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LIMESTONE CAVERN ROCK-UNIT PROFILES FOR THE MISSISSIPPIAN AGE BLUE RIVER GROUP IN LEONARD SPRINGS AREA OF SOUTHERN INDIANA

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ABSTRACT. The downward movement of groundwater through epikarst, caves, and springs is strongly influenced by bedrock structural dip, jointing, relative solubility, and ductility. The bedding geometry, thickness, and sequencing of the various lithologies in the bedrock column influence the position, direction, and gradient of cave levels that correlate with some geomorphic features. The Mississippian age Blue River Group in southern Indiana averages 80 to 100 meters in thickness in the Crawford Upland and includes numerous and extensive cavern systems. The Leonard Springs and Garrison Chapel areas have more than 35km of surveyed caves flanking State Road 45 southwest of Bloomington, Indiana. Environmental studies often require more stratigraphic detail for karst areas, often to member level. Dye tracer test are the primary tool for determining karst flowpath connectivity in caves, and rock-unit stratigraphy often provides guidance for planning and evaluating traces. This study combines five previously described cavern profiles from the Garrison Chapel area and eight additional profiles from the Leonard Springs area.

Keywords: Mississippian Stratigraphy, Blue River Group, Indiana Karst, Leonard Springs Area

Rock-unit profiles for eight limestone caverns in the Leonard Springs area of southern Indiana were measured as part of a continuing study of regional karst geology in the Crawford Upland. This physiographic division of Indiana was described by Malott (1922). The Leonard Springs area and adjacent Garrison Chapel area are 5 km southwest of Bloomington, Indiana on both sides of State Road 45 (Fig. 1). More than 25km of surveyed caves in the Garrison Chapel area were dye traced and described by DesMarais (1981), Five rock-unit profiles were described in Garrison Chapel caves by Conner (1986). More than 9 km of surveyed caves in the Leonard Springs area were described by Conner (1987). These caves drain karst valleys located east of State Road 45 that are a part of the 11 karst valleys within the headland basin of Indian Creek. The name Leonard comes from Malott's reference to an erosional steephead with limestone springs (Malott,1952). Beede recorded features and drainage in this area with photographs that included Shirley Spring and Cave within the Steephead (1911). A survey in the present study counted more than 26 flowing springs in this Steephead. Another 46 karst springs were counted from both the Leonard Springs and Garrison Chapel area for this study. These all had their initial karst flow paths discharging from a micritic unit. None of the observed springs initially flowed from an oolitic or calcarenite unit.

The Crawford Upland cave and spring profiles measured in the study area are in rocks of the Mississippian Blue River Group. Hierarchial descriptions for the Blue River Group and the constituent formations are found in Shaver (1986). The relevant works describing outcrops in the Crawford Upland are Malott (1952) and Perry and Smith (1958). Carr described an upward shoaling marine cycle for the upper part of the Blue River Group (1973). The stratigraphic column for the study area is shown with the right side divided to organize the beds as they are exposed within the caverns (Fig. 2).

The Ste. Genevieve and Paoli Limestones reveal shoaling upward sequences described by Carr (1973). Each cycle began with deposition of carbonate pelletal mud, micrite, followed upward by fossiliferous calcarenties and an upward shoaling oolite bar. This cycle was completed with deposition of impure carbonates, argillaceous and thin sandy beds. Three or more cycles can usually be recognized in the Ste. Genevieve limestone. Other truncated cycles are often recognized. Carr's study focused on the oolite body geometry and

