one of the highest values in Western Civilization has always been knowledge simply for the sake of knowledge. For the National Park Service, wilderness research is the major source of data for interpretive programs.

More specifically, such data is essential to responsible park planning. Knowledge of nature features and processes in a park is required in order to predict whether developments will disturb the natural environment. More and more important in recent years as outside development encroaches on park boundaries, knowledge of natural processes is necessary for active programs of the restoration, maintenance, and protection of natural features. Research on the ecological role of predators, fire, and water regimes have been of revolutionary value in recent years. The parks themselves are the main places where such data can be gathered.

A most important specific example of research centering in Mammoth Cave National Park that has regional value is the continuing program of hydrological studies. Much of the Appalachian Mountains and Interior Lowland Provinces of the eastern United States is underlain by limestone. There are considerable problems of water supply and sanitation as a result of urbanization. Natural conditions are largely disturbed in these areas, but karst drainage there can be understood in part by analogy to the results of park studies. Comparisons can also be made in studies of soil erosion on limestone terrains.

Research on the evolution and ecology of specialized cave animals can be of great value to the understanding of evolution in general and of adaptation to extreme environments. Such information may ultimately be applicable to problems of human genetic engineering. Circadian rhythm research has already been useful to the space program. And the simple cave communities are ideal for the study of individual and group life system dynamics. Some of the simplest cave communities are analogous to early stages of disturbed or polluted ecosystems that occur outside caves, and so knowledge about them can help in our fight against a polluted environment. Very basic scientific research on cave animals is turning out to have practical value in the new explosion of biological knowledge following the discovery of the genetic code that was not dreamed of a few years ago.

Only a few examples of the values of wilderness re-

search are given above. Enough has been said, however, to establish the wide range of practical benefits that follow from the knowledge gained.

3.3.3. Environmental Benchmark and Management Baseline.

One purpose wilderness lands serve is to provide environmental benchmarks that exhibit natural features and processes against which to compare land that has been developed or disturbed. Such benchmarks are of particular importance when the question is one of restoring disturbed land to natural conditions. They also serve as guides against which to predict and to gauge the amount of disturbance that various developments may cause. Environmental benchmarks also contain gene pools, that is, they contain a great variety of plants and animals. As remarked in Chapter I above, man simplifies the natural environment when he introduces a few domesticated crops and animals in place of large numbers of different species of wild plants and animals. It is, however, of intrinsic value to preserve examples of all the wild species, and it is quite possible that some little known species will have great value in the future either through being domesticated themselves or crossed with domesticates.

In much the same way, wilderness lands act as management baselines for administrators of lands of all sorts. Against such baselines managers can plan and measure the effects of development decisions. For example, measurements of a great number of parameters such as temperature, humidity, carbon dioxide content of the air, water pollution, density and diversity of cave animals, and so on in the wild caves of Mammoth Cave National Park can be compared to similar measurements in the developed portions of Mammoth Cave. In effect, the introduction of visitors on a large scale in Mammoth Cave is an experiment, and its effects can be determined only by reference to the baseline. Manipulation of various factors in the developed cave could be undertaken to seek optimum conditions for showing the cave while at the same time maintaining its natural environment.

Several studies of this sort in France have shown how visitors affect a cave. In one a photographic expedition that remained in one location for three days reduced the number of beetles in a large cave room for a radius of 50 yards and reversed the order of abundance of the two commonest cave species for several months thereafter. Another study conducted in a small show cave indicated that the numbers of all permanent cave dwellers was reduced drastically throughout the cave although only about one-third of it was shown to visitors.

In Mammoth Cave National Park, it is known that occasional sewerage contamination in the Eyeless Fish Trail area and the general backflooding of Green River has added such toxins to the food chains as blue-green algae and saline oil scum. In other areas the presence of litter provides excess food resulting in increased populations of some cave animals at the expense of others. At Frozen Niagara species are found today that are normally unable to live in caves at all.

Some of these effects are harmful, but others may not be. The only way to discover either the effects or their significance is through comparison with wilderness portions of the cave systems. In Mammoth Cave National Park, all three main ridges contain the same species, but Flint Ridge and Joppa Ridge contain ecological communities that are not common or not known in Mammoth Cave Ridge. This is probably in part because Mammoth Cave has been shown to visitors for over 100 years. For example, Mammoth Cave has no known examples of vertical shaft stream communities, and its large river trunk drain, Roaring River is a hydrological backwater compared to the trunk drains of the Flint Ridge and Joppa Ridge Cave Systems. Thus the original conditions under which trunk drain communities evolved is found now only in the large underground rivers that feed the big springs of Flint Ridge and Joppa Ridge.

