Groundwater Movement and Cavern Development in the Chester Series in Indiana[1]

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The hills and valleys of the Crawford Upland of south-central Indiana (Figure 1-A) are underlain by rocks of the West Baden and Stephensport Groups (Chester Series) (Figure 1-B). These rocks typically consist of repeated sequences of dense jointed limestone underlain by shale and overlain by thick jointed sandstone. Groundwater movement is mostly within the sandstones and limestones, for the shales are relatively impermeable. Furthermore, groundwater movement seems to be most active in a zone adjacent to the outcrop.

Evidence of ground water movement within the rocks of the West Baden and Stephensport Groups is mostly in the form of springs along the outcrop and solution features in the limestones. The most common solution features noticeable along the outcrop of the limestones are enlarged vertical joints. These are particularly prominent in shallow road cuts and quarry exposures. The solution of limestone along bedding planes is uncommon except at the base of the limestones, and is secondary to solution along vertical joints. Small solution channels are common along the base of the limestones and some of these feed small springs that are characteristic of the Crawford Upland. Larger solution channels and caverns feed larger springs, usually situated in spring alcoves, although many of the caverns cannot be entered because their entrances are blocked by collapse of the rock faces above the springs.

Caves are abundant along the outcrop of the various West Baden and Stephensport limestones (3). Most of the caves are small and extend only a short distance from the outcrop to places where the passage is blocked by collapse material or becomes too small to traverse. McGrain and Bandy (1) described four short caverns in the Beech Creek Limestone which are typical of most caverns in limestones of the Chester Series. They stated that ground water from the overlying sandstone supplies the water for cavern development by joint enlargement, and that modification by collapse is minor.

The areal extent of the outcrop of the relatively thin limestones of the West Baden and Stephensport Groups is very limited in comparison to the underlying thicker limestone of the Blue River Group which crop out extensively on the Mitchell Plain to the east of the Crawford Upland. Karst features, which are typical of the Mitchell Plain, exist but are not common on the limestone surfaces of the Crawford Upland. The lack of sinkholes and sinking streams on some limestone surfaces of the Crawford Upland that are known to be underlain by well developed caverns indicates that these caves have been formed by some means

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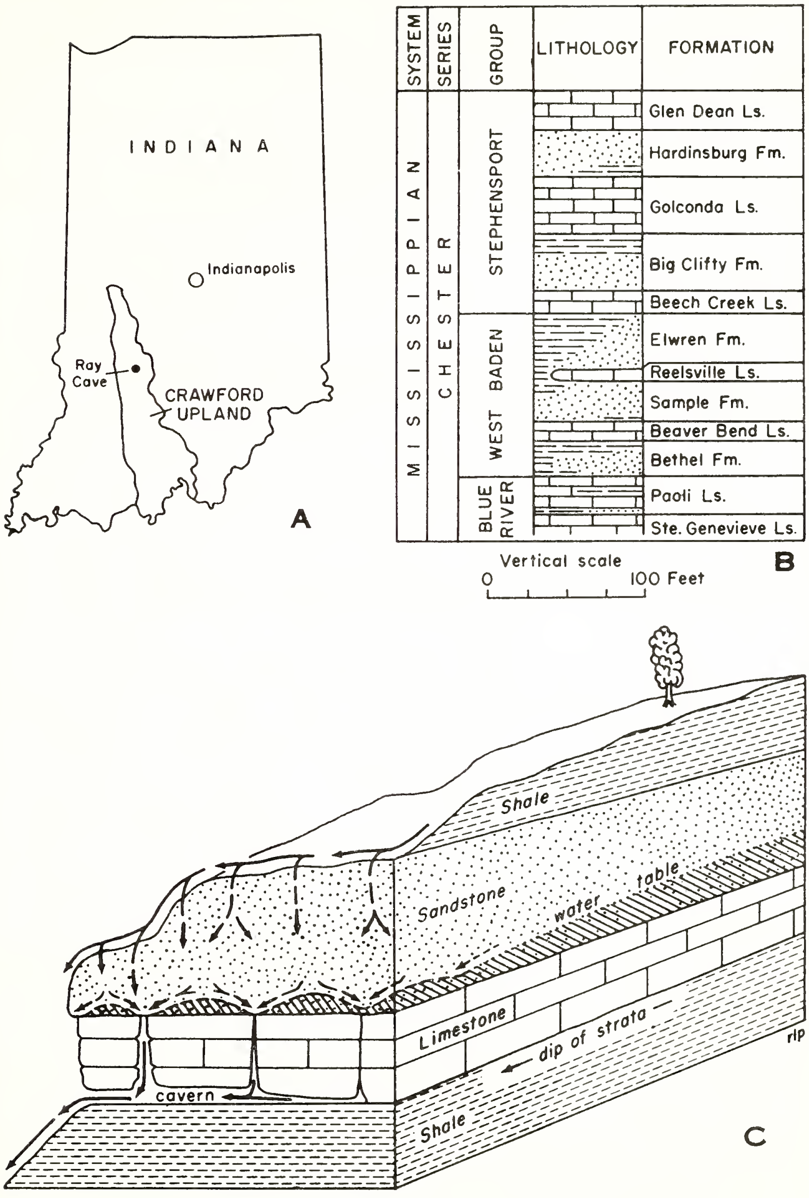