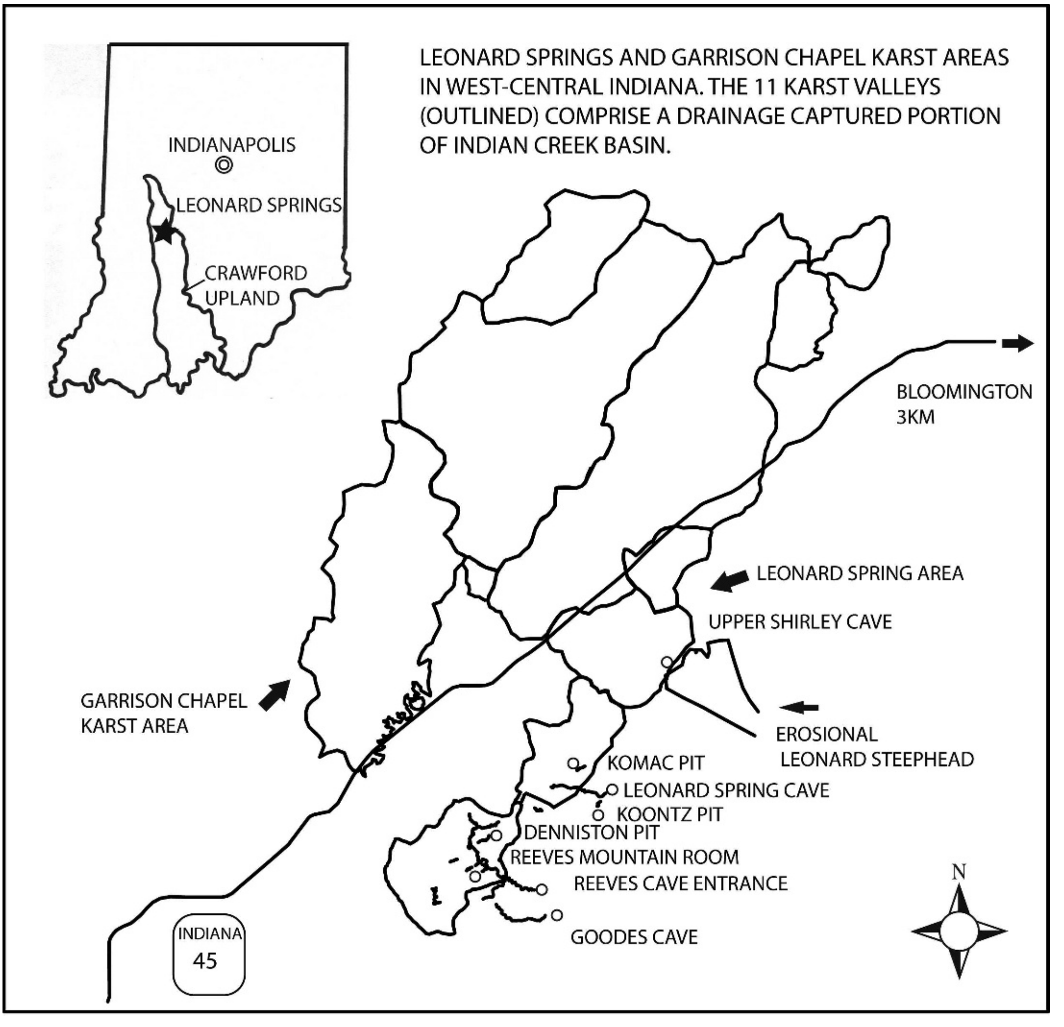

Figure 1.—Leonard Spring Area in Monroe County, Indiana.

overlooked the prominence of micritic beds as they are presently important to spring development and karst studies.

The lower part of the Blue Biver Group is the St. Louis Limestone. It was deposited in a shallow restricted basin represented by carbonate muds, pelletal, and argillaceous facies with a gypsum and anhydrite bearing interval. The profiles provide much more detail for the Ste. Genevieve caves than for the St. Louis caves. The upper Shirley Cave profile shows most of the St. Louis Limestone, but does not expose the anhydrite mineralization found farther south and west.

The eight measured sections presented here indicate a very uniform extension of bedrock units and thickness across both the Leonard Spring and Garrison Chapel karst areas in Monroe County. The lithology and bedding are consistent with Conner (1986) and include detail for an exposure of the St. Louis Limestone. The importance of detailed stratigraphic sections should not be underestimated when considering epikarst features and geomorphic interpretations. Often geomorphic interpretations of karst plain origins are concluded with a cursory description of the limestone formations that does not indicate which beds guide the lithologic control. The terms aquifer, aquiclude, and aquitard are relative in a carbonate sequence because of variability in bedding, jointing, and fracturing.