It should be obvious from what has been stated and implied above that the wilderness areas of Mammoth Cave National Park serve quite valuable functions as environmental benchmarks and management baselines.

CHAPTER IV

MAMMOTH CAVE NATIONAL PARK WILDERNESS IN A REGIONAL CONTEXT

In Chapter I we show how Mammoth Cave National Park is geographically integrated in the Central Kentucky Karst. From geological and biological viewpoints, the park is the hub of the region. In Chapter III we describe uses of the park, all of which have regional implications. Some of the finds of research in the park are of value to all mankind. Of more immediate interest are the implications of recreational uses. For well over 100 years Mammoth Cave has been the main attraction in the Kentucky Cave Country. Tourists come from all over the world to see this cave, and the regional economy is in part dependent on tourist revenue. In this final chapter we begin with a survey of the regional potential for recreational and tourist services. We conclude by considering the role of wilderness in Mammoth Cave National Park as the heart of the tourist industry in the region.

4.1. Show Caves in the Kentucky Cave Country.

People are attracted by the big cave. But this does not mean that Mammoth Cave is the only one they see when they come to Kentucky Cave Country. The primary feature of Mammoth Cave is its bigness. It does not contain a wealth of dripstone and flowstone decoration like Carlsbad Caverns, nor is it very pretty in a conventional sense. Features that would stand out in smaller caves are lost in its vastness.

Tourists are always impressed by Mammoth Cave, but very often they still want to see a cave full of stalactites, stalagmites, and other decorations. There are many such small caves around the southern borders of the Mammoth Cave Plateau, and as many as 20 of them have been shown to tourists at one time or another since Mammoth Cave was opened. This need is now met by such private developments

as Mammoth Onyx Cave, Diamond Caverns, Park Mammoth Resort, and Crystal Onyx Cave. There is possibly room for more. For example, the opening of Hidden River Cave again would increase both the attractiveness and the tourist revenue of the town of Horse Cave.

There is certainly good reason for cooperation between private show caves and the National Park Service. Service literature should describe Mammoth Cave in the regional context with clear indications of the many different kinds of caves one can see in the area surrounding the park. It is a difficult thing to put across without making the Service seem stodgy, but it is worth telling people somehow that the private caves are more "colorful" than Mammoth Cave. Not simply that some are more highly decorated with features different from those in Mammoth Cave, but that others can be presented as "entertainment" with colored lights, music, and fanciful tales that would be inappropriate in a national park. Anyone who has visited a small cave developed by a real showman will know what we mean. This would probably not take any great pressure off of Mammoth Cave itself because tourists on vacation generally want to see both kinds of caves. But it would help to spread the load.

When properly described, Mammoth Cave does not compete with private show caves. Rather, Mammoth Cave is the internationally known lure that brings millions of tourists to the Kentucky Cave Country marketplace.

4.2. Campgrounds, Motels, Restaurants, and Souvenirs.

In 1966, $23 million was spent in the Kentucky Cave Country for business and pleasure. $15 million came from non-Kentuckians and was probably spent mostly on vacations. It can be inferred that a considerable number of the 28 million non-Kentuckians who came to Kentucky for a vacation during that year were attracted by caves. More recent studies would undoubtedly show growth in expenditures.

A considerable portion of this money is spent on sleeping accomodations, food, and souvenirs. Supposing people come to see Mammoth Cave, there is no possibility that all of these services could be provided entirely in Mammoth Cave National Park, nor is there any reason why more than a fraction should be.

Tourist services of most immediate access to visitors to Mammoth Cave National Park are found along the main roads around the southern borders of the park, primarily Interstate Highway I-65, U.S. Highway 31W, and Kentucky State Road 70 (see Figure 7). Facilities are concentrated at the interchanges of the interstate highway, and in four small towns: Horse Cave, Cave City, Park City, and Brownsville. The first three towns have long provided excellent services, from modern motels with swimming pools to meals of real country ham. The interstate highway, however, was routed between these towns and Mammoth Cave National Park. Tourists can now leave the interstate to drive west to the park without being aware of facilities existing just a mile or two to the east. Businessmen have responded by building at the interstate interchanges, but a considerable amount of publicity and planning must continue if the established tourist industry in these towns is to be maintained. One excellent way to do this is by stressing regional facilities in National Park Service literature about Mammoth Cave National Park.

