60th Annual Meeting of the
American Institute of Professional Geologists

Celebrating 60 years of professional geoscientists exchanging information and technology in the many facets of geoscience.

September 16-19, 2023 | Covington, Kentucky

Karst Geology of the Mitchell Plateau, South-Central Indiana

Field Trip, Sunday, September 17, 2023

Donald K. Lumm, Ph.D., C.P.G, D.K. Lumm Geological Consulting, Lexington, KY
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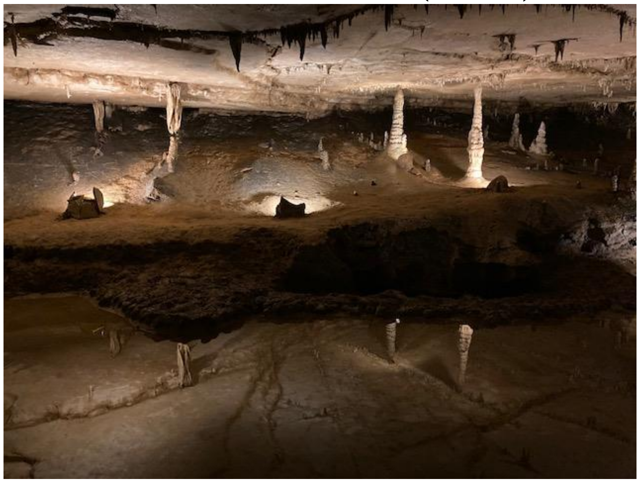
North view of road cut exposure of Ste. Genevieve Limestone (STOP 1).

Road cut exposure of *Lithiostrontionella*, sp. coral in Ste. Genevieve Limestone (STOP 1).

Coalescing stalagtites and stalagmites, Dripstone Tour, Marengo Cave (STOP 2).



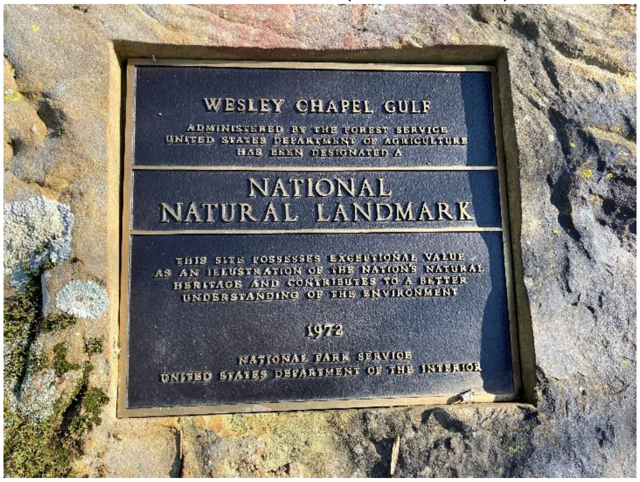
Reflection pool, Crystal Cave Tour, Marengo Cave (STOP 2).

Southwest view of soybean crop planted on karstic terrain at Ross Farms property (STOP 3).

West view of haycrop planted on karstic terrain adjacent to Ross Farms property (STOP 3).

West view of Lost River "dry channel bed" after late winter flood event (near STOP 4).

South view of crop field near Lost River "dry channel bed" after late winter flood event (near STOP 4).



U.S. Forest Service signage for Wesley Chapel Gulf National Landmark (STOP 4).

Hanging valley incised in Ste. Genevieve Ls. with surface drainage into Wesley Chapel Gulf (STOP 4).

Signage for Orangeville Rise of Lost River (STOP 5).

North view of Orangeville Rise of Lost River (STOP 5).

Field Trip Itinerary (All times Eastern Daylight Time)
Sunday, September 17, 2023

7:30 a.m. Depart Covington Radisson Hotel
9:30 a.m. Arrive **STOP 1**, Roadcut of Ste. Genevieve Limestone, Milltown, IN
10:15 a.m. Depart STOP 1
10:20 a.m. Arrive **STOP 2**, Marengo Cave, Marengo, IN
12:15 p.m. Lunch (after STOP 2 cave tours)
1:00 p.m. Depart STOP 2
1:30 p.m. Arrive **STOP 3**, Ross Farms Property, Syria, IN
2:00 p.m. Depart STOP 3
2:15 p.m. Arrive **STOP 4**, Wesley Chapel Gulf Collapse Sinkhole, Orleans, IN
2:50 p.m. Depart STOP 4
3:00 p.m. Arrive **STOP 5**, Orangeville (Lost River) Rise, Orangeville, IN
3:15 p.m. Depart STOP 5
5:30 p.m. Arrive Covington Radisson Hotel

Aerial Image of Field Trip Stop Locations

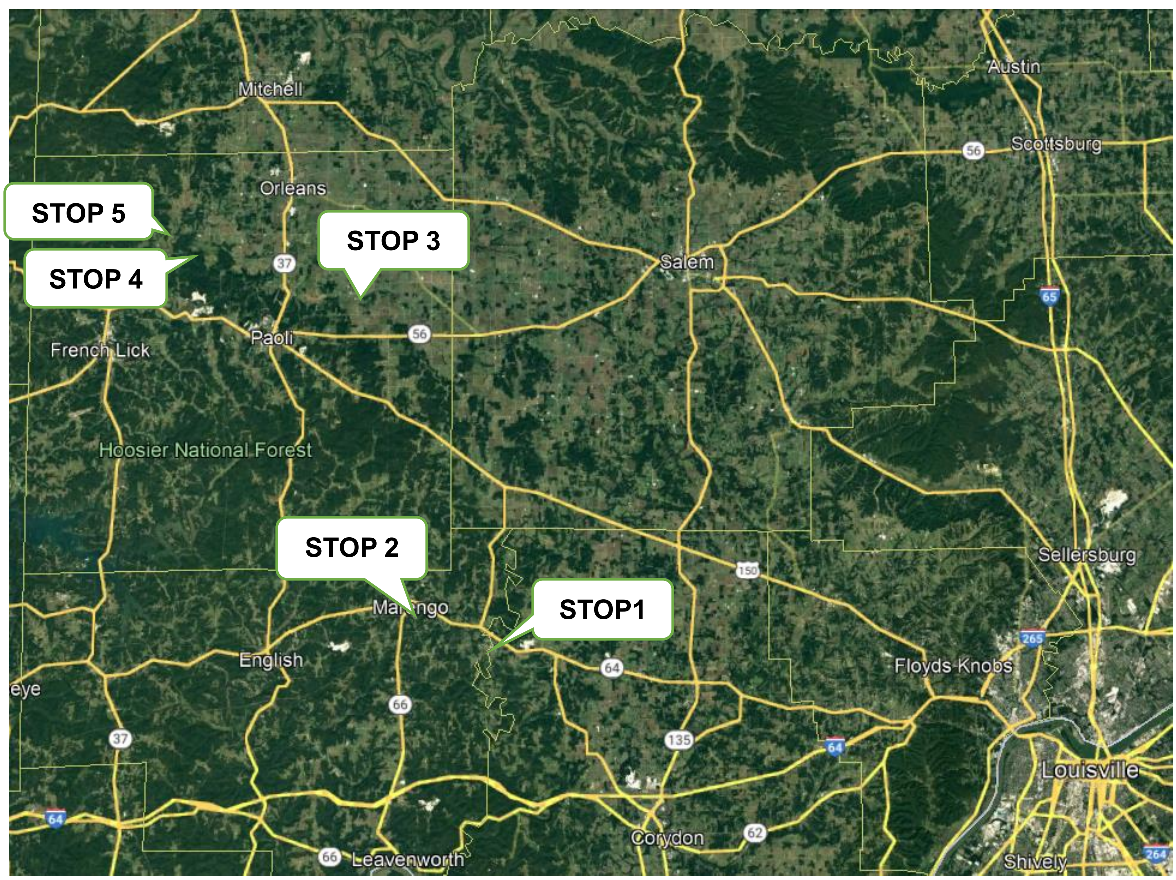


Image Scale: 1 in. = 10 mi. (approx.)