Figure 1

A. Map of Indiana showing the location of the Crawford Upland and Ray Cave.

B. Generalized stratigraphic column showing the rock types of the West Baden and Stephensport Groups.

C. Idealized block diagram showing the relationships of groundwater movement to rock types.

other than by the type of subterranean stream piracy or stream diversion that is characteristic of the Mitchell Plain.

Sinkholes have developed on locally extensive limestone surfaces in the Crawford Upland, particularly on the thicker limestones. Most of these are collapse sinkholes, which have developed over caverns where the limestone has been removed from a larger area than the overlying rocks can span without collapsing.

Caverns within the Chester limestones are nearly always situated where the limestone is underlain by shale and overlain by permeable sandstone. The outcrop of the limestone in the vicinity of many of the caverns consists of a nearly vertical face beneath overhanging ledges of sandstone. Thus the limestone has practically no areal extent on the outcrop except where an occasional gully has been eroded through some of the sandstone.

Groundwater within the sandstones and limestones of the West Baden and Stephensport Groups is derived from direct infiltration of precipitation plus some surface run-off from the hillside (Figure 1-C). Run-off descending the slope above the sandstone cannot enter the sandstone to become groundwater until it has passed over the lowest overlying impermeable zone, generally a shale. Thus the zone of surface water infiltration is closely related to the areal extent of the outcrop of the sandstone. The water is not uniformly absorbed by the sandstone because of local differences in permeability. Water entering a permeable sandstone descends rapidly to the water table where it moves laterally to a release point. Inasmuch as the standstones are commonly underlain by rocks of even less uniform permeability, groundwater in the basal part of the sandstone constitutes a perched water body. If shale underlies the sandstone the groundwater must flow laterally to a spring at the outcrop or to where a more permeable lithology underlies the sandstone. Where jointed limestone underlies the sandstone, descending groundwater flows laterally on top of the limestone, then downward into joints in the limestone. The volume, rate and direction of flow of water from the sandstone depend upon the amount of water available and the size and spacing of the openings along the joints at the upper surface of the limestone.

The movement of water through the limestone depends upon the character of the jointing. Two sets of joints are common, but systems with three, four and five sets are known. The amount of open space along these joints determines the rate and volume of water that may enter the limestone. Many of the joints that can be viewed from within a cave are tight and do not appear to be water bearing; others range from shallow to deep and narrow to broad crevices. Joints are generally more widely opened along the outcrop where mass wasting has caused slight movement of the blocks of limestone.

Groundwater descending through joints in the limestone differentially dissolves portions of the walls of the joints. The magnitude of solution depends upon the acidity of the water, its amount and rate of flow, and the solubility of the limestone with which it comes in contact. In general, the greater the rate of flow, the greater the rate of solution;

therefore those joints which receive the greatest amount of water are those most likely to be further enlarged. Nearly all cave passages in the limestones exhibit joint control (1).