Brownsville has only recently started developing to service tourists visiting the park. Much further development could be profitable in this area. Brownsville is scenically located along Green River, so that campgrounds and motels can offer access to the river for fishing or boating. There is also fine scenic country on State Road 70 leading from Brownsville into the park, along which campgrounds would be useful. Brownsville is further central to planning that stresses regional relationships between Mammoth Cave National Park and the Nolin Reservoir. A natural route for vacationers enjoying the advantages of both the park and the reservoir is through Brownsville.

Three other towns should serve as regional focuses in the Kentucky Cave Country. Munfordville to the north, Glasgow to the southeast, and Bowling Green to the southwest are main entry ports. Establishment of highly visible tourist information services at these points could assure that tourists would have a proper regional view of the Kentucky Cave Country. Rather than tunneling their vision on Mammoth Cave, tourists would then realize that the region is a vacationland with a considerable variety of offerings.

Campsites, motels, restaurants, and souvenir shops are needed in large numbers to service the millions of people who come to the Kentucky Cave Country each year. In this section we give only a sketch of a regional view of this aspect of the tourist industry. Obviously it implies enlightened cooperation among private developers and between them and the National Park Service.

4.3. Roads and Transportation.

In general, regional planning for roads in the Kentucky Cave Country requires the careful analysis of routes between major attractions and services, and then the designing and placement of enough road signs to enable tourists to find their way about easily. In particular, routes from Brownsville and from Munfordville to the Nolin Reservoir should be well-marked both on the ground and in tourist literature. The need for this for services in towns close to Mammoth Cave National Park is mentioned above.

Transportation within Mammoth Cave National Park poses a special problem. Today visitors travel to park headquarters by private automobiles. They park their cars in a huge parking lot, and then many of them return along the same roads in National Park Service buses to Mammoth Cave entrances near the edge of the park. After their cave trips, they return along the same roads in buses again to their cars. And then for the fourth time over the same roads, they leave the park. The description of this relay race suggests some obvious possible improvements that would both open new private commercial possibilities and improve natural conditions in the park.

There is no reason for day-visitors to take their cars into the park at all. Tourists could be met at entrances on the park boundaries by visitor centers to receive orientation and interpretation guides. They would park their cars in privately run parking lots outside the park. Inside the park,