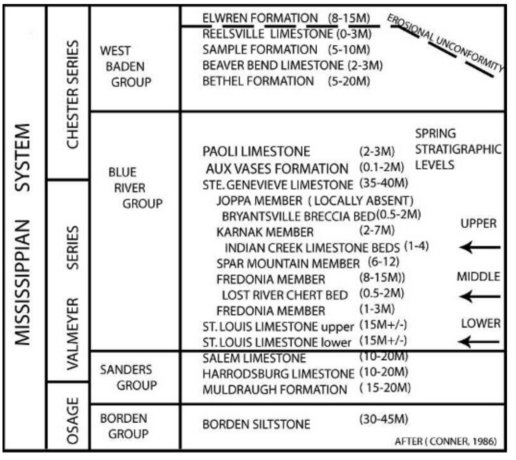

Figure 2.—Stratigraphic Column for Mississippian Blue River Group and related units in Indiana.

Carbonate bedrock matrix heterogeny is often considered problematic in lithologic control. The present study emphasizes details of carbonate stratigraphy for two karst areas and relates spring stratigraphic levels to micrite beds in the shoaling upward sequence. Bedrock matrix is very regular, with sharp contacts, and exceptionally homogenous in the high purity beds of the Blue River Group.

REFERENCE PROFILES FOR EIGHT CAVERNS

Goodes Cave Profile.—The Goodes Cave entrance is an exposure of the lower beds in the Fredonia Member and includes chert-bearing intervals (Fig. 3). The Lost River Chert Bed is found above the Goodes Cave entrance in a sequence of sublithographic and micritic limestone beds bearing brachiopods and fenestrate bryzoas. Small black chert nodules occur 2m below this unit that includes a 2cm chert band. Subjacent to the chert band is a 3m interval of dense dolomicritic beds and a chert band that forms a cascade in the stream. The chert band is exposed in an opening on the south side of the alcove at the elevation of the spring flowline. The beds in this profile are intercalated beds with Ste. Genevieve and St. Louis characteristics. Locally the formational contact is picked 6m below the base of the Lost River Chert Bed following Elrod (1899) and Malott (1952), or approximately 2m below the floor of Reeves Cave spring.

Reeves Cave Entrance Profile.—Reeves Cave entrance exposes the entire Fredonia Member along the lower 1km section of the cave (Fig. 3). Two silt and shale lentils mark the base of the Spar Mountain Member and the upper Fredonia bed is a thick sparry oolite. The two ball chert zones in the middle Fredonia occur in a lithographic to finely crystalline limestone interval; white to gray color and includes spirifer brachiopods, horn corals, and the rugose coral (*Lithostrotion harmodites*). Two buff stained microsucrosic dolostone intervals occur below a ball chert zone. These units have uniform grain size and are porous and dun colored. They weather to form thin bridges or ribs that span the cave's width. These beds form the cave ceiling and also show several vertical joints per decimeter across the ceiling. They contain translucent white calcite and pale-green chloritic stains. Below the lower dolostone, lies a 75cm zone of cream white to gray sub-lithographic limestone that contains invertebrate fauna. This unit is capped with a 5cm band of chert. Within and below this interval are numerous 3cm chert nodules forming a nearly continuous layer. The more resistant chert supports a projection over a cascade in the stream floor near the spring. This 75cm thick sub-lithographic interval includes the Lost River Chert Bed. Below it and extending toward the spring is a 50cm bed of white dolostone. At the spring a white, sub-lithographic micrite is exposed with abundant spirifer brachiopods and fenestrate bryzoas. Bed thicknesses range from 3 to 10cm, and this micrite bed contains pervasive small chert nodules that form 2cm thick discontinuous lentils. This chert lies well below the Lost River Chert Bed of Elrod (1899).