Field Trip Route

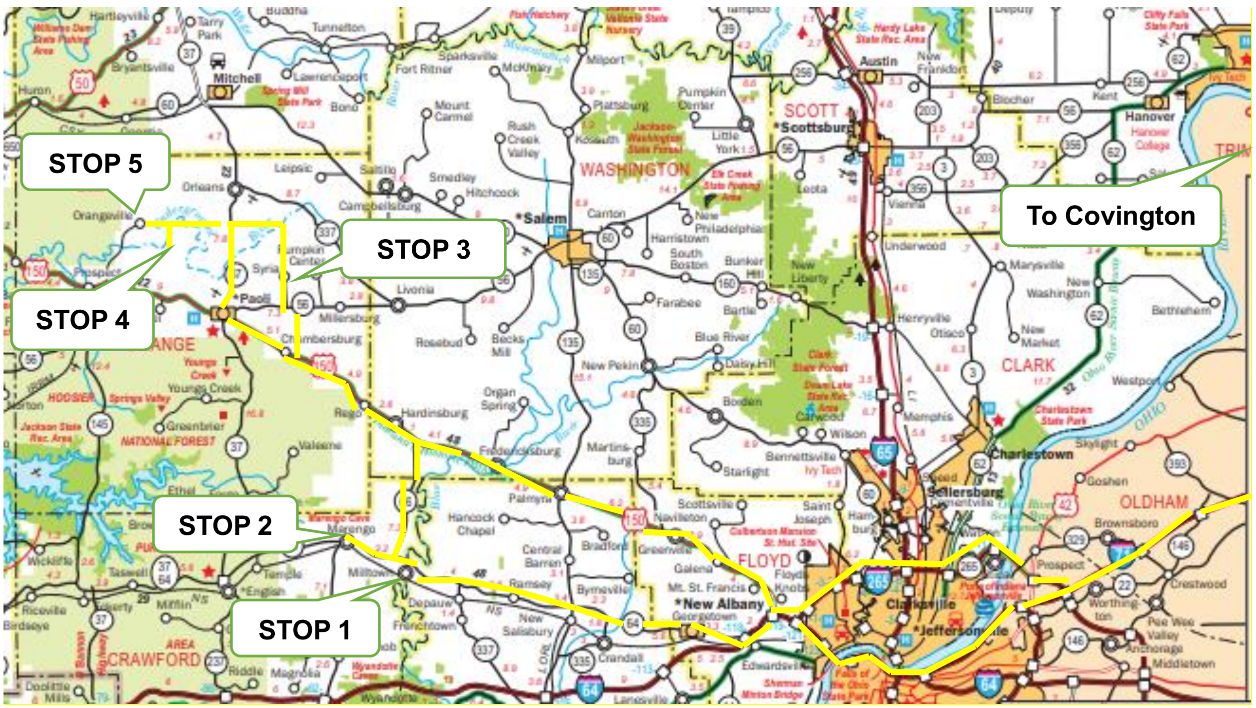
The field trip route from the AIPG conference hotel in Covington, Kentucky to the field trip sites is a 325-mile-long trek from northern Kentucky to southern Indiana along a combination of interstate highways and rural two-lane public roads. The field trip road log and mileage are listed below.

<u>Route</u>	<u>Mileage</u>
(BEGIN) Radisson Hotel to KY Hwy. 8 (5th Street), Covington, KY	0.05
KY Hwy. 8 (5th Street-one way) East to Philadelphia Street	0.10
Philadelphia Street North to KY Hwy. 8 (4th Street)	0.10
KY Hwy. 8 (4th Street-one way) West to Junction I-71/I-75 (Exit 192)	0.20
I-71/I-75 South to Junction I-71 (Exit 173), Walton	18.20
I-71 South to Junction I-64, Louisville, KY	77.00
I-64 West to Junction IND 64 (Exit 118), Georgetown, IN	12.00
IND Hwy. 64 West to Millville **(STOP 1)**	20.00
IND Hwy. 64 West to Marengo Cave Entrance Road, Marengo	4.80
Marengo Cave Entrance Road North to Marengo Cave **(STOP 2)**	0.20
Marengo Cave Entrance Road South to IND 64	0.20
IND Hwy. 64 East to IND Hwy. 66	3.40
IND Hwy 66 North to US Hwy. 150, Hardinsburg	7.00
US Hwy. 150 West to S CR 475 E, Chambersburg	5.90
S CR 475 E North to S CR 500 E (Tate Rd.)	0.20
S CR 500 E North to IND Hwy. 56	3.00
IND Hwy. 56 West to N CR 350 E	1.50
N CR 350 E North to E CR 200 N, Ross Farms Property **(STOP 3)**	2.00
E CR 200 N (County Farm Road) West to N CR 300 E	0.50
N CR 300 E North to E CR 500 N	3.00
E CR 500 N West to IN Hwy. 37	3.10
IN Hwy. 37 South to W CR 500 N	0.10
W CR 500 N West to N CR 350 W	3.60
N CR 350 W South to Entrance Wesley Chapel Gulf **(STOP 4)**	0.30
N CR 350 W North to W CR 500 N	0.30
W CR 500 N West to W CR 540 N	0.25
W CR 540 N West to N CR 500 W	1.40
CR 500 W South to Orangeville (Lost River) Rise **(STOP 5)**	0.40
CR 500 W North to W CR 540 N	0.40
W CR 540 N to W CR 500 N	1.50
W CR 500 N to IND Hwy. 37	3.90

CONTINUED NEXT PAGE

Route (CONTINUED)	**<u>Mileage</u>**
IND Hwy. 37 South to US Hwy. 150, Paoli	5.70
US Hwy. 150 E to Junction I-64 (Exit 119), Floyds Knobs	36.50
I-64 East to Junction I-265 (Exit 121), New Albany, IN	2.10
I-265 East to Junction I-71 (Exit 35), Louisville, KY	17.40
I-71 North to Junction I-71/75 (Exit 77), Walton	68.00
I-71/75 North to KY Hwy. 8 (4^{th} Street; Exit 192), Covington	18.20
4^{th} Street E to Entrance Radisson Hotel **(END)**	<u>0.10</u>
TOTAL	**325.60**

Route Map with Field Trip Stop Locations



Map Scale 1 in. = 12 mi. (approx.)

Acknowledgements

The authors gratefully acknowledge Mr. Kerry Ross for permission to visit and observe his farm property near Paoli, Indiana.

Table of Contents

Introduction

The term "karst" has traditionally been used to refer generally to regions of exposed soluble bedrock having an abundance of surface landforms, such as sinkholes, sinking streams, and springs, that reflect the presence of subsurface voids or caves (Ford and Williams, 2007). However, during the last few decades, a distinction has been made between karst features that represent surficial (*epigenic*) solutional processes and karst features that reflect deep-seated (*hypogenic*) solutional processes, both of which result in bedrock voids (Palmer, 1981). Consequently, the usage of the term "karst" has broadened, as recognition of karst features existing deep in the subsurface in numerous environments has gained greater attention (Klimchouk, 2007).

Karst landscapes and processes have a significant worldwide environmental and economic impact. In the United States, all 50 states contain bedrock with potential for karst development, and about 18 percent of their area is underlain by soluble rocks having karst or the potential for development of karst features (Weary and Doctor, 2014). The Interior Low Plateaus Physiographic Province of the east-central United States has a significant land area affected by karst development, predominately on or within Mississippian and Ordovician age limestone **(Figure 1)**.

The Mitchell Plateau of south-central Indiana is the northernmost area of the Interior Low Plateaus exhibiting karst landforms and solutional processes. The Mitchell Plateau consists of approximately 1,350 mi^2 in parts of six Indiana Counties and contains thousands of sinkholes and hundreds of caves and springs, and sinking streams developed in Mississippian age carbonate rocks. Malott (1945) estimated there may be as many as 300,000 sinkholes in the karst area of southern Indiana. As of 2021, the Indiana Cave Survey lists more than 3,400 documented caves in the State (Florea, 2021).

The Mississippian bedrock in south-central Indiana varies from approximately 200 feet thick along the eastern outcrop belt and thickens westward to greater than 1,200 feet in the surface and shallow subsurface due to basinward thickening and the prevailing structural dip. South of the Ohio River, the karst landscape and Mississippian bedrock of the Mitchell Plateau continues into west-central and south-central Kentucky where it is known as the "Pennyroyal" or Mississippian Plateaus physiographic sub province of the Interior Low Plateaus. In the latter area, the karst landscape broadens up to 150 miles in an east-west orientation. South of Kentucky, the karst landscape and Mississippian geologic bedrock is breached by the Nashville Dome and its erosional Central Basin of Middle Tennessee into the Western Highland Rim. The total length of the karst landscape from Southern Indiana to Middle Tennessee is approximately 250 miles.