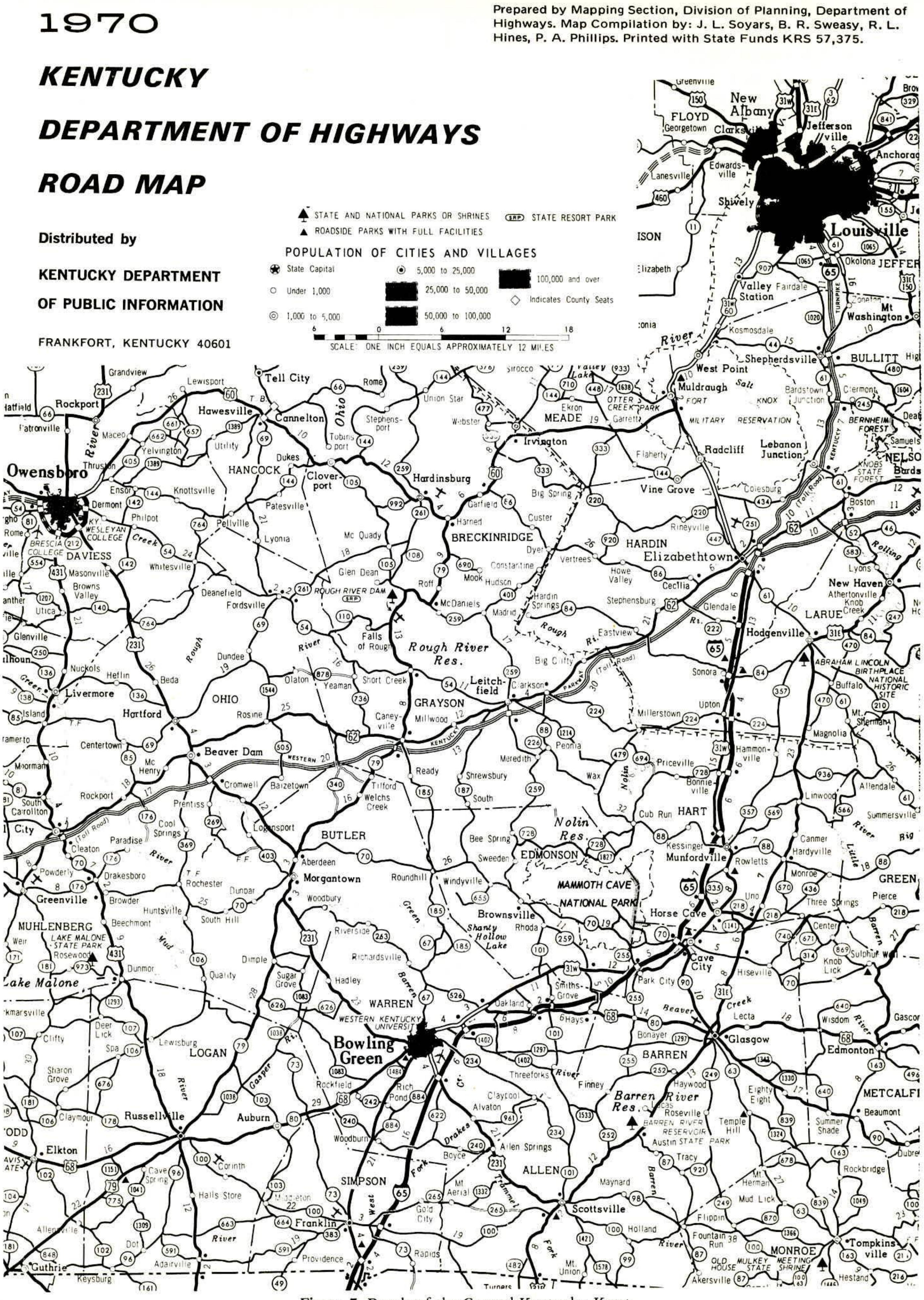

Figure 7. Roads of the Central Kentucky Karst.

they could be taken to cave entrances and park headquarters by buses scheduled to run, say, every 15 minutes or so, which is about how long it takes to reach park headquarters from the boundary. At headquarters they could visit the museum, the main entrance to Mammoth Cave, and nature trails. The park is small enough that many trails could start on the boundaries and end at park headquarters. Day hikers could then use bus transportation to return to their cars outside the park. Obviously, it would be most appropriate if the bus service were run by a private concessions company.

4.4. Developed Regional Recreation.

Show caves are discussed above as the most obvious recreational developments in the region. There are many other such special feature attractions such as a chair lift to the top of a knob, a wax museum, golf courses, swimming pools, riding stables, and a miniature railroad. Park Mammoth Resort is a superb vacation development, combining as it does rooms, restaurant, show caves, and a wide variety of organized outdoor activities. It is also one of the several establishments in the region that has facilities large enough for banquets and conventions.

Noteworthy among attractions are pageants, such as those depicting the tales of the Shepard of the Hills and of the Death of Floyd Collins. More summer stock theatre would surely find audience in the Kentucky Cave Country. It is also clear that conventional entertainments such as drive-in movies and bowling alleys have not been exploited with tourists in mind at all to the degree that might be possible. Souvenir shops aim directly at tourists, but grocery and dry goods stores often miss the opportunity to attract tourist trade.

Beyond these, there are not enough specialized recreation businesses in the Kentucky Cave Country. Businessmen should look more into the possibilities of state assistance and aid from the U.S. Department of Agriculture for the development of camp grounds, golf courses, archery ranges, rifle and skeet ranges, fishing ponds, and other outdoor recreational uses of marginal land. It is probable, for example, that one of the small towns close to Mammoth Cave National Park could profit from the installation of a small airstrip for private airplanes.

Hunting is a popular form of recreation in the Kentucky Cave Country. Deer hunters from all over the state come for particularly fine hunting where the Mammoth Cave National Park deer population spreads out over its boundaries. Surplus deer from the park herd become a valuable statewide resource as they are captured in the park to be exported hundreds of miles away. In the absence of natural predators, this is a logical way of reducing the quantity of deer in the park to an ecologically balanced number.

Fishing is also quite popular. One resource that has not been exploited as it might be, however, is the stretch of Green River that runs from Munfordville to Brownsville through Mammoth Cave National Park. Float trips could start at Munfordville with parties spending one or two nights camping along the river before taking out at Brownsville. John boats for fishing and canoes or kayaks for sport might be made available at Munfordville, and perhaps at Brownsville also, for trips on down the Green.

