Caves

Speleology and Karst Hydrology

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Introduction

Tales of endless caverns and of rivers swallowed by the earth were part of the earliest folklore of southern Indiana. Features now well known, such as Wyandotte Cave, were reported in somewhat exaggerated accounts by early visitors. Wyandotte Cave was a source of nitrate for gunpowder during the War of 1812, and nearby Harrison Spring, the largest in Indiana, was the site of a water mill owned by William Henry Harrison, the first territorial governor of Indiana. As of the present date, about 700 caves have been discovered in southern Indiana, and several sinking streams have been traced to their outlets from subterranean passages. The caves and associated karst features of Indiana have become known throughout the world. The longest mapped cave in Indiana, Blue Springs Cave in Lawrence County, is the fifth longest cavern in the United States and the eighth longest in the world.

Cave and Karst Areas

Caverns, subterranean drainage, and associated karst features, such as sinking streams, sinkholes, and cave springs, are common in two areas of south-central Indiana: a glaciated area where limestones of Silurian and Devonian age crop out and a partly glaciated area where limestones of Mississippian age are the surface rocks (Fig. 29). Limestone, which can be dissolved by running water to form caves, underlies much of the bedrock surface of Indiana, but five-sixths of the State, including most of the limestone area, is veneered with glacial drift which fills or obscures perhaps thousands of caverns formed before the advance of ice sheets. Evidence of these caverns is frequently found in drill holes and quarries.

There are some sinkholes, a few natural bridges, and about 30 known caves in the eastern karst in Indiana (Fig. 30).

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The caves are mostly small and only a few have been mapped. The cave streams are tributary to surface streams, primarily the Muscatatuck, East Fork White, and Ohio Rivers, which are westward-flowing meandering streams entrenched into the carbonate strata, which dip to the west (Fig. 31). No sinking streams are known, but water enters the caves through sinkholes and groundwater from the glacial drift rather than from direct surface runoff.

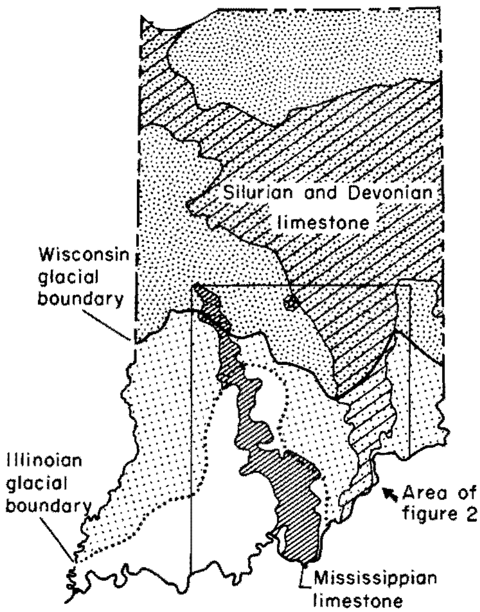


Fig. 29 Map of Indiana showing the areas of limestone bedrock and extent of Pleistocene glaciations.

The major cavern and karst region of Indiana, the area which has gained the attention of most speleological research, is in the south-central nonglaciated part of the State (Fig. 30.)[9] The karst features and most of Indiana's caverns, including the longest and largest ones, have been dissolved in limestones of the Sanders and Blue River Groups of middle Mississippian age. These rocks crop out in a belt extending northward from the Ohio River in Harrison County to northern Putnam County and southward into the cave region of Kentucky. The northern third of the belt of limestone is partly covered with glacial drift which has filled some caves and sinkholes. Some caves, but very few sinkholes, are situated in the thin limestones of the West Baden and Stephensport Groups of late Mississippian age. The rocks of all these groups