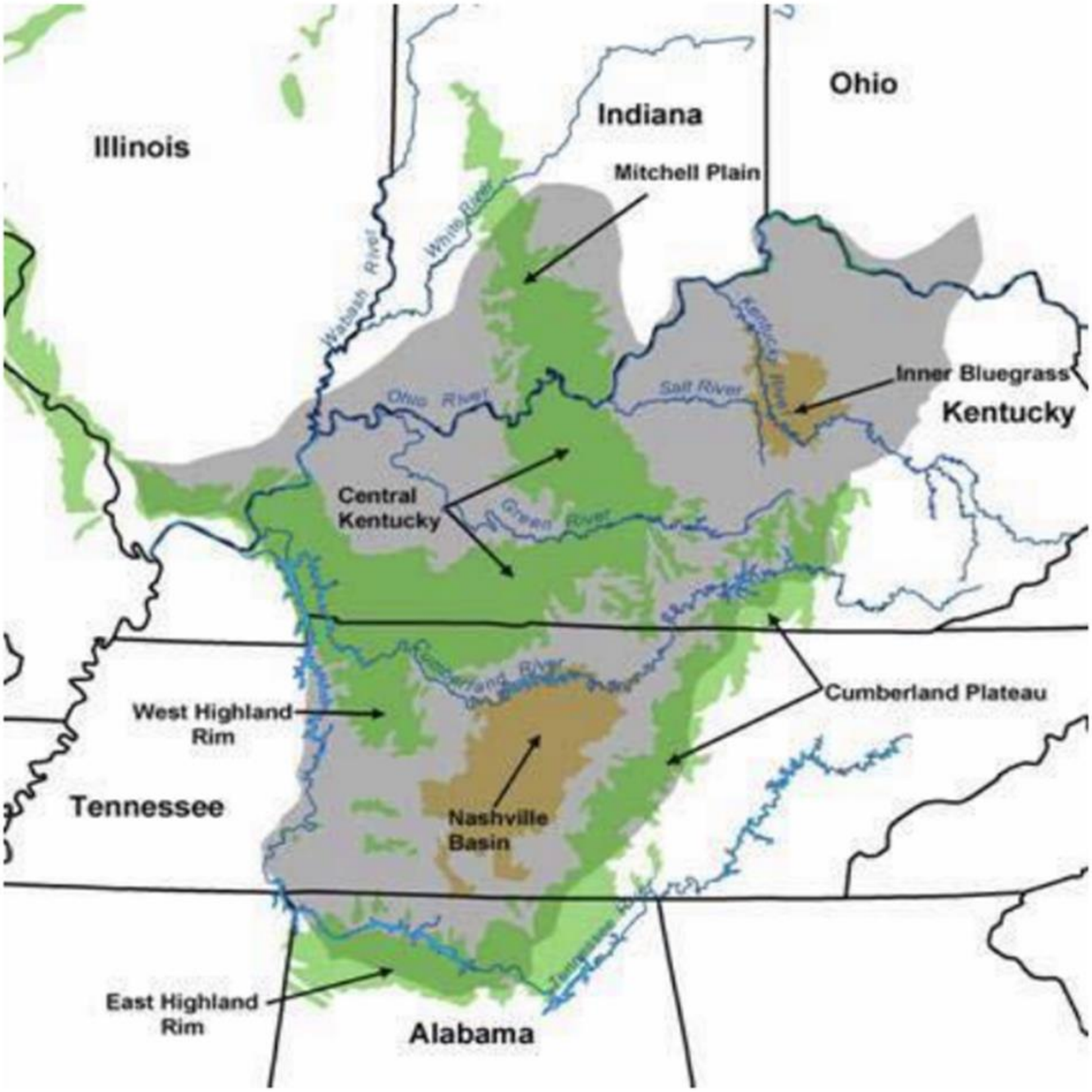


Figure 1. Major karst areas in the Interior Low Plateaus region. Karst areas underlain by Mississippian limestones are shaded green, and karst areas underlain by Ordovician limestone are shaded tan. Gray shading indicates areas with no karst or minor karst. The green shaded areas identified as "Central Kentucky" is better known as the Mississippian or "Pennyroyal" Plateau (from USGS, Karst Hydrology Initiative, 2017, https://ky.water.usgs.gov/projects/cjt_karst/index.html)

Karst terrain, characterized by a very high calcium carbonate ($CaCO_3$) content of exposed or shallow subsurface limestone bedrock, is environmentally sensitive. It is geologically and ecologically vulnerable to contamination because of direct interaction of surface streams and groundwater, a basic link in the hydrological cycle. Streams may gain water from the inflow of groundwater through the stream bed or lose water to the groundwater system by outflow through the streambed. Although this relationship occurs in most geologic and climatic settings, it is exacerbated by very permeable limestone bedrock in the broad Mitchell Plateau, where adjacent elevated and sloping areas are typically overlain by a porous, intensively leached residual subsoil, and in turn a veneer of silt or clay loam, derived from loess, that is well drained and moderately permeable. Areas along streams are poorly drained with some wetlands developed at sink areas.

South-central Indiana, excepting the southernmost tier of counties, has a humid continental climate (Koppen Classification "*Dfa*"), with hot summers and cold winters, with year-round precipitation. Mitchell, Lawrence County (Latitude 38.74° N, Longitude -86.47° W, elevation 692 ft. MSL), near the approximate center of the Mitchell Plateau has a mean annual temperature of 53.7°F and an annual precipitation of 47.3 inches, 12.0 inches falling as snow (USA.com, Mitchell IN Weather, http://www.usa.com/mitchell-in-weather.htm). The growing season has 168 frost free days (Almanac.com, Mitchell, IN https://www.almanac.com/gardening/frostdates/IN/Mitchell).

The Mitchell Plateau is a rural agricultural region, and the primary land use is row crop production, anchored by low density (widely spaced) farm residences. There are some very small towns with limited commercial and industrial development. Land use and crop production is usually dictated by the amount or percentage of slope. Land with 0 to 6 percent slope is intensively cultivated in row crops, typically corn and soybeans, and to a much lesser extent, wheat crop. Land with 6 to 12 percent slope is usually cultivated in hay crop or less commonly livestock pasture. Land greater than 12 percent slope, which occurs on the margins of the Mitchell Plateau on siltstone or sandstone bedrock, is devoted to livestock pasture or retained as old growth forest, defined as a western mesophytic forest, dominated by oak (Greenburg et al., 1997).

The region is considered to have prime farmland, defined by the U.S. Department of Agriculture as land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oil seed crops and is available for these uses (USDA, Prime and other Important Farmlands, https://efotg.sc.egov.usda.gov/references/public/LA/Prime_and_other_Important_Farmland.html). In general, prime farmland has an adequate and dependable supply of water, but because of the hummocky karst topography, the thickness and quality of soil types, residuum, and depth to bedrock is locally variable in the Mitchell Plateau, and so is the water balance. Small and large acreage farms alike rely upon domestic well water, which is susceptible to contamination by runoff from fertilizers and pesticides commonly applied to crop fields, livestock waste containing *Escherichia coli* bacteria, poorly lined septic tanks, and so on. In recent years, livestock production in the region has migrated from pasture raised cattle and sheep to concentrated production of turkeys and chickens at commercial poultry farms (U.S. Department of Agriculture, 2012; Florea et al., 2018). The impacts of these facilities have not been evaluated, but the potential loading of nutrients from leaking sewage lagoons distributed spreading of the dry waste typical of poultry operations can certainly contribute to increased nutrient loading of surface water and groundwater (Florea, 2019). It is assumed that the karst aquifer provides limited attenuation of the nutrients and *E. coli*, transporting them longer distances than would be expected in a surface-flow system (Florea et al., 2018).

The source of drinking water supply for most rural farms and residences in the Mitchell Plateau is domestic wells drilled to solid but permeable Mississippian limestone bedrock. However, small towns such as Bedford, Mitchell, and Orleans rely on treated water from the West Fork of the White River and other towns like Paoli rely on the few surface reservoirs in the adjacent upland areas such as Patoka Lake.

The crown jewel of the region is the Lost River, an 86-mile long west flowing meandering stream which heads in western Washington County, and has a 13.3 mile meandering surface presence before it sinks in swallow holes into an underground system and reappears as springs in Wesley Chapel Gulf, a massive 8.3-acre collapse sinkhole up to 95 feet deep in Orange County, and reemerges again 7.5 aerial miles west of the first sinks near Orangeville (Malott, 1952). A “dry bed” channel of the Lost River meanders above and near the course of the underground stream for 25 miles, and gains flow during heavy rainfall and flood events. The main discharge emerges at the True Rise of the Lost River about 0.7 miles south-southwest of Orangeville and the surface stream meanders west another 47.7 miles to join the East Fork of the White River in southern Martin County.

The unique character of the Lost River is also acknowledged by Indiana environmental protection rules. The river and all surface and underground tributaries are rated as an exceptional use stream per Indiana Administrative Code 327 IAC 2-2-3a(6) (Hasenmueller et al., 2003). Such waters provide unusual aquatic habitat, support unique assemblages of aquatic organisms, or considered an integral feature of an area of exceptional natural beauty or character. Waters of exceptional use are regulated and maintained without degradation (Hasenmueller et al., 2003).

The purpose of this field trip is to provide an overview of the karst geology of the Mitchell Plateau region of south-central Indiana. Field trip participants will have an opportunity to observe and discuss representative karst landforms and carbonate bedrock exposures, cave development and speleothems, surface and groundwater hydrology, agricultural practices, and environmental issues of the region.