Kentucky is famous for horse racing, and the possibility of modest track development might be investigated in the Kentucky Cave Country. Dog tracks and stock car tracks are further possibilities.

On a larger scale, one of the finest recreational resources in the Kentucky Cave Country is the Nolin Reservoir with its 5000 acre lake newly constructed and administered by the Army Corps of Engineers. Fishing, camping, water sports, and many other activities are available here only a short drive from Mammoth Cave National Park. Construction of facilities at the reservoir is just beginning, so that considerable opportunity exists for private development and regional planning. Here, also, vacation home development can take place as it cannot in the park. Barren River Reservoir State Park, Rough River Dam State Park, and Lake Cumberland State Park offer other developed alternatives to the more natural scene at Mammoth Cave National Park.

4.5. Water Supply and Sewers.

The water supply and sewer systems in Mammoth Cave National Park are inadequate. They also disrupt the natural environment as described above. With all developed park services concentrated in the headquarters area, it is feasible to lay lines from outside the park for water input and sewer outgo. There are several water supply districts in the region, one of which should be integrated with Mammoth Cave National Park. Along with trucking systems to remove trash and garbage from the park, development of water and sewer systems adequate to service the park and consistent with the maintenance of natural lands offers possibilities for profitable cooperation between private interests and the National Park Service.

4.6. Tourist Services in Mammoth Cave National Park.

It is traditional in the National Park System to provide some overnight accomodations, filling stations, light grocery stores, restaurants, souvenir shops, and sometimes special touring services such as the boat ride on Green River. These facilities have been developed by the concessioners in Mammoth Cave National Park to quite reasonable limits. There are about 150 overnight units in the park, besides Service provided campsites. The restaurant is so good that it is an embarrassment, because it attracts local club meetings and convention groups. The craft shop offers some fine items.

The museum, nature trails, and Mammoth Cave itself all center at headquarters in the park, and there is certainly room there for a limited number of people to stay a few days for a quiet vacation. Just what this limit can be while still maintaining the natural atmosphere of the park should be carefully studied. In all probability it should not exceed present accomodations.

Ideally, the cottages and motel rooms provided in the park, along with the limited number of campsites, should be used by visitors who wish to stay in the park for several days to a week. People who want merely to take a cave trip, or to visit the park for a couple of days, can be quite adequately accomodated outside the park. Very careful

regional planning could establish this pattern. This has already begun with the campsites, because the demand for them has reached such proportions that limits on number of campers in the park have been imposed. This, of course, has opened opportunities for commercial campsites outside the park. It may be necessary to place park campsites in a reservation system before very long and to ration their use.

Development that should be initiated to increase the carrying capacity of Mammoth Cave National Park is a trail system and campsites for overnight hikers. These must be carefully designed, both to maintain the wilderness aspect of the park, and because campfires in such a densely wooded area are fire hazards. However, it is this forest and the ruggedness of the terrain that would make the park so attractive to hikers and campers were it developed with them in mind. There is practically no hiking and camping in the park at the present time. Thus it is to be stressed that such development would attract a new kind of tourist to the park, the wilderness hiker. It would make the park more attractive for the service of more people, without disturbing the present pattern of day tours in Mammoth Cave. It is important to recognize this, because some people have the mistaken view that wilderness locks up resources. Quite to the contrary, without disrupting the present inflow of tourists to the region who wish to see Mammoth Cave, proper management of wilderness in the park would open it to even more users.

Development of a wilderness trail system is something that might be undertaken by the trainees of the Job Corps Camp that is now situated in the park. However, we believe that the placement of the Job Corps Camp in Mammoth Cave National Park is an obvious adverse use of park lands. In the regional context, the Job Corps Camp could be much more appropriately and profitably situated outside the park where trainees could learn to build and maintain roads and similar skills to the benefit of the local communities rather than to the detriment of natural conditions in the park.

4.7. The National Scene.

We have said little in this report about the increase in population in the United States and the consequent increases in pressures for development in national parks. Everyone knows that these pressures will get more intense. It is our thesis that development should be regional, with formalized tourist facilities planned to integrate with rather than to overwhelm the natural character of Mammoth Cave National Park. As population increases and as most lands are developed, primitive land will increase in value in a multitude of ways. Wilderness land will become more and more rare, and will appear exotic and unique in the setting of regional development.