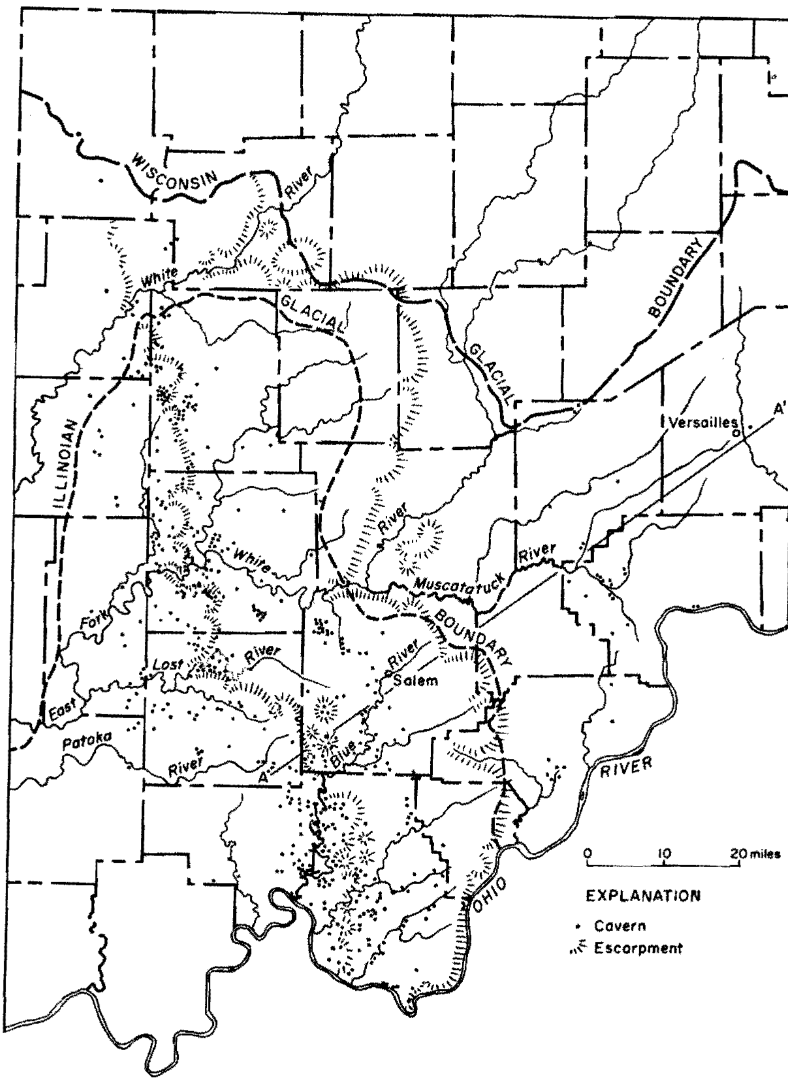


Fig. 30. Map of south-central Indiana showing the location of limestone caverns with respect to major drainage routes. Modified from Powell, 1961.

dip to the southwest at about 30 feet per mile, but local variations of the rate of dip are common (Fig. 31).

Origin of the Mitchell Plain

The area of outcrop of the Sanders and Blue River Groups is a westward-sloping sinkhole-pitted surface called the Mitchell Plain.[5] The Mitchell Plain is actually a low limestone plateau crossed by several major deeply entrenched streams: the Ohio, Blue, East Fork White, and White Rivers. The surface of the Mitchell Plain on the interfluves is an erosional and depositional surface beveled before the late Tertiary and early Pleistocene entrenchment of the surface streams and development of sinkholes and other karst features. The upper surface of the plateau is regionally inclined to the west and locally toward the major streams. The general westward slope of the Mitchell Plain is not as steep as the dip of limestone bedrock, but the structure of the bedrock has greatly influenced the development of the surface and the configuration of the drainage routes across and beneath it (Fig. 31).[1] Cavern development has been primarily down the dip of the strata along joints in the limestone. The streams that shaped the surface of the Mitchell Plain during Tertiary time headed a few miles east of the plain where the slope extends onto a belt of shales and siltstones of the Borden Group. These streams, with a few exceptions, had much the same drainage basins as at present. The sinkholes on the Mitchell Plain were formed after the streams cut below the level of the adjacent limestone plateau. Blue Springs Cave in Lawrence County is a good example (Fig. 32) of cavern development beneath the Mitchell Plain.

Development of Karst Features

Although sinkholes and swallow holes are the primary openings through which surface water enters subterranean channels, the bedrock surface is nearly everywhere crisscrossed with smaller openings developed by solutional widening of joints.[6] These vertical channels, or grikes, are usually filled with soil, but they form a subsoil drainage network that is tributary to an underground solution channel or cave. Some of the grikes extend into caves where they are seen as loosely cemented cobbles and gravel in a clay matrix in the ceiling of the passage. The irregular upward projections of the limestone bedrock are pinnacles or lapies.