Regional Physiography and Topography

For a Midwestern state, Indiana has a rather diverse physiography **(Figure 2)**. The northern half of the State is part of the Central Lowland Physiographic Province, a vast

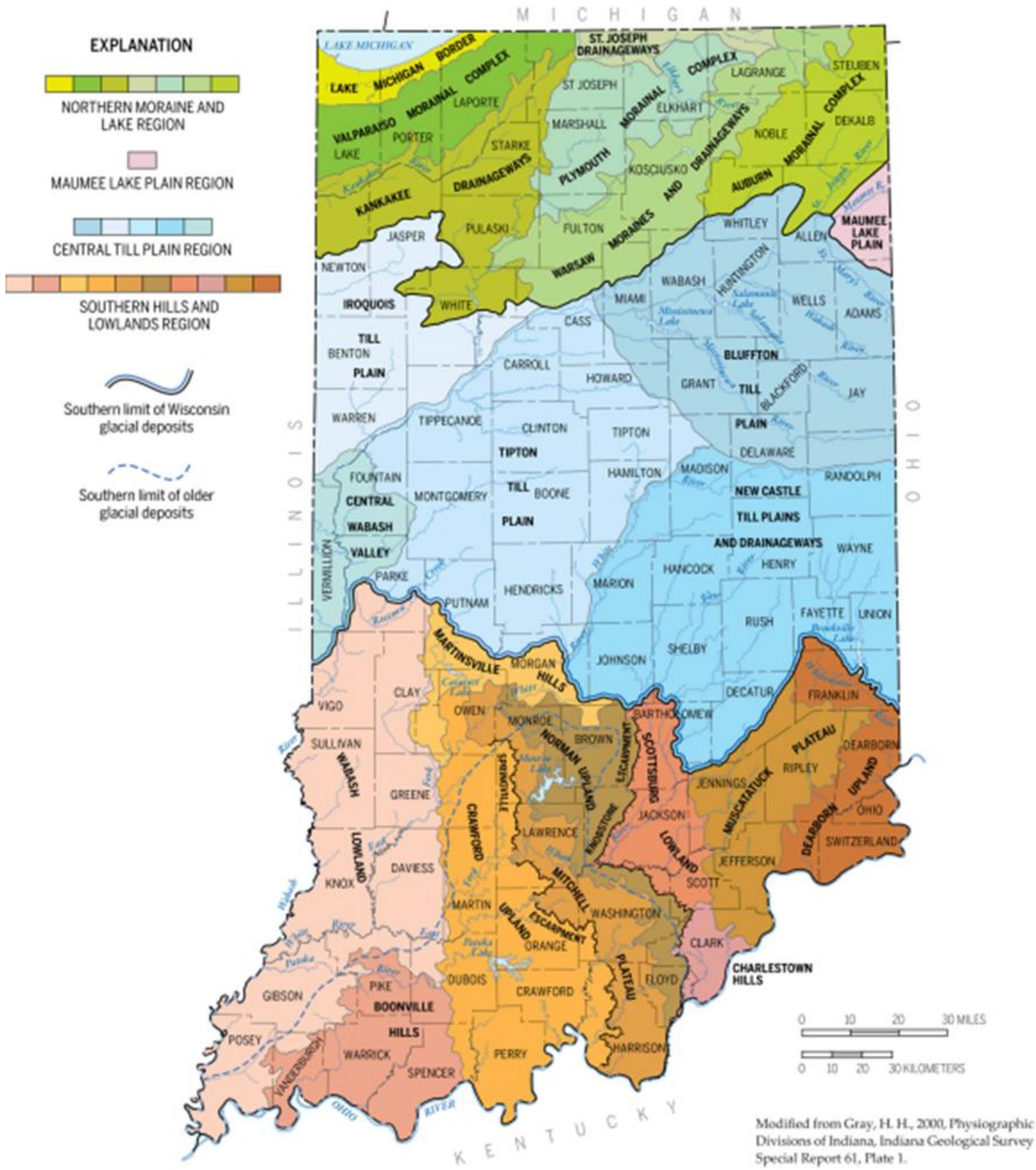


Figure 2. Physiographic Map of Indiana, showing the various sub provinces of the Central Lowland (blue and green shaded areas) in the north and the Interior Low Plateaus (brown and tan shaded areas) in the south (from Gray, 2000).

region of the U.S. continental interior extending from eastern Ohio to eastern Kansas and encompassing the entire Great Lakes, upper Mississippi River, and upper Missouri River valley regions to the Canadian border. The Central Lowland, as the name implies, is a region characterized by flat to gently rolling topography of low relief and elevation, modified by repeated fluctuations of Wisconsinan (Late Pleistocene) continental glaciation and associated unconsolidated sediments. The maximum southern extent of Wisconsinan glaciation in Indiana forms a wavy border between the Central Lowland and the Interior Low Plateaus to the south. The latter extends from extreme southcentral Ohio to extreme southern Illinois and from southern Indiana to northwestern Alabama. The Interior Low Plateaus are characterized by gently to moderately rolling topography formed by erosionally resistant and horizontal to gently dipping Paleozoic strata, dissected by moderate to locally steep sloped, incised dendritic streams and river valleys.

Within Indiana the Interior Low Plateaus are subdivided into ten (10) north-south trending sub provinces based primarily upon tectonic and subsurface structural control of the regional Paleozoic outcrop belt and its resistance to subaerial erosion **(Figure 3)**. The Mitchell Plateau was named for Mitchell, Lawrence County, Indiana, and it was originally referred to as the Mitchell Plain (Malott, 1922; Gray, 2000). The classic karst terrain is sited upon a 5 to 20 mile wide, 110-mile-long north-northwest trending plateau of low relief. The landscape is developed on highly soluble middle Mississippian carbonate bedrock, and bordered by hilly, more resistant, siliceous lower Mississippian bedrock of the Norman Upland to the east and hilly, more resistant upper Mississippian and lower Pennsylvanian sandstone bedrock of the Crawford Upland to the west. The Springville Escarpment is a transition area between the Mitchell Plateau and the Crawford Upland (Florea et al., 2018). It is characterized by karst development where soluble carbonate bedrock outcrops in stream valleys or outliers beneath the overlying sandstone caprock.

The northern extent of the Mitchell Plateau terminates near Quincy, Owen County, Indiana where the Martinsville Hills sub province is characterized by hilly, pre-Wisconsinan glacial modification of the underlying lower Mississippian to upper Mississippian bedrock (Gray, 2000). The principal surface drainage feature in the northern part of the Mitchell Plateau is the southwest flowing West Fork of the White River and in the central part the west flowing East Fork of the White River. These rivers join near Petersburg, Pike County and in turn flow southwest and join the Wabash River near East Mount Carmel, Gibson County. The Lost River is another significant surface drainage feature in the central part of the Mitchell Plateau whose discharge submerges within cavernous voids near Orleans, Orange County and flows 25 miles before reemerging at Orangeville. The Lost River subsequently joins the East Fork of the White River near Yenne, Martin County. The Blue River and Indian Creek are the principal surface drainage features in the southern part of the Mitchell Plateau. These rivers flow south and join the Ohio River in Harrison County.

Geologic Setting and Structure

The Mitchell Plateau is sited on the western flank of the Cincinnati Arch, a north to north-northeast striking anticlinal flexure extending from west central Ohio to Middle Tennessee **(Figure 3)**. The Cincinnati Arch bifurcates into the northwest trending Kankakee Arch in northern Indiana and to the north-northeast trending Findlay Arch in northwestern Ohio. To the south, the Cincinnati Arch is expressed as the Cumberland Saddle in south-central Kentucky and culminates as the Nashville Dome in Middle Tennessee.

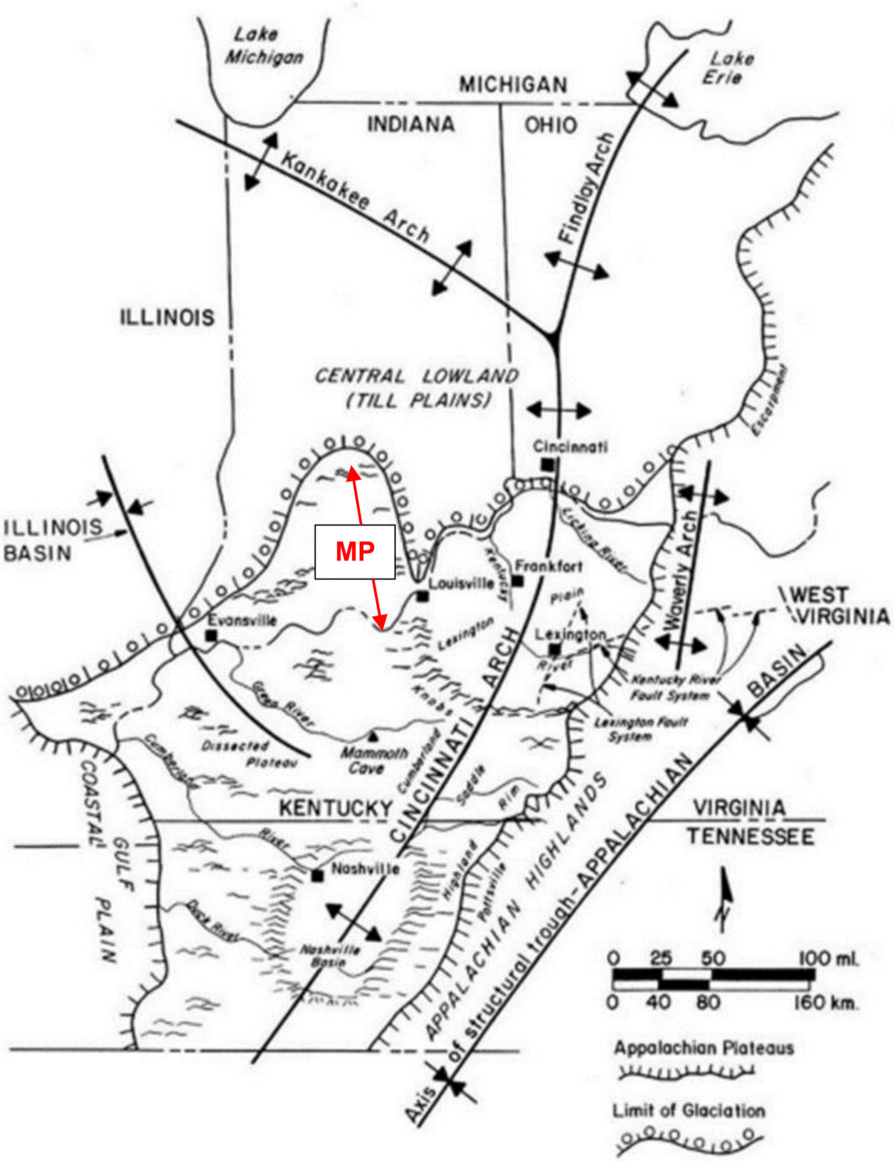


Figure 3. Regional structure map of the Cincinnati Arch showing the relationship between adjacent structural and physiographic features of the Mitchell Plateau (map symbol "**MP**"; modified from Hunt, 1974).