Reeves Cave Mountain Room Profile.—Reeves Cave Mountain Room is near the upper part of the extended entrance profile and overlaps with the two shale lentils and the upper Fredonia oolitic unit shown in Figure 3. It lies approximately 1km upstream through the main passage of Reeves Cave to the junction with the Mountain Room (Fig. 3). The entire Spar Mountain interval is visible and characterized by thick cross-bedded oolitic and calcarenite beds. These units include thin sandy lentils of clear and frosted quartz and rounded dark chert grains. The base of the Indian Creek Beds is exposed in the mid-level of the room. Above the room and offset into the ceiling a crevice exposes a thick oolitic interval in the upper beds of the Karnak Member. Above the

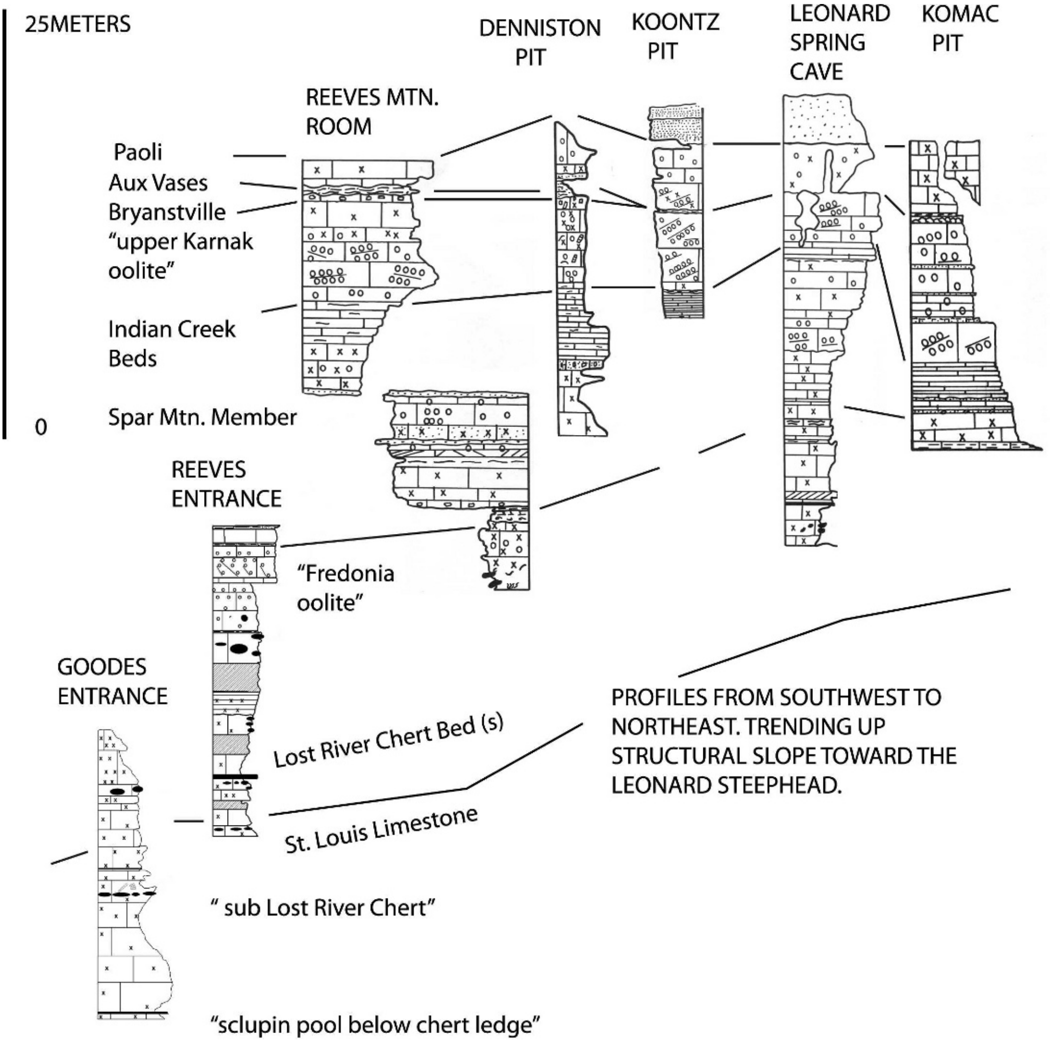

Figure 3.—Reference Cavern Profiles.