Mammoth Cave National Park is situated as the only piece of wild land larger than a few acres in the central United States that is protected in perpetuity by law. In looking at this park in a regional context, one sees that it is the heart of the tourist industry of the Kentucky Cave Country. So long as Mammoth Cave exists, it will continue to attract visitors from every place where its name is known. Looking to the future, it is without question that the maintenance of the park in natural conditions will enhance its attractiveness immensely. It is the gem for which surrounding commercial development can provide the regional setting. It is a park important not just because of big caves, but also because of its forests, ridges and valleys, the Green River gorge, and the hilly country north of the river. It is our conclusion and prediction that on the 100th anniversary of the dedication of Mammoth Cave National Park, it will be admired and visited as much because it contains a rare remnant of prehistoric American wilderness as for Mammoth Cave.

CONCLUSION

This report demonstrates that the local Mammoth Cave area is geographically integrated with the Kentucky Cave Country region, and that underground features are physically and ecologically connected with the surface. It is obvious that the management and protection of natural features locally and underground is influenced by and in many cases depends on the details of development of the overlying surface and the general region. Thus, to examine adequately the potential of the wilderness resources of Mammoth Cave National Park, it is necessary to place the park in a regional context. If the park is to be preserved and exhibited in its natural state, it must be maintained as a predominately natural area in the context of regional development.

Our general conclusion, then, is that Mammoth Cave National Park can be used and protected best if it is managed primarily as a primitive area in the setting of a private, regional tourist industry. We have described how this can be done. The park will continue in its value as the central attraction of the Kentucky Cave Country. Millions of people will continue to come each year to see some of the world's most spectacular cave scenery in its natural state. They will find at the same time comprehensive private tourist facilities in the region surrounding the park. In a carefully planned program of regional development, Mammoth Cave National Park can serve the public's need for recreation and refreshment in a primitive, natural setting, without competing with the endeavor of private enterprise to provide a wide range of Kentucky Cave Country tourist attractions and services.

SELECTED BIBLIOGRAPHY

CAVE RESEARCH FOUNDATION AND MAMMOTH CAVE NATIONAL PARK

Bridwell, M. M. (1959) *The Story of Mammoth Cave National Park, Kentucky*, n.p. 64 pp.

Brucker, R. W. (1955) "Recent Explorations in Floyd Collins' Crystal Cave" *National Speleological Society Bulletin* No. 17, pp. 42-45.

Halliday, W. R. (1966) *Depths of the Earth*. New York: Harper & Row, 398 pp.

Hovey, H. C. (1970) *Celebrated American Caverns*. Facsimile reprint of the 1886 edition with a new introduction by W. R. Halliday. New York: Johnson Reprint Corporation, 228 pp.

Lawrence, J. Jr. and R. W. Brucker (1955) *The Caves Beyond*. New York: Funk and Wagnalls, 283 pp.

Scott, W. R. (1962) *A Pictorial Study of Mammoth Cave and Mammoth Cave National Park*. Mammoth Cave: National Park Concessions, 40 pp.

Smith, P. M. (1957) "Discovery in Flint Ridge, 1954-1957" *National Speleological Society Bulletin* No. 19, pp. 1-10.

Smith, P. M. (1964) "The Flint Ridge Cave System, 1957-1962" *National Speleological Society Bulletin* Vol. 26, pp. 17-27.

Smith, P. M. and R. A. Watson (1970) "The Development of the Cave Research Foundation" *Studies in Speleology* Vol. 2, pp. 81-92.

Thompson, R. S. (1970) *The Suckers' Visit to the Mammoth Cave*. Facsimile reprint of the 1879 edition with a new introduction by J. F. Bridge. New York: Johnson Reprint Corporation, 128 pp.

MAPS

Brucker, R. W. and D. P. Burns (1966) *The Flint Ridge Cave System*. Washington, D.C.: Cave Research Foundation, 34 pp.

U.S. Geological Survey (1930) Topographic Map of the Mammoth Cave National Park, Kentucky.

GEOLOGY

Brown, R. F. (1966) *Hydrology of the Cavernous Limestones of the Mammoth Cave Area, Kentucky*. U.S. Geological Survey Water-Supply Paper No. 1837, 64 pp.

Brucker, R. W. (1966) "Truncated Cave Passages and Terminal Breakdown in the Central Kentucky Karst" *National Speleological Society Bulletin* Vol. 28, pp. 171-178.

Cushman, R. V., R. A. Krieger, and J. A. McCabe (1965) *Present and Future Water Supply for Mammoth Cave National Park, Kentucky*. U.S. Geological Survey Water-Supply Paper 1475-Q, 46 pp.