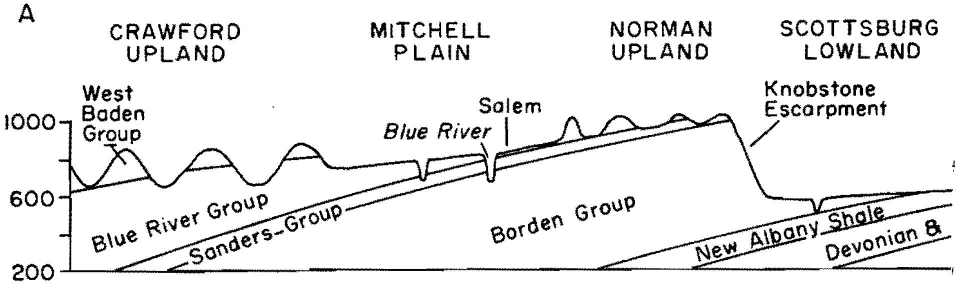
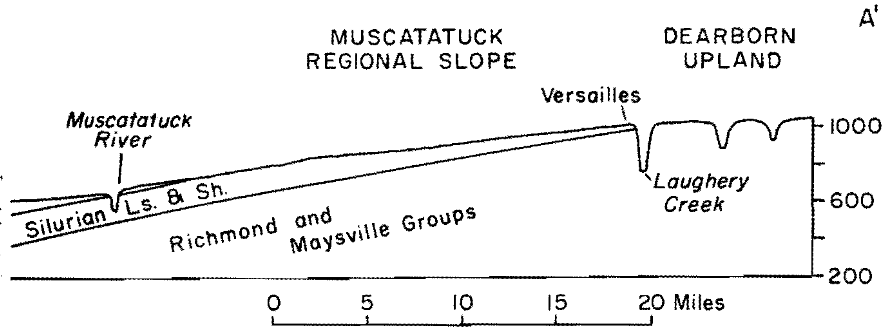


Fig. 31. Generalized geologic cross section showing relationship of physiographic units to bedrock geology. Line of section indicated on Figure 30.

Sinkholes form in places where the descending surface water most rapidly dissolves the bedrock. Some deep sinkholes in bedrock appear to be shallow because they contain large accumulations of soil; others contain ponds because their outlets are plugged. Collapse sinkholes are formed where the roofs of underlying caverns collapse to the surface. A large collapse sinkhole of this type is called a gulf or a uvala. Wesley Chapel Gulf near Lost River in Orange County covers 8 acres.[7] Karst windows, such as those at Twin and Bronson Caves in Spring Mill State Park, are collapse sinkholes opening into a cave passage from above or to the side to expose the upstream and downstream segments of the cave passage.

Solution of the limestone leaves insoluble particles of clay which accumulates in grikes and sinkholes or is washed into cave passages. This insoluble residue is generally termed terra rossa, although such material is yellow or brown as well as red. Large tracts of upland on the Mitchell Plain, generally remote from areas of entrenched surface drainage and cavern development, lack sinkholes and are covered with thick clayey soils. They are at least in part alluvial sediments derived from pre-Pleistocene surface streams which flowed across the upland surface of the Mitchell Plain. The soils include thin beds of chert gravel and cobbles and are overlain by loess of Pleistocene age. The chert was derived from beds near the base of the Sanders Group which cropped out to the east or from lenses near the middle of the Blue River Group. Some of these materials wash into the caves to form sedimentary deposits in the passages.

The relative local relief of the Mitchell Plain is greatest near



the major streams where it ranges from about 70 feet to as much as 200 feet. Some sinkholes adjacent to the streams are of comparable depth. Away from the major streams the sinkholes are much shallower and local relief is 50 feet per square mile or less in areas underlain by thick soil. The number of deep sinkholes commonly is greater above large caverns (Fig. 32).

Development of Cave Passages

Acidic water that enters the bedrock through open joints, especially floodwater that fills the underground openings, drops rapidly to the water table and then flows laterally toward a surface outlet. The greater the velocity of the flowing water, the greater the amount of limestone that will be dissolved from the walls of the passage. The passage is enlarged most rapidly during flood periods when the acidic water comes in contact with the walls and ceiling of the solution channel or embryonic cave. The rate of enlargement decreases as the volume of floodwater becomes insufficient to fill the cavern. Climatic changes during the Tertiary and Pleistocene Periods have greatly influenced formation of caves in Indiana. Cold winter precipitation contains more carbon dioxide than warm summer precipitation and is therefore a more active solvent. That solution of the limestone is more effective than mechanical erosion is indicated by the fact that caves are the result of a stream piracy—that is, in limestone terraces many surface streams cannot downcut their channels as rapidly as subterranean channels can be formed beneath them by solution. Such easily eroded layers as thin shale beds project into cave passages as resistant ledges. Analysis of water from caves shows a high carbonate mineral content, an indication of the extent of solution involved.