In much of Indiana and western Kentucky the west dipping flank of the Cincinnati Arch is synonymous with and structurally equivalent to the west dipping flank of the Eastern Interior (Illinois) Basin. The latter is a north-northwest striking cratonic basin filled with up to 30,000 feet of Paleozoic strata in its deeper and overthickened late-Cambrian rift fills of the Reelfoot Rift and Rough Creek Graben of extreme southern Illinois and western Kentucky (Goetz et al., 1992, Kolata and Nelson, in Kolata and Nimz, eds., 2010). The region of south-central Indiana is considered part of the eastern shelf of the Illinois Basin, a relatively shallow, stable region with few deep-seated faults. In this area, the Paleozoic strata thicken west from the Cincinnati Arch into the Illinois Basin. The regional structural dip is approximately 30 feet per mile on near surface bedrock.

It should be emphasized that the near surface bedrock of south-central Indiana and surrounding region was subjected to a prolonged period of subaerial exposure following Late Cretaceous time, as no Tertiary sediments are present in the region. The effects of Late Paleozoic plate collision of Africa and North America culminating in the Alleghenian orogeny uplifted the Appalachian Plateau and created the fold belts of the Valley and Ridge and extended far into the U.S. midcontinent. Major basement rooted fault systems of the Appalachian Basin and Illinois Basin were either produced or reactivated from Late Precambrian or Cambrian tectonism, regional joint patterns likely developed, and in some areas of the Illinois Basin and Ozark Dome, hosted the emplacement of various types of ore bodies and minerals. Subaerial erosion during the Tertiary Period drastically reduced the volume of Paleozoic sedimentary bedrock and the topographic relief of the region, and likely affected crustal rebound or extension and joint development. The fluctuations of repeated Pleistocene continental glaciations, while not directly reaching most of south-central Indiana, nonetheless affected stream base level rise and fall in response to sea level rise and fall, enhancing vertical joint systems and promoting the development of lateral hydrologic conduits along bedding planes. In summary, the combined tectonic and structural forces and climatic effects upon the carbonate bedrock have produced the iconic karst terrain and cavern system of the Mitchell Plateau and adjacent regions.

Geologic Bedrock

The geologic bedrock of the Mitchell Plateau is composed primarily of middle Mississippian limestone strata with thin interbeds of siliciclastic sandstone and shale. In ascending stratigraphic order, these include the Ramp Creek, Harrodsburg, and Salem Limestone Formations assigned to the Sanders Group, which crop out in the up dip eastern part of the region and in the deeper stream valleys in the south and in the north, and the St. Louis, Ste. Genevieve, and Paoli Limestone Formations of the overlying Blue River Group, which crop out in a much broader area to the west **(Figures 4 and 5)**.

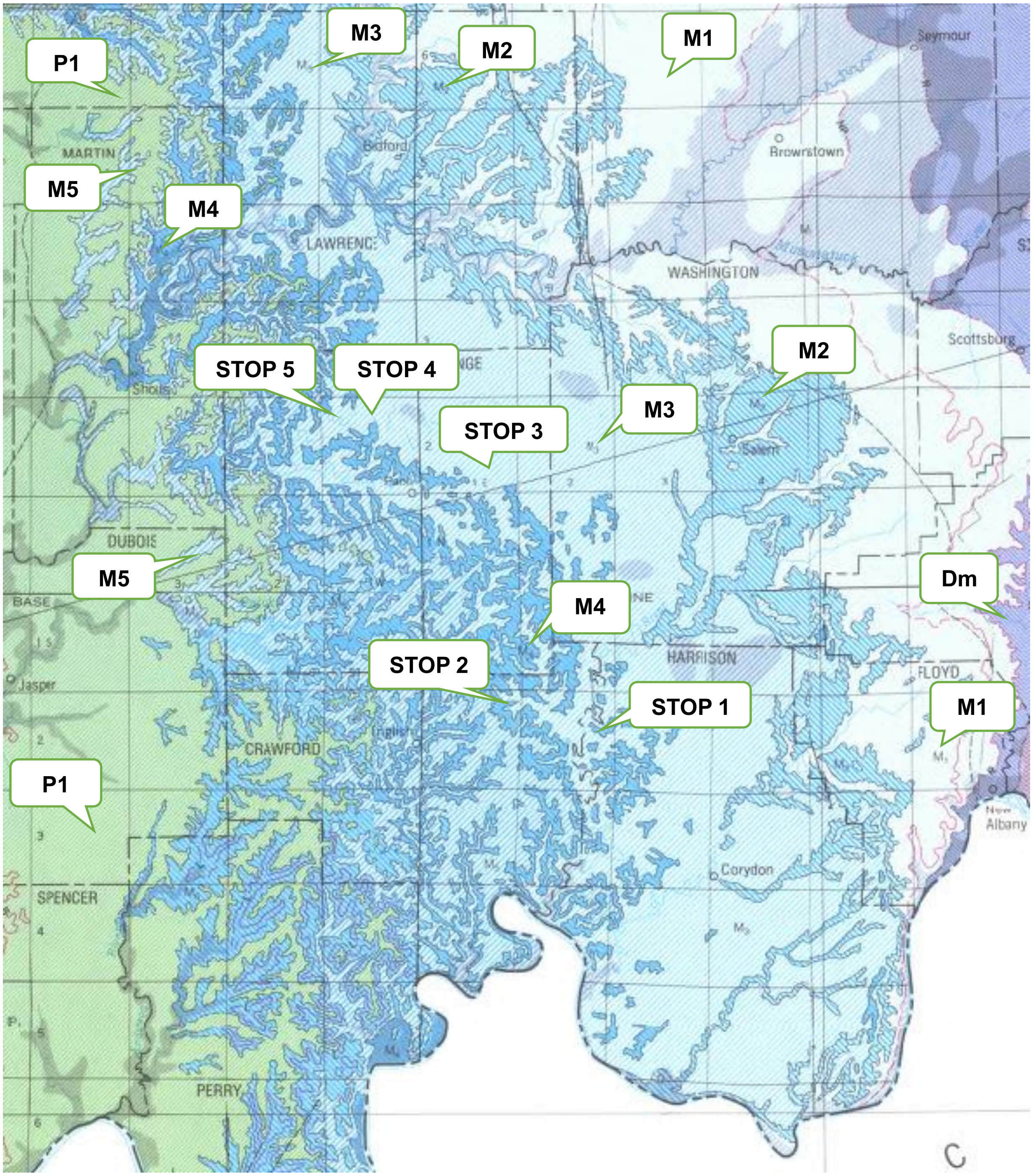


Figure 4. Part of the geologic bedrock map of south-central Indiana. The Mitchell Plateau includes all the Blue River Group and portions of the adjacent Sanders Group on the east and West Baden Group on the west. (Dm = Middle Devonian New Albany Shale Group; M1 = Mississippian Borden Group; M2 = Sanders Group; M3 = Blue River Group; M4= West Baden Group; M5 = Stephensport Group; M6 = Buffalo Wallow Group; P1 = Pennsylvanian Racoon Creek Group (from Gray et al., 1987; Map Scale: 1 in. = 10 mi.)