Karnak is a micritic interval with angular lithographic tidal clasts at the top. This breccia is the Bryantsville Breccia. Above lies a green and bluish green silty sand with numerous (*Allorisma*) and (*Composita*) assigned to the Aux Vases Formation as described along the Indiana exposures by Malott (1952). The Aux Vases Formation was later designated as a subunit of the Paoli Limestone for this area. The supradjacent Paoli beds are very finely crystalline and hacky thin slabs of this unit have collapsed into this upper passage.

Denniston Pit Profile.—Denniston Pit Cave exposes most of the Paoli in the pit with a reentrant Aux Vases interval above the Bryantsville Breccia Bed. The upper Karnak Member is oolitic and biocalcarenitic limestone and is exposed down to the top of the Indian Creek Beds. The Spar Mountain Member's upper contact is on the top of a tidal breccia exposed near the top of a narrow vadose dissolution canyon intersecting with the pit (Fig. 3).

Koontz Pit Cave Profile.—The top of the Paoli is exposed in Koontz Pit below sandstone float from the Bethel formation (Fig. 3). Upper Paoli beds reveal a well developed oolite bar containing large undeformed oolites with thick cortical rinds, in a very clear spar cement. The Aux Vases Formation is a 0.5cm thick interval above the subjacent cross-bedded oolite bar in the upper Karnak beds. The Indian Creek Beds are exposed at the base of the pit and talus fills the shaft drains which extend into the upper Spar Mountain beds.

Leonard Spring Cave Profile.—The Leonard Spring Cave section was measured in a large circular karst window with a rubble column formed by the upward collapse of beds from the upper Fredonia beds to the Paoli(Fig. 3). Paoli Limestone is exposed in the ceiling and upper walls and extends downward where observed in the offset Flat Room Pit. Aux Vases sandstone was not exposed or may be represented by a thin clay parting. The Bryantsville was not observed, but a thick oolitic interval was identified as the upper Karnak. The Indian Creek Beds are only 1.3 meters thick in the profile. The Spar Mountain Member is a finely crystalline sparite that includes a 3.3m oolite bed. The typical sandy lentils and facies were not observed. The Fredonia beds are exposed in a pit in the adjacent Flat Room. This exposure includes lithographic beds with ball chert and (*Lithostrotion*). The subjacent interval includes a gray color sucrosic dolostone with very closely spaced vertical joints, similar to the interval in the Reeves Cave entrance profile. The finely crystalline beds in the stream thalweg include the upper portion of the Lost River Chert Beds.

Komac Pit Cave Profile.—Komac Pit Cave is high on the interior flank of a karst valley (Fig. 3). It extends down a narrow sloping rift from the Paoli Limestone. The Aux Vases is represented by 9cm of sandy shale. The subjacent Bryantsville Breccia has subaerial laminar crust enclosing micrite tidal clasts. The upper Karnak oolite interval is thick and conspicuously cross-bedded. It also includes several laminations of very fine sand and olive colored clay. The thicker upper Karnak beds succeed a corresponding thinning in the Indian Creek Beds which show a wavy scour base resting on a thin sandy horizon in the upper Spar Mountain. Finely crystalline and lithographic beds with thin sandy laminations comprise the Spar Mountain Member. The karst flow path traversing the floor of the chamber exposes a finely crystalline limestone with very thin clay laminations typical of the upper Fredonia beds.