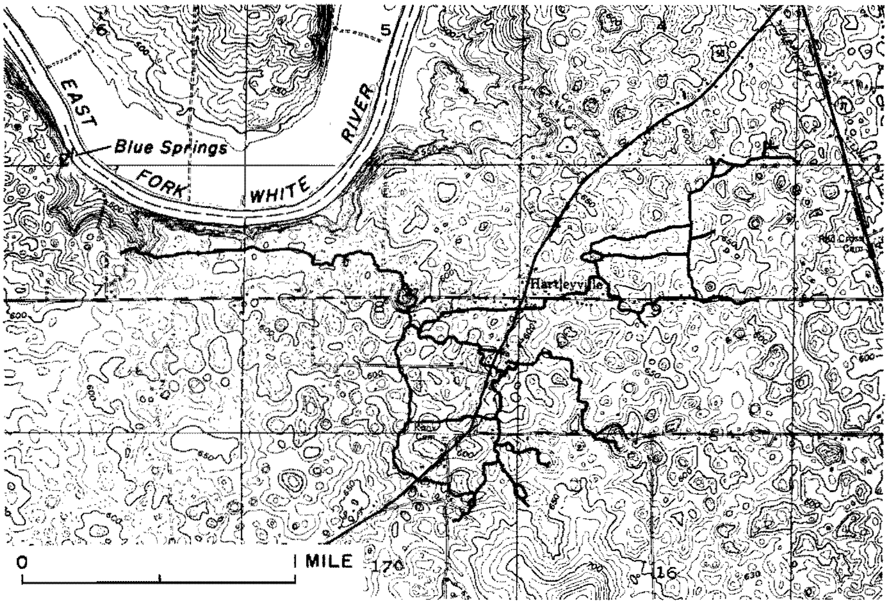


Fig. 32. Topographic map showing relationship of Blue Springs Cave to sinkholes and local drainage. The passages are developed along joints in the Salem Limestone, and the sinkholes are formed in the St. Louis Limestone. Modified from Palmer, 1965.

Development of Subterranean Drainage

Karst features formed on the upland surface of the Mitchell Plain as the major streams and their tributaries downcut their channels in several successive stages during late Tertiary and early Pleistocene time. Some surface tributaries lost their streams to interconnected joints which opened into the main streams at lower elevations. The open joints became enlarged by solution as water continued to flow into them, and became swallow holes or sinks in the old stream bed. Eventually these sinks took all but flood flows of the stream. These swallow holes are usually choked with debris and sediments from floods and generally lie several feet below the level of the former surface channel or dry bed which carries surplus floodwaters downstream. Lost River, a sinking stream in Orange County, has along its dry bed five major swallow holes, each of which receives the surplus floodwaters from those upstream.[7] Thus, rather than downcutting their channels, the former surface streams of the Mitchell Plain dissolved subterranean drainage routes as tributaries to the lower surface streams. The cavern passages developed headward beneath the former surface tributaries. Some of the cavern passages are developed at different levels and indicate that the downcutting of the surface streams was in progressive stages.

Caverns Formed by Subterranean Stream Piracy

Due west of the Mitchell Plain is the rugged Crawford Upland, a dissected cuesta with an eastward-facing escarpment broken in many places by through-flowing streams.[5] The hills of the upland are underlain by beds of sandstone, shale, and limestone of the West Baden and Stephensport Groups, but the streams along the eastern side have cut into the limestones of the Blue River Group (Fig. 31). Caverns are common along these valleys, especially where they receive underground drainage from the Mitchell Plain to the east. Generally the larger streams of the eastern margin of the Crawford Upland are about 100 feet lower than adjacent areas on the Mitchell Plain. Precipitation on the western part of the Mitchell Plain commonly is diverted westward through caverns trending down the dip of the strata into the surface streams at lower elevations. Many of the caverns have several levels which correlate with stages of downcutting in the valleys of the Crawford Upland. In places the cavern levels are superimposed and the cave passage is a high narrow subterranean canyon. This process of subterranean stream piracy has entirely diverted the headwaters of some ancient streams on the surface of the Mitchell Plain.[2] Sinkholes formed in the ancient valleys while caverns were dissolved beneath them. Similar streamless valleys in the Crawford Upland are situated at about the same level as the Mitchell Plain and are pitted with sinkholes. These karst valleys are a part of the former Tertiary drainage pattern.[11]