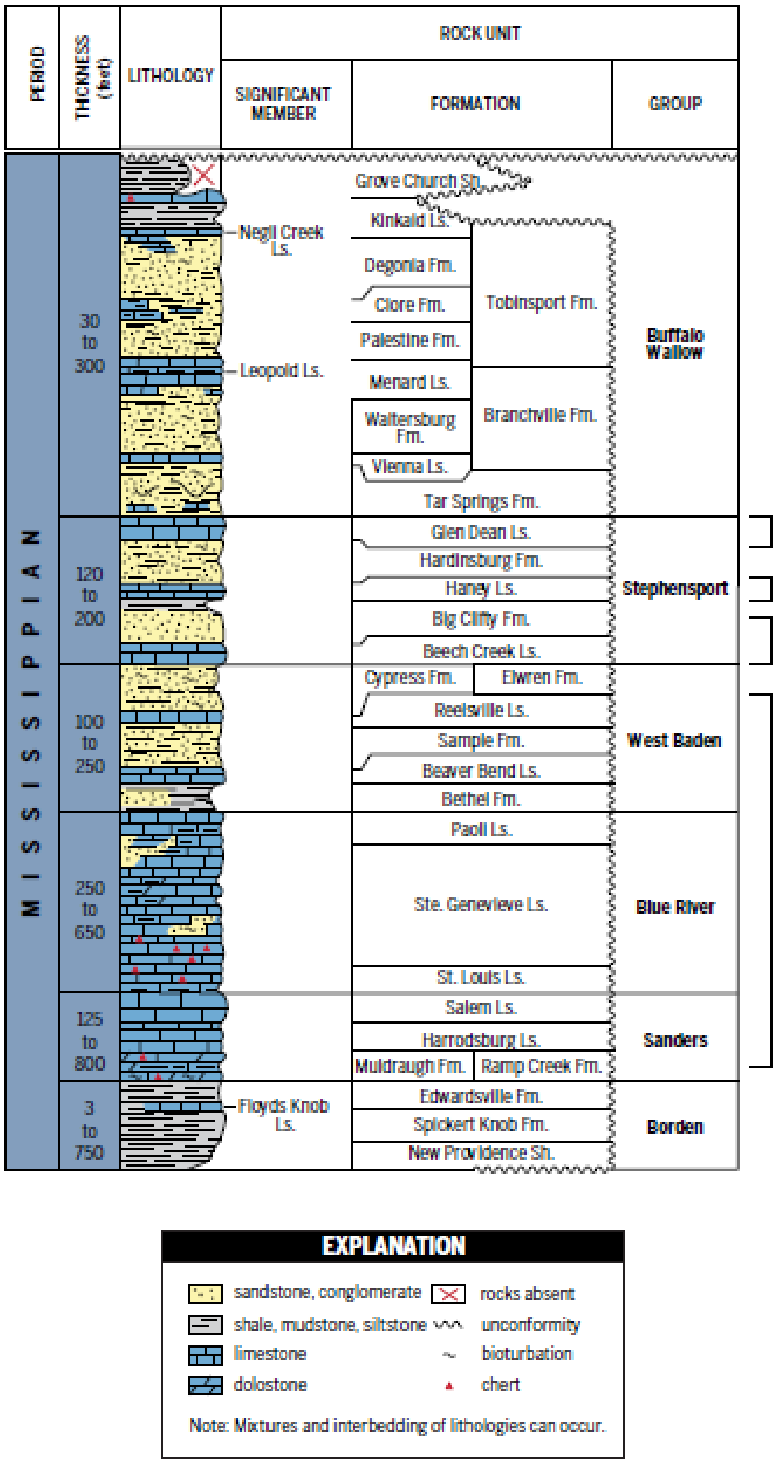


Figure 5. Generalized stratigraphic column of Mississippian bedrock in south-central Indiana. The side brackets indicate the development and presence of caves within the host strata. The great thickness range of rock groups reflects the difference of field measurements of partially eroded outcrop belts to subsurface measurements from exploration drilling (from Florea et al., 2018).

The Mississippian sedimentary package can be broadly characterized by a shallowing upward transition from deep water deltaic siltstones and shales of the Borden Group (Valmeyeran) to broad, mostly shallow marine carbonate platforms of the Sanders Group (Valmeyeran) and Blue River Groups (Valmeyeran and Chesterian), to marginal marine and mixed siliciclastics and carbonates of the West Baden, Stephensport, and Buffalo Wallow Groups (Chesterian). To a large degree, all Mississippian bedrock groups and their constituent formations thicken to the southwest or south from the outcrop belt and shallow subsurface in south-central Indiana to the deeper part of the Illinois Basin in southern or southeastern Illinois. The following discussion will focus on the Sanders and Blue River Groups which are the more prominent karst forming groups in the south-central Indiana region as well as the areas visited on the field trip.

The Sanders Group consists of carbonate rocks in complex facies relationships (Rexroad, 1986). The Ramp Creek Formation, which is 16 to 34 feet thick in the outcrop belt, and the overlying Harrodsburg Limestone, which is up to 70 feet thick in the outcrop belt, are more prominently exposed in the Lawrence and Monroe Counties in the northern part of the Mitchell Plain, but both are impure, containing some argillaceous limestone and small amounts of siltstone and shale, and occasionally chert (Rexroad, 1986). Although the Harrodsburg Limestone contains a few small caves and many small springs (Powell, 1961), the mixed carbonate clastic content of these formations limit involvement in regional karst aquifers (Florea et al., 2018). The Salem Limestone, which overlies the Harrodsburg Limestone, is better known as the world famous "Indiana Limestone" quarried and sold as dimension stone. It is also an established producer of oil in the Illinois Basin. The Salem Limestone thickness ranges from 60 to 100 feet in the central and southern parts of the outcrop belt (Pinsak, 1957), and has complex facies dominated by fossiliferous grainstone with well-rounded grains (Brown, 1987, 1990, Thompson et al., in Thompson ed., 1990). The Salem Limestone contains several caves, many of which are considered large (Powell, 1961) and is a significant unit of karst aquifer development and contains several caves in the Mitchell Plateau (Florea et al., 2018).

The Blue River Group consists largely of carbonate rocks but has significant amounts of gypsum, anhydrite, shale, chert, and calcareous sandstone (Rexroad, 1986). The combined thickness of the constituent formations is 540 feet in southern Crawford and Harrison Counties (Carr, 1978, 1986a), thins to about 400 feet in northwestern Orange County (Gray et al., 1960), and 240 feet thick in southern Monroe County (Malott, 1952).

The St. Louis Limestone contains a suite of shallow water carbonate facies with repeated cycles of lagoon, tidal flat, sabka (low relief tidal-evaporite flats), and subaerial exposure (Florea et al., 2018). On outcrop, the lower two-thirds of the St. Louis Limestone consists mainly of pellet-micritic limestone, calcareous shale, and silty dolostone (Carr, 1986b).

Evaporites including gypsum are present, but largely removed by circulation of meteoric groundwater (Florea, et al. 2018). The lower part typically contains blue-gray colored chert nodules and lenses. The upper part consists of micritic, pelletal, and skeletal limestone and very thin beds of shale (Carr et al., 1978). The St. Louis Limestone has been quarried for ag lime and crushed stone along the outcrop belt and deep mined for gypsum to the west in Martin County (Shaffer, 2016), and is a locally significant producer of oil in the subsurface of southwestern Indiana (Cazee, 2004). The St. Louis Limestone is 70 feet thick in Putnam County in west-central Indiana and thickens southward to 150 feet in Washington County (Sunderman, 1968) and up to 300 feet in a quarry in southern Crawford County (Carr et al., 1978). The St. Louis Limestone contains many caves of varying sizes (Powell, 1961) and is especially noteworthy for its signature topographic expression of closely spaced, broad and moderately sloping to locally smaller and steeply sided sinkholes in the Mitchell Plain and Pennyroyal region of west-central Kentucky.

The Ste. Genevieve Limestone is a carbonate-dominated sequence, characterized by oolitic, skeletal, micritic, and detrital limestone (Carr, 1986c). Thin beds of calcareous sandstone and sandy limestone, traceable for many miles, are present in the upper half of the formation (Atherton et al., in Willman et al., 1975). The lower part is cherty and has a regionally persistent marker bed known as the Lost River Chert (Florea et al., 2018). The Ste. Genevieve Limestone has been extensively quarried for ag lime and crushed stone throughout the Illinois Basin outcrop belt and is a significant producer of oil in the shallow subsurface of the region. The formation crops out in a northward narrowing belt from the Ohio River to west-central Putnam County. The formation is 45 feet thick but thickens to 220 feet to the south and southwest (Carr et al., 1978). The Ste. Genevieve Limestone is especially noteworthy for its sinkhole terrain, great and numerous caverns, and influence of the groundwater hydrology of the region.

The Paoli Limestone, which forms the caprock of much of the transitional area between the Mitchell Plateau and the Crawford Upland, consists of in ascending order the Aux Vase Sandstone Member, a calcareous, fossiliferous shale interbedded with shaly to fine grained sandstone (Droste and Carpenter, 1990), the Renault Member, a wackestone and mudstone interbedded with thin fossiliferous shale, the Yankeetown Member, a calcareous shale with shaly siltstone with thin discontinuous beds of mudstone and wackestone, and the Downeys Bluff Member, an oolitic and biofragmental grainstone and packstone (Florea et al., 2018). The Renault Limestone is a local producer of oil in the deeper parts of the Illinois Basin. The combined thickness of the constituent formations in the outcrop area is 20 to 36 feet (Carr et al., 1978). As a result of the abundance of impure siliciclastic beds and subordinate thickness in the south-central Indiana region, the Paoli Limestone Formation can be characterized as an impermeable sedimentary sequence in the region.

Surface and Subsurface Hydrology and Mapping

Karst investigations of the Mitchell Plateau date to the mid-19th century, when brothers and pioneering geologists Richard and David Dale Owen produced a sketch of a "swallet" (sinkhole) and cave and written reference to the disappearance of the Lost River in Orange County (Owen, 1862, Florea et al., 2018). Owen also visited the "Rise of the Lost River" at Orangeville (Owen, 1862; Florea et al., 2018). Geologic mapping of the Lower Carboniferous area of southern Indiana by Ashley and Kindle (1903) provided a subsequent basis for more detailed investigations of karst features, caves, and their development by Clyde A. Malott (1922, 1929, 1932, 1945, 1952).