Upper Shirley Cave Profile.—Upper Shirley Cave is located along a gravel lane at the top of the Leonard Steephead with the sink hole rim at 246m (809 ft) msl. The section starts about 3m above this collapsed sink hole surrounded by a red clay talus that includes weathered nodules from the Lost River Chert Bed. Malott placed the top of the St. Louis Limestone at an elevation of 249 m (820ft.) msl in the top of the steephead (1952). The measured section through upper Shirley Cave provides detail for most of the St. Louis Limestone (Fig. 4). The top of the section at 246m msl is estimated to lie 3m above the top of the St. Louis Limestone and 5m below the base of the Lost River Chert Bed. Lithology exposed downward to the top of the subterranean gallery 0.6 hectares in area (1.4 acres), is typical of the Fredonia Limestone, except oolite beds are absent and pelletal beds are present. Farther down section beyond the collapsed blocks a massive dolostone interval contains vugs 6cm

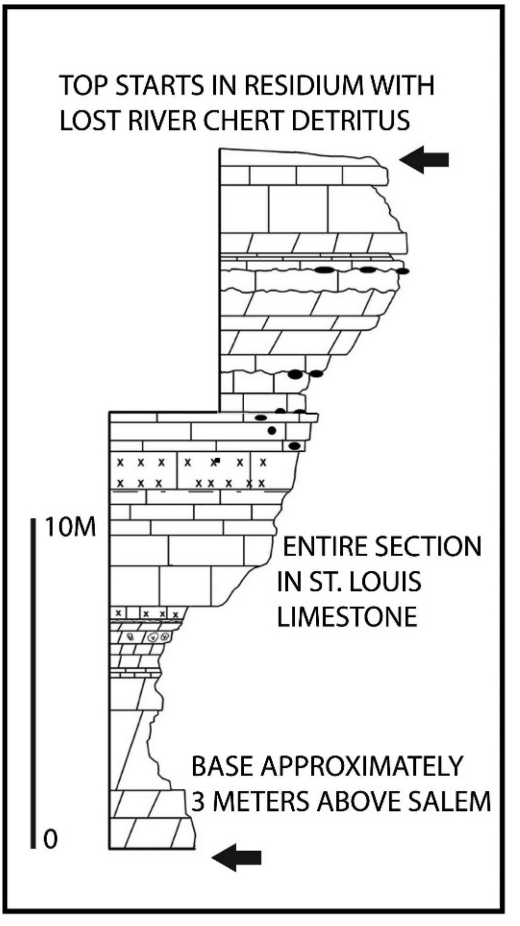

Figure 4.—Upper Shirley Cave Profile.

in diameter, and these are drusy with short prismatic calcite crystals. Subjacent to that, a dolostone measuring 6cm in thickness is hard, dense, and gray to black in color, and has a strong sulphuorous odor. Sparry and porous beds composed of ramous bryzoa fragments are brown and black in color, and occur downdip to the west in this interval. The lower 4m of the room is obscured by large slabs and blocks which have fallen from the ceiling so the lower St. Louis beds are not accessible. The top of the Salem Limestone is believed to lie about 4m lower, and is exposed in the floor of the Steephead at the entrance to Thundering Cave 150m to the south.

SPRING STRATIGRAPHIC LEVELS & LITHOLOGY

Stratigraphic profiles have been measured for more than 46 karst springs draining the 11 karst valleys and surrounding ridges in this study area. The springs identified in the Blue River Group are not randomly distributed in the rock column, but are strongly associated with three stratigraphic positions, contacts, in the Blue River Group shown in Figure 2. These contacts can be described as spring stratigraphic levels. The initial karst flow paths drained by these springs were controlled by fracture traces in micrite beds instead of the oolitic or calcarenite beds. The lithologic control of karst spring development observed in the study area is being evaluated regionally over a larger portion of the Crawford Upland. The cave levels are generally controlled by geomorphic levels and base level hydrology, but locally the stratigraphic control is more evident. Most hydrologist agree that base level hydrology is the primary control of limestone cave development and lithologic control is secondary. The present study finding springs strongly associated with micritic intervals and their repetition within the shoaling oolite sequence offers potential for evaluating geomorphic erosional and depositional features where they may be preserved in an upland tributary setting and can be correlated with the cave levels. Perhaps the lithologic and stratigraphic control observed in the Leonard Springs and Garrison Chapel areas indicates that these controls precede the work of base level hydrology in the evolution of karst physiography. The expanded study will include all of the Crawford Upland karst physiography between White River and East Fork in southern Indiana.

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