Caverns Formed by Groundwater

The thin dense limestones of the West Baden and Stephensport Groups are commonly overlain by a permeable sandstone and underlain by impermeable shale. The rocks of the Crawford Upland are greatly dissected and most of the outcrops of the various strata are on hillsides well above the streams in the deep valleys. Caves in the limestones have been dissolved almost entirely along sets of joints. In general the caves closely parallel the outcrop of the limestone. Only in a few places are sinkholes and other karst features found on the surface above the caves.

Precipitation and runoff from the hillside above the sandstone is absorbed and becomes a perched water body above the limestone.[12] The release of the stored water is toward the outcrop or into open joints in the underlying limestone. The rate and volume of water release are controlled by the permeability of the sandstone and the size and location of open joints in the limestone. The joints are enlarged by solution in proportion to the amount of water which flows through them. Thus, those joints that receive the greatest volume of water enlarge most rapidly and, consequently, release more water from the sandstone.

The water within the joints in the limestone is also a perched water body above the underlying impermeable shale. Discharge of water in the joints or caverns is generally down the dip of the rock to the outcrop. The cave passages are commonly developed just above the level of the shale and extend to the overlying sandstone through high narrow fissures or domes that mark the points at which most groundwater enters the cave. Speleothems are rare in these caves, apparently because the groundwater entering the passages has not passed through overlying limestone beds where it could obtain calcium carbonate to carry in solution. Breakdown in the caves commonly contains sandstone cobbles and boulders. Blocks of limestone that fall into the cave stream from the ceiling are dissolved by the flowing water.

Development of Pits and Domes

Where the local relief and limestone thickness is sufficient, water that enters the limestone bedrock may drop nearly vertically into a cave passage below. The water flowing down the walls of the open joints dissolves vertical channels or grooves which coalesce as they are widened and deepened. Vertical pits and domes in caves appear to have been formed below relatively impermeable strata, such as shale or less soluble limestone beds. The insoluble strata may be overlain by permeable reservoir rock or exposed at the surface. The water above the cap rock flows into a joint which permits its descent to the top of the soluble limestone. The water then either directly penetrates open joints or flows laterally to enter open joints which permit its rapid descent to a lower level. A permeable rock above acts as an infiltration bed and absorbs water which would be lost as surface runoff, only to release it into joints or domes as rapidly as rock permeability and available openings allow. The presence of small waterfalls in some domes indicates that they may be fed by groundwater from overlying rocks and are not dependent entirely on direct precipitation and runoff. Collapse or solution of the roof of a dome may extend to the surface to form a pit or shaft, which may permit entry into cave passages, depending upon the amount of collapsed material or breakdown at the bottom of the pit.

Cavern Collapse

The process of cavern development by solution creates a potential for collapse of the strata overlying the cavity. The occurrence and magnitude of roof and wall failure are mainly determined by width of the cave passage, closeness of jointing, and thickness and competence of the roof and wall strata. The collapsed material or breakdown is primarily of two types, blocks and slabs. Block breakdown is common in thick beds, whereas slab breakdown is formed by collapse of thin-bedded rock. Block breakdown is generally limited to the walls and lowest ceiling bed, whereas slab breakdown tends to affect numerous beds above the passage. Thin-bedded strata tend to sag above the cave passage and shear off near the walls to form slab breakdown. Each succeeding higher bed is better supported, so that the unsupported sagging layers over a cave passage form a tension dome. Collapse of the sagging layers usually results in a domed roof containing a mountain of breakdown, such as Rothrock's Cathedral and Monument Mountain in Wyandotte Cave. Obviously there are situations and conditions where the types are indistinguishable or mixed, particularly in wide passages where the failure may include numerous beds above the passage.