A conceptual cross-sectional model of groundwater aquifers in the Mitchell Plateau and Crawford Upland of south-central Indiana produced by Florea et al. (2018) succinctly shows the generalized topography, regional westward dipping Mississippian carbonate bedrock groups, surface recharge areas, groundwater flow paths, and areas of artesian springs **(Figure 6)**.

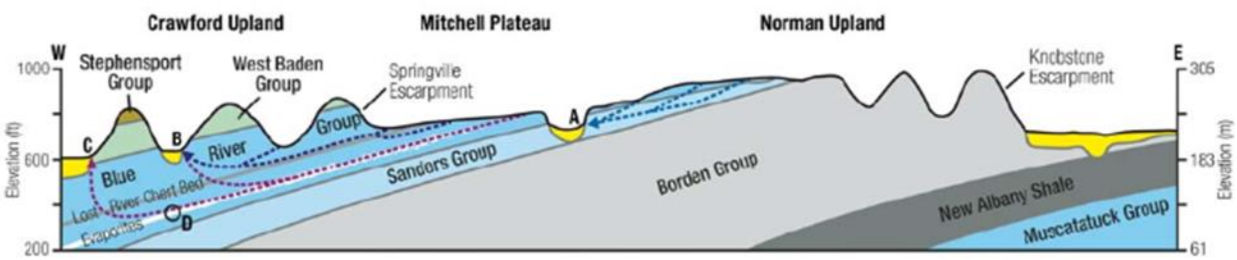


Figure 6. Generalized east to west cross section of the Mitchell Plateau and Crawford Upland showing the conceptual model of groundwater aquifers. Quaternary alluvium and glacial outwash appear in yellow color; carbonates appear in blue color, and mixed carbonate-clastics appear in green color. A: Small, shallow karst aquifers convey water to stream valleys on the Mitchell Plateau from groundwater flow (medium blue dashed lines) from surface recharge areas in the outcrop belt of the Sanders Group and lower part of the Blue River Group. B. Intermediate-size karst basins accumulating water on the Mitchell Plateau with flow paths in the Blue River Group (dark blue dashed lines) that discharge to alluviated springs in incised rivers. C: The regional aquifer system accumulating water from the Mitchell Plateau with flow paths centered upon breccia zones in the lower part of the Blue River Group associated with the position of soluble evaporite beds (purple dashed lines) to mineralized springs (from Florea et al., 2018).

The Lost River Karst Basin spans 160 mi^2 in Washington, Lawrence, and Orange Counties (McGregor and Rarick, 1962), and is adjacent to two other karst basins identified as Bluespring Caverns Basin and Mill Creek-Mosquito Creek Basin **(Figure 7)**.

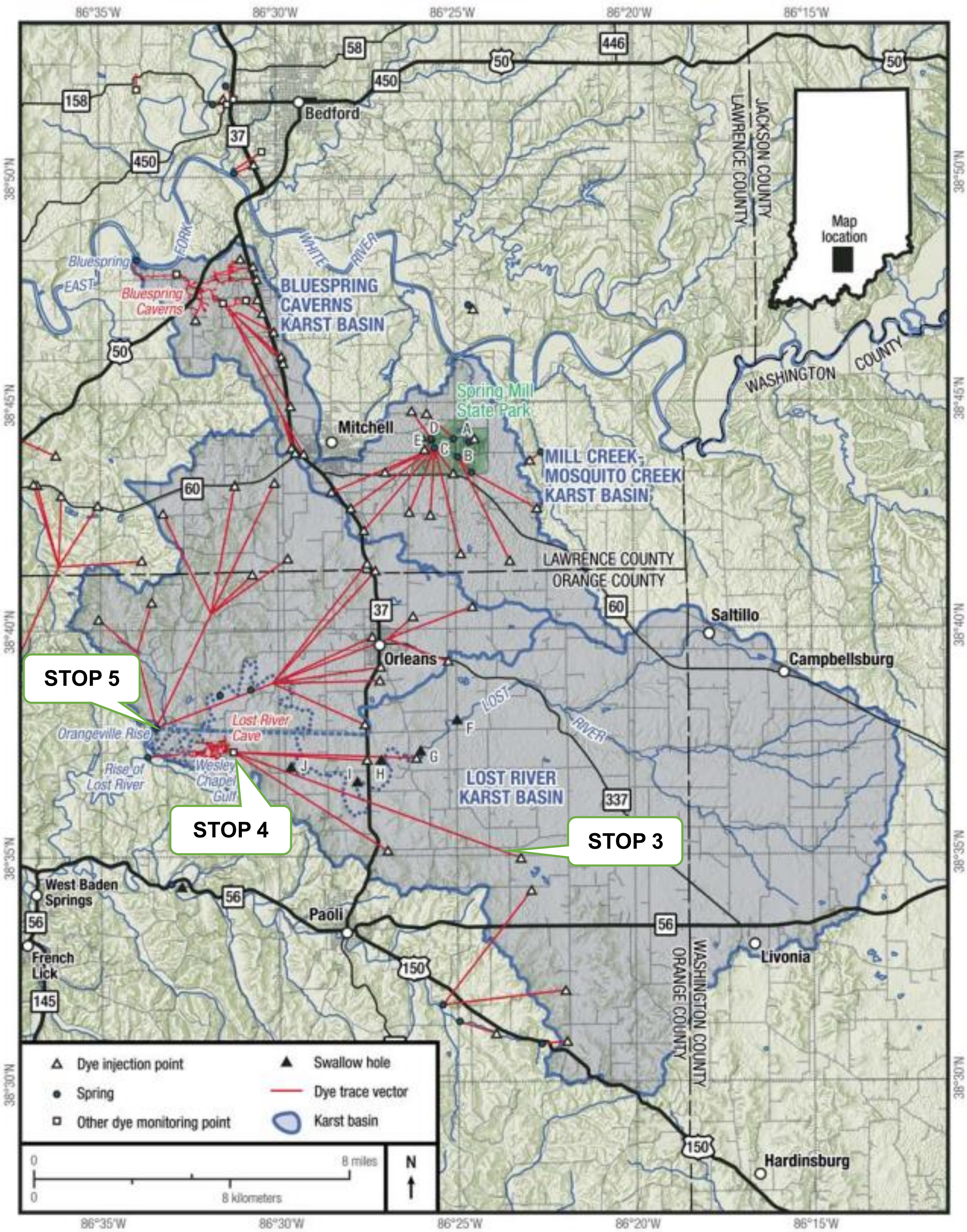


Figure 7. Map showing the location and identification of karst drainage basins, swallow holes, springs, and dye injection and monitoring points in parts of Lawrence, Orange, and Washington Counties (from Florea et al., 2018). The location of Field Trip stops is shown and are described in the following text.

STOP 1: Roadcut in Ste. Genevieve Limestone, Milltown, Indiana

The first stop of the field trip gives participants an opportunity to examine a roadcut exposure of karst bedrock in the Ste. Genevieve Limestone (Mississippian) on IND Hwy. 64 in the Crawford Upland near Milltown, Harrison County, Indiana **(Figures 8 and 9)**.

Figure 8. Aerial image showing the location of roadcut at **STOP 1** near Milltown, Indiana (Image Scale: 1 in. = 100 ft. approx.).

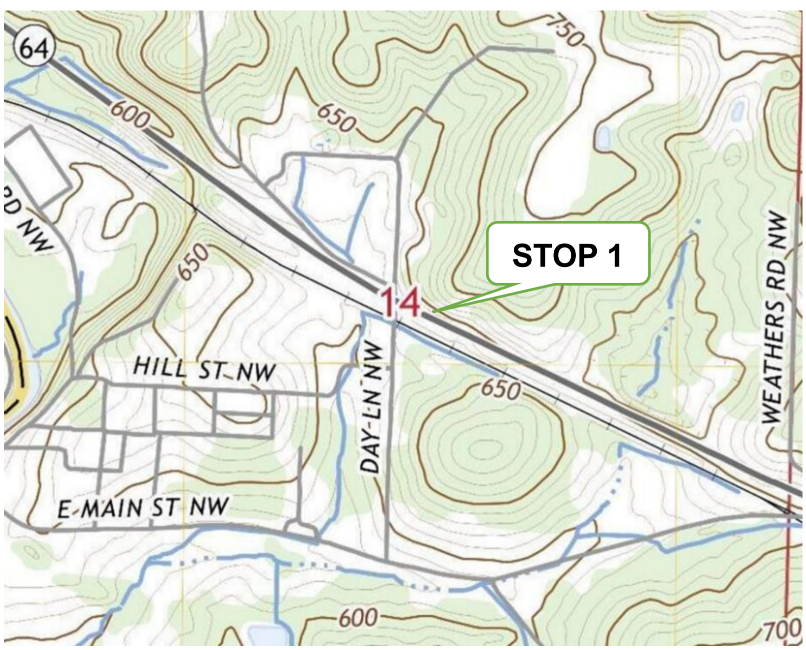


Figure 9. Part of Milltown, IN 7.5' Topographic Map showing the location of roadcut at **STOP 1** near Milltown, Indiana (Map Scale: 1 in. = 750 ft. approx.).