Shale most commonly underlies the limestones of the West Baden and Stephensport Groups. Water descending through joints in the limestone is therefore forced to flow laterally along joints near the base of the limestone, thus forming a second perched water body. Secondarily enlarged bedding plane surfaces and horizontal solution scars are occasionally prominent in the otherwise joint controlled passages. Water is released from the narrow vertical joints either into cavern passages or to the outcrop. The caverns usually open onto the outcrop within a spring alcove formed by erosion of the impermeable shale downstream from the entrance of the cave, subsequently undermining the jointed limestone, and causing mass wasting of the limestone and overlying sandstone.

Ray Cave, located at the type locality of the Beech Creek Limestone, shows the close relationship of a typical cavern to the outcrop. The limestone here is 24.5 feet thick and is overlain by 37 feet of sandstone and 20 feet of shale and underlain by 46 feet of shale and sandstone (2). Ray Cave is developed down the dip of the strata, which is to the west at about 45 feet per mile in the vicinity of the cave (Figure 2-A).

Ray Cave is the longest known cave within limestones of the West Baden and Stephensport Groups. It consists of passages that have been mapped for a distance of about 9000 feet without finding a terminus. The cave contains a small stream for its entire length. The main passage is large enough to permit walking, but many collapsed areas require climbing and crawling over and through breakdown. There are few side passages, but there are two in the downstream part of the cave (Figure 2-B). One side passage near the entrance extends from the cave stream level in the main passage to the top of the outcrop of the limestone, and another trends northward along the ridge. A third opening to the surface extends through the sandstone at the first collapsed area across the main passage.

Ray Cave closely follows the surface exposure of the Beech Creek Limestone, rather than meandering at random beneath the ridge (Figure 2-A). The cave lies within 300 feet of the outcrop for most of its mapped distance. The greatest known distance from an adjacent outcrop is about 700 feet, which is at a place where the cave passes beneath a small spur north of the main ridge (north of Combs School). The main ridge has an average width of about 3000 feet at the level of the Beech Creek Limestone and is about 2000 feet wide at its narrowest place, near the eastern or upstream end of the mapped cavern.

Ray Cave contains numerous domes ranging from 15 to 20 feet high which extend upward from the ceiling of the cave passage, often to the base of the overlying sandstone. In addition, there are several high open joints. These vertical solution features indicate that water has entered the cave from the top of the limestone, and most likely from the overlying sandstone. The domes and high fissure passages are located where Ray Cave is closest to the outcrop (Figure 2-B). Some