In some places roof failure extends to the bedrock surface and forms a collapse sinkhole, karst window, or gulf. Frost action, which does not take place within cave passages, greatly accelerates collapse of the cave roof near the surface. Breakdown formed by mechanical weathering is composed of much small rubble and soil, commonly mixed with block and slab breakdown. These deposits commonly form a steep talus slope in the cave passage where the latter terminates at a hillside, such as the entrance to Wyandotte Cave, or in association with a sinkhole.

Cave Deposits

Deposits in caves fall into two distinct groups, mechanical sediments and chemical mineral deposits. Mechanical deposits in caves include breakdown and alluvial, colluvial, or lacustrine sediments. The bedrock floors of few Indiana caves are exposed, for most of the caves are partly filled with clays, silts, sand, gravels, and cobbles deposited by the streams which flowed through them. Most of these materials appear to have been washed into the cave and limestone fragments are not dominant, nor common, as a constituent. Limestone that falls into the cave is easily removed by solution. The stream deposits are generally in irregular beds, although silts and clays may also be plastered onto the cave walls. Charcoal layers, perhaps derived from ancient forest fires, and finds of animal bones and plant remains are rare. Evidence from a few caves indicates that several feet of sediments have accumulated owing to erosion and slope wash that have resulted from poor land-use practices during the past 150 years. Most cave deposits, however, are of Tertiary or Pleistocene age. Many of the valleys to which caves are tributary are partly filled with deposits of Pleistocene age. Pleistocene lacustrine clays, including varved clay concretions, were deposited by glacial lakes which backed up into cave passages where contemporaneous sediments were deposited. Colluvial deposits, consisting of soil and rubble, are common in sinkholes that enter cave passages. Breakdown may rest on, be buried by, or be mixed with the sedimentary cave deposits or cavern fill materials.

Most chemical mineral deposits or speleothems in caves are accumulations of calcium carbonate as aragonite or calcite formed owing to a loss of carbon dioxide from calcium bicarbonate laden water that enters the air-filled cave passages.

The ultimate cause of deposition may have been a change in temperature, a loss of hydrostatic pressure, the presence of trace elements or organic agents, or a combination of these. Although most speleothems in Indiana caves are alternately banded calcite and aragonite or calcite pseudomorphs after aragonite, suggesting cyclic deposition, no method has been devised to interpret the deposition of speleothems. The cause of alteration of aragonite to calcite also is unknown. Although comparisons with Tertiary and Pleistocene climatic conditions would be desirable, the complicated mode of origin and unknown rate of growth have hindered any basis for such a study. But the deposition of speleothems is a great aid in the interpretation of the sequence of events in determining the depositional history of a cave, which in turn may be correlated with other known events in geomorphic history. Flowstone layers and stalagmites are in places buried by later mud deposits or suspended from the ceiling or wall where the unconsolidated fill has been eroded from beneath them.

Indiana's Largest Caves and Cave Streams

When Indiana became a state 150 years ago, Wyandotte Cave was considered the largest cave in the State (Fig. 33). Additional passages discovered in 1851 led to the claim that the cave was the second largest cave in the United States. Although the size of the cave has been exaggerated, it is indeed a large cave.[3] Some of the passages in Wyandotte are the largest in Indiana, including the largest room, Rothrock's Cathedral, which contains Monument Mountain, the largest known pile of breakdown in an Indiana cavern. A remarkable feature of Wyandotte Cave is the dryness of its passages, for very little water or mud is found in them. Wyandotte Cave contains only one very small stream which flows for a very short distance through a side passage. A few seeps account for the other wet places. The stream that dissolved the passages of Wyandotte was probably diverted from Blue River about 2 miles to the northeast.[4] Blue River, then flowing at a much higher level than now, was captured through joints in the limestone. After passing through an underground route that was substantially shorter than the surface route, the stream reentered the lower Blue River valley at a much lower altitude. This large stream, of late Tertiary and early

Pleistocene age, was probably longer than that flowing through the Lost River Cave System in Orange County at the present time. Many of the passages of Wyandotte terminate at hillsides or valleys that postdate cavern development.