Davies, W. E. and Chao, E. C. T. (1959) *Report on Sediments in Mammoth Cave, Kentucky*. U.S. Geological Survey Administrative Report, 115 pp.

Deike, G. H. III. (1967) *The Development of Caverns of the Mammoth Cave Region*. Pennsylvania State University Ph.D. Dissertation, 235 pp.

Lobeck, A. K. (1928) *The Geology and Physiography of the Mammoth Cave National Park*. Kentucky Geological Survey Series 6, Pamphlet 21, 69 pp.

McGrain, P. and A. Livesay, *Geology of the Mammoth Cave National Park Area*. Kentucky Geological Survey Series 10, Special Publication 7, 40 pp.

Pohl, E. R. (1955) *Vertical Shafts in Limestone Caves*. National Speleological Society Occasional Paper No. 2, 24 pp.

Pohl, E. R., R. V. Cushman, et al. (1964) *Geological Society of Kentucky Field Trip, Itinerary: Geologic Features of the Mississippian Plateaus in the Mammoth Cave and Elizabethtown Areas, Kentucky*. Kentucky Geologic Survey, 32 pp.

Pohl, E. R. and W. B. White (1965) "Sulfate Minerals: Their Origin in the Central Kentucky Karst" *American Mineralogist*, Vol. 50, pp. 1461-1465.

Watson, R. A. (1966) "Central Kentucky Karst Hydrology" *National Speleological Society Bulletin* Vol. 28, pp. 159-166.

White, W. B. (1968) "Sulfate Mineralogy in Some Caves in the United States" *Proceedings of the IVth International Congress of Speleology* Vol. 3, pp. 645-654.

White, W. B., R. A. Watson, E. R. Pohl, and R. W. Brucker. (1970) "The Central Kentucky Karst" *Geographical Review* Vol. 60, pp. 88-115.

Wright, H. E., B. Spross, and R. A. Watson (1966) "Pollen Analyses of the Sediment from Sinkhole Ponds in the Central Kentucky Karst" *National Speleological Society Bulletin* Vol. 28, pp. 185-188.

Quinlan, J. F. (1970) "Central Kentucky Karst" *Mediteranee* No. 7, pp. 235-253.

Swinnerton, A. C. (1932) "Origin of Limestone Caverns" *Geological Society of America Bulletin* Vol. 43, pp. 663-694.

BIOLOGY

Bailey, V. (1933) "Cave Life of Kentucky Mainly in the Mammoth Cave Region" *American Midland Naturalist* Vol. 14, pp. 385-635. Reprinted as a book by The University Press, Notre Dame, n.d., 256 pp.

Barr, T. C. Jr. (1962) "The Blind Beetles of Mammoth Cave, Kentucky" *American Midland Naturalist* Vol. 68, pp. 278-284.

Barr, T. C. Jr. (1967) "Ecological Studies in the Mammoth Cave System of Kentucky. I. The Biota" *International Journal of Speleology* Vol. 3, pp. 147-204.

Barr, T. C. Jr. and R. Kuehne (in press) "Ecological Studies in the Mammoth Cave System of Kentucky. II. Ecological Communities" *Annales de Speleologie* Vol. 26.

Culver, D. C. and T. L. Poulson (in press) "Studies of Community Boundaries: Faunal Diversity around a Cave Entrance" *Annales de Speleologie* Vol. 26.

Delbouteville, G. D. and M. Cabidoche (1967) "Perturbations Apportees aux Populations Troglobites par les activites humaines ou les amenagements" *Bulletin Museum National d'Histoire Naturelle* 2° Serie, Vol. 38, pp. 753-756.

Mohr, C. E. and T. L. Poulson (1966) *The Life of the Cave*. New York: McGraw-Hill, 232 pp.

Nicholas, Bro. G. Sullivan (1967) *Observations on the Population Dynamics of a Cavernicolous Ecosystem*. Notre Dame University Ph.D. Dissertation.

Nicholas, Bro. G. Sullivan and R. W. Brucker (1965) "Establishment of a Quadrat System for Quantitative Ecological Studies in Cathedral Cave, Kentucky" *National Speleological Society Bulletin* Vol. 27, pp. 97-103.

Poulson, T. L. and D. C. Culver (1969) "Diversity in Terrestrial Cave Communities" *Ecology* Vol. 50, pp. 153-158.