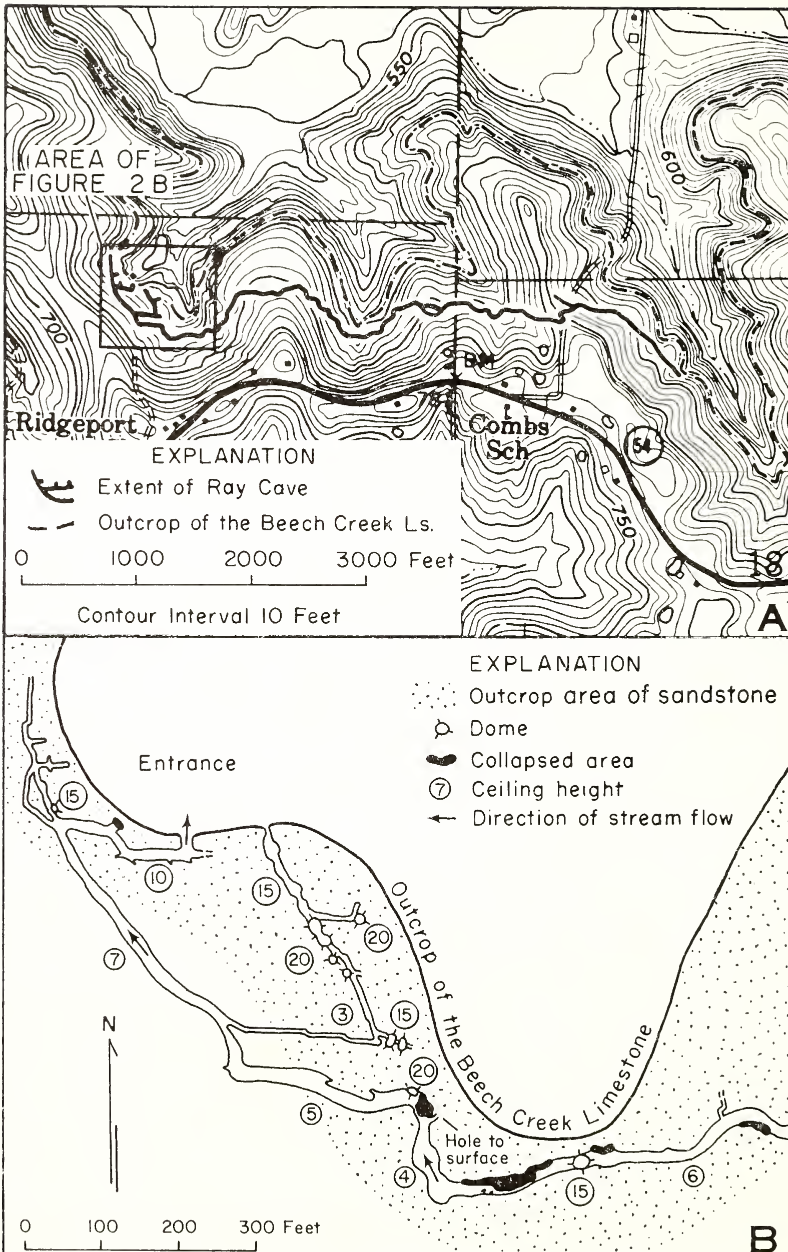

Figure 2

A. Topographic map showing the location and extent of Ray Cave and the outcrop of the Beech Creek Limestone. Base modified from the Solsberry Quadrangle.

B. Map of the downstream portion of Ray Cave showing the relationship of the Cave to the outcrop of limestone and sandstone.

water enters the cave passage at the collapsed areas which are also very close to the outcrop (1). The collapsed material is mostly limestone but contains some sandstone blocks and sandstone is exposed at the top of several of the collapse areas. Collapse and vertical solution features are not found where the cave lies more than a few hundred feet from the outcrop.

No sinkholes are known along the ridge above Ray Cave nor adjacent to the outcrop of the Beech Creek Limestone. Thus, the stream in Ray Cave is not fed by surface drainage as are the caves beneath the Mitchell Plain. The flow regimen of Ray Cave is not similar to that of a stormwater cavern. The stream in Ray Cave does not appear to dry up completely, as do some stormwater caverns, nor does it appear subject to flash flooding. The observed and inferred flood levels in Ray Cave are low in comparison to those of stormwater caverns. Similar observations have been made for most of the caves in limestones of the West Baden and Stephensport Groups. The relatively uniform permeability in the sandstone and the storage capacity of its perched water body may serve to regulate the flow of water in the caves in these limestones.

In summary, the features of the known caverns in all of the limestones of the West Baden and Stephensport Groups indicate the direction and amount of groundwater movement within the caverns and the overlying strata. The presence of high open joints and domes in these caves is proof that groundwater has entered the cave from an overlying permeable zone. The nearness of the caverns to the outcrop indicates that there is a close relationship between amount of groundwater flow and proximity to outcrop. The cavern passages tend to follow widened joints down the dip of the strata. The flow characteristics of the springs and caverns indicate that the flow is somewhat regulated, perhaps by storage and release of water from an overlying perched water body which is recharged by surface run-off and precipitation. Although the caves are not generally associated with surface karst features which would indicate their presence, the collapse of the cave passage at points near the outcrop creates surface openings for the direct infiltration of small amounts of surface water.

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