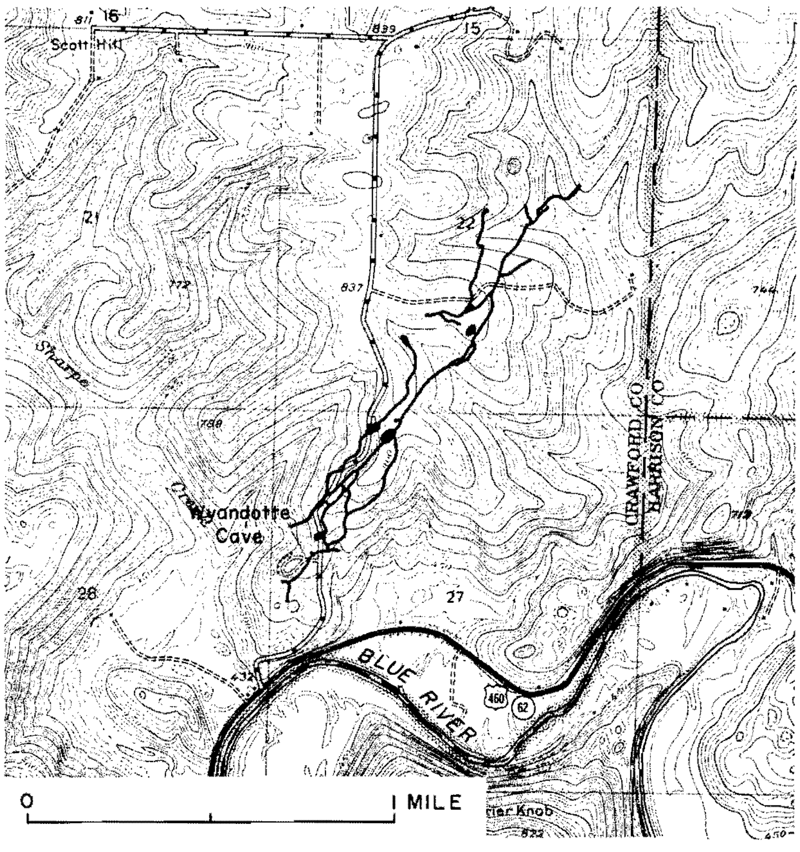


Fig. 33. Topographic map showing the mapped extent of Wyandotte Cave and its relationship to valleys in the Crawford Upland. The passages are developed in the Ste. Genevieve Limestone (Blue River Group). Base from Leavenworth Quadrangle, 1947.

Lost River is in direct contrast to Wyandotte Cave. Most of the passages are small and those that may be entered are wet and muddy.[7] The underground passages of Lost River are several times the length of Wyandotte, but most of them are flooded all of the time and the remainder flood with every light rain in the area. The parts of underground Lost River that may be entered indicate that the subterranean drainage route consists of a series of nearly parallel passages in a general east to west direction over a distance of about 7 miles. The surface channel or dry bed, which carries surplus floodwaters, is about 21 miles long between the uppermost swallow hole and the rise or artesian spring which discharges the cave stream back to the surface. The rise of Lost River, about 1 mile south of Orangeville, is a cave outlet which has been dammed by alluvial and lacustrine sediments of late Pleistocene age.[10] This cavern network was probably open during the late Tertiary when the major surface streams were downcutting their channels. Sinkholes and swallow holes developed simultaneously on the Mitchell Plain.

Blue Springs Cave, on the south side of the East Fork of White River near Bedford (Fig. 32), contains over 12.1 miles of mapped passages on several levels.[8] The downstream exit of the cave stream is a cave spring, but the dam across the East Fork at Williams has backed water up into the passage for a long distance. This cave stream is a small river which requires a boat to traverse the cave passage containing it. Side passages contain smaller streams and some at higher levels are dryer. The passages of this cave are fed entirely by drainage from sinkholes and a few short sinking streams on the overlying Mitchell Plain. Several deep sinkholes lie immediately adjacent to the cave passages, but no dry bed or surface channels are prominent. The cave stream is under heavy hydrostatic pressure when the passages are completely flooded, for water is known to fill some of the surface sinkholes to a level of about 100 feet above the adjacent river level. In spite of the dangers of exploring and surveying this cavern with its subterranean river, plans to map an estimated 5 miles of additional passages have been made.

Future Studies

Spelunkers and speleologists in Indiana will search for longer and larger caverns, not merely to establish new records of size, but also to better understand how caves are formed and how they are related to local hydrology and geology. Caves will be studied in greater detail with respect to their geochemistry, meteorology, and biology to determine their effect on water supply, pollution, and engineering problems. Speleology is expanding from a field of casual interest to geologists, biologists and hydrologists to one dominated by the speleologist, an individual specifically trained for research on caverns and related phenomena.

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