Poulson, T. L. and W. B. White (1969) "The Cave Environment" *Science* Vol. 165, pp. 171-181.

ARCHEOLOGY

Benington, F., C. Melton, and P. J. Watson (1962) "Carbon Dating Prehistoric Soot from Salts Cave, Kentucky" *American Antiquity* Vol. 28, pp. 238-241.

Ehman, M. F. (1966) "Cane Torches as Cave Illumination" *National Speleogical Society News* Vol. 24, pp. 34-36.

Faust, B. (1967) *Saltpetre Mining in Mammoth Cave, Kentucky*. The Filson Club, 96 pp.

Meloy, H. (1968) *Mummies of Mammoth Cave*. Shelbyville, Indiana, 40 pp.

Schwartz, D. W. (1965) *Prehistoric Man in Mammoth Cave*. Eastern National Park & Monument Association Interpretive Series No. 2, 28 pp.

Watson, P. J. (1966) "Prehistoric Miners of Salts Cave, Kentucky" *Archaeology* Vol. 19, pp. 237-243.

Watson, P. J. (1969) *The Prehistory of Salts Cave, Kentucky*. Illinois State Museum Reports of Investigations No. 16, 86 pp.

Watson, P. J. and R. A. Yarnell (1966) "Archeological and Paleoethnobotanical Investigations in Salts Cave, Mammoth Cave National Park, Kentucky" *American Antiquity* Vol. 31, pp. 842-849.

Wilson, G. (1967) *Folkways of the Mammoth Cave Region*. National Parks Concessions, 64 pp.

WILDERNESS

Curl, R. (1962) "Speleology: Peculiar Laboratories for the Study of Evolution, Caves Fascinate Scientists from many Disciplines" *Science* Vol. 137, pp. 285-287.

Davidson, J. K. (1968) *Statement of the President, Cave Research Foundation, at the Meeting with the Mammoth Cave National Park Master Plan Study Team, May 25, 1968*. Washington, D.C.: Cave Research Foundation, 5 pp.

Hart, W. J. and W. S. Boardman (1968) "A Wilderness Plan for Mammoth Cave National Park and the Surrounding Region" *National Parks Magazine* Vol. 42, No. 244, pp. 14-16.

Hartzog, G. B. Jr. (1967) Speech, Dept. of Interior Press Release.

Leopold, A. S., S. A. Cain, C. Cottam, I. N. Gabrielson, and T. L. Kimball (1963) "Wildlife Management in National Parks, Report of the Secretary of Interior's Advisory Board on Wildlife Management, 4 March 1963" reprinted in *Sierra Club Bulletin* Vol. 48, pp. 4-11.

Schmidt, V. A. (1967) *A Wilderness Proposal for Mammoth Cave National Park, Kentucky*. Arlington, Virginia: National Speleological Society, 20 pp.

Smith, P. M. (1960) *Speleological Research in the Mammoth Cave Region, Kentucky: Elements of an Integrated Program*. Washington, D.C.: Cave Research Foundation, 18 pp.

Smith, P. M. (1961) *The Flint Ridge Cave System: A Wilderness Opportunity*. Washington, D.C.: Cave Research Foundation, 15 pp.

Watson, R. A. (1967) *The Preservation of Wilderness Karst in Central Kentucky, U.S.A.* Washington, D.C.: Cave Research Foundation, 12 pp.

Watson, R. A. and P. M. Smith (1963) *The Mammoth Cave National Park Research Center*. Washington, D.C.: Cave Research Foundation, 50 pp.

Watson, R. A. and P. M. Smith (1968) "The Flint Ridge Cave Research Center, Mammoth Cave National Park, Kentucky" *Proceedings of the IVth International Congress of Speleology* Vol. 3, pp. 645-654.

Watson, R. A. and P. M. Smith (1969) *Underground Wilderness*. Washington, D.C.: Cave Research Foundation, 12 pp.

Wilderness Act (1964) 78-Stat. 890.

REGIONAL PLANNING

Copeland, L. C. (1968) *Travel Spending in Kentucky, 1967*. A Report Prepared for the Travel Division of the Department of Public Information, Commonwealth of Kentucky.

Smith, P. M. (1967) "Some Problems and Opportunities at Mammoth Cave National Park," *National Parks Magazine* Vol. 41, No. 233, pp. 14-19.

Smith, P. M. (1968) "New Approaches to National Park Service Administration and Management" *National Parks Magazine* Vol. 42, No. 245, pp. 14-18.