This roadcut was selected for viewing and personal sampling because of its location on the primary route to nearby Marengo Cave **(STOP 2)** and for the safety afforded to charter bus parking on the paved frontage road west of the roadcut. To the senior author's knowledge and desktop research, the roadcut and exposed strata have not been previously or formally described in detail. Regional bedrock mapping (Map Scale 1:250,000) indicates the roadcut is in the upper part of the Blue River Group, and the top of the bedrock knob is mapped in the overlying Paoli Limestone (Gray et al., 1987).

The Indiana Highway 64 roadcut trends west-northwest and is approximately 1,300 feet (0.25 miles) long and 30 to 40 feet in excavated height. The western end of the roadcut is at MM 87.4 (approx.) of IND Hwy. 64 at the intersection of Day Lane. A small (< 1 acre) abandoned and overgrown quarry or prospect pit is concealed by dense woods on the east side of Day Lane. Due to time constraints, field trip participants will only be able to examine the westernmost portion of the south facing and westbound side of the roadcut.

There is an apparent dip of bedding in the roadcut of 1.5° to the west. The dip is virtually imperceptible because the paved road surface descends from east to west at nearly the same dip-slope as the bedding, from 650 ft. MSL on the east to 620 ft. MSL on the west.

Three arbitrary "mapping units" of limestone strata can be informally defined based upon the presence of a prominent bedding plane surface separating a lower, mostly light gray to light brownish gray colored limestone unit ("Unit 1") from a middle, medium gray colored limestone unit ("Unit 2"), and a thin claystone break separating the middle gray colored limestone from an upper medium gray colored limestone unit ("Unit 3"). Approximately 30 feet of well exposed section is described in the following text.

Unit 1 (road level): 12.0 ft.; Limestone, very light gray to light yellow-gray, weathers to light yellow brown; beds typically 6 to 28 in. thick and very fossiliferous, with prominent oolitic cross beds, but some beds 0.5 to 2 in. thick and micritic, locally cherty with nodules up to 4 in. diameter; locally and pervasively fractured, joint surfaces dip 50° to 60° W.

Unit 2.: 6.0 ft.; Limestone, light medium gray to light bluish gray, weathers brownish gray, appears massive, some beds 12 to 30 in. but others 1 to 9 in. thick., slight cross bedding but non oolitic, finely crystalline to micritic, sparse fossil content except for thin lag zones, prominent basal bedding surface; lacks fractures and joints of Unit 1 below.

Unit 3.: (top of section): 12.0 ft., Limestone, mostly calcarenite, medium gray, weathers light brownish gray, beds 3 to 15 in. thick and planar, fine fossil fragments, prominent 2" claystone basal bedding surface; lacks fractures and joints. The top of "Unit 3" forms an engineered bench of the roadcut that is scaled back and covered by residuum.

STOP 2: Marengo Cave, Marengo, Indiana

Marengo Cave is a privately owned and managed "show cave" located off Indiana Hwy. 64 in Marengo, Crawford County, Indiana. The cave is listed as a U.S. Historic Landmark for its historic and geological significance. Field trip participants will partake in two separate guided tours which exhibit various types of cave speleothems (depositional features).

The cave system is developed in the Ste. Genevieve Limestone in the Crawford Upland. The cave extends approximately 5 acres and lies beneath a bedrock ridge capped by a veneer of impermeable sandstone within the Paoli Formation. The local topographic relief is approximately 200 feet **(Figure 10)**. Surface drainage is part of the Blue River Drainage Basin and flows to the east and joins the Blue River near Milltown, Indiana.

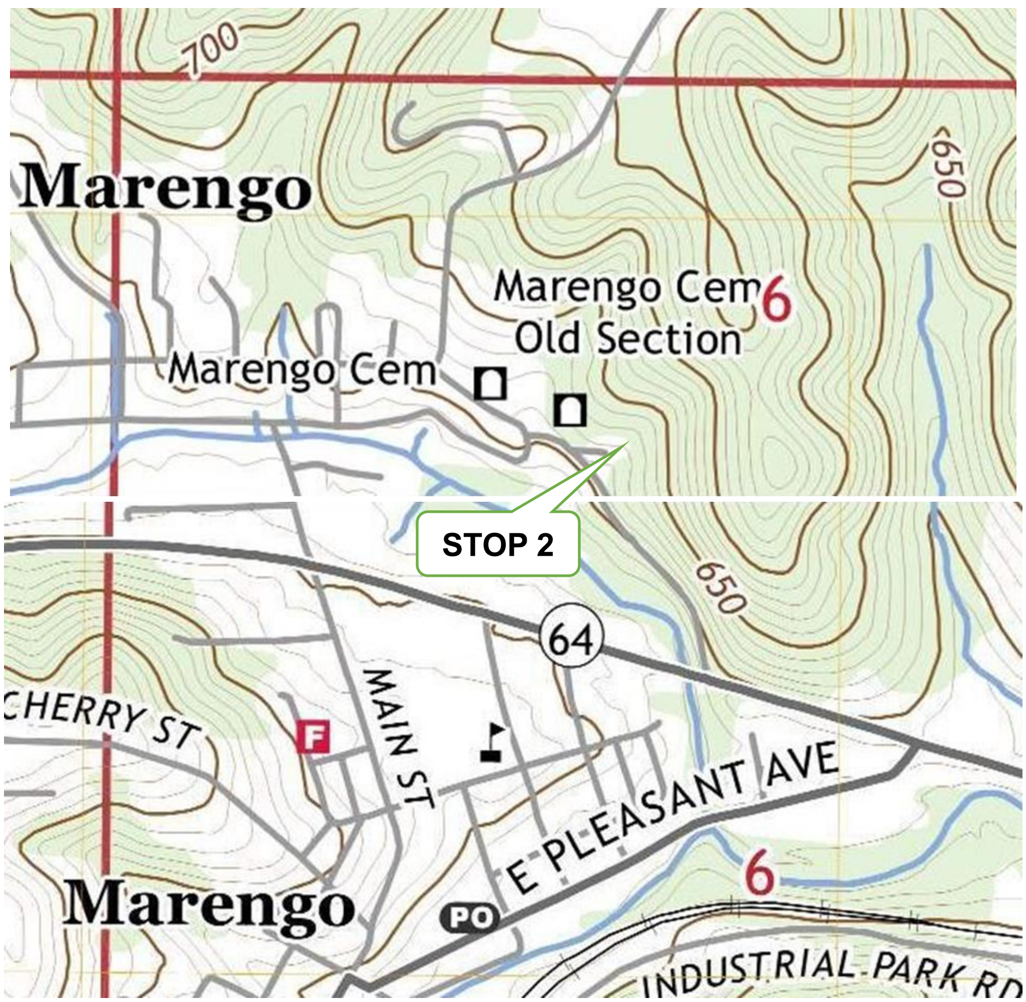


Figure 10. Parts of Hardinsburg, IN 7.5' and adjoining Marengo, IN 7.5' Topographic Maps showing the surface terrain at Marengo Cave (**STOP 2**; Map Scale 1 in. = 700 ft. approx.).

The cave was discovered at the base of a sinkhole by 15-year-old Blanche Hiestand and her 11-year-old brother Orris after school one day in September 1883. Their discovery was reported to the landowner, Samuel Stewart, who soon enlarged the entrance, built a stairway, and charged 25 cents admission to visitors (Marengo Cave, Historical Timeline, https://marengocave.com/individuals/the-cave/timeline).

The Crystal Palace Entrance was excavated in 1910 and the Dripstone Trail Entrance was opened in 1979 as a separate tour within the same cave network. The latter part of the cave was designated as a National Landmark by the National Park Service in 1984 Marengo Cave Historical Timeline, https://marengocave.com/individuals/the-cave/timeline).

The original discovery consisted of approximately 3,900 feet of passages, with later exploration in 1992 extending the length to 15,480 feet (2.93 miles). Subsequent discoveries connected the Old Town Spring Cavern for an additional 4,552 feet, yielding a total of 20,392 feet (3.86 miles; Indiana Geological Survey, Geo Notes, https://igws.indiana.edu/ReferenceDocs/GeoNotes/GeoNotes_MarengoCave.pdf).

Two commercial staff guided tours are offered. The 40-minute, 1,000-foot-long Crystal Palace Tour features a large variety of dripstone, flowstone, and rimstone deposits **(Figure 11**). The 70-minute, 5,000-foot-long Dripstone Tour covers dripstone "soda straw" formations in the southern part of the cave and partially overlaps the Crystal Palace Tour. With comfort and safety in mind, the asphalt paved footpaths have floor lighting and there is ample wall mounted and backlit lighting to illuminate the cave features and formations. The footpaths are mostly level and dry, and there is ample head clearance throughout the cave. The cave temperature is the local annual mean temperature of 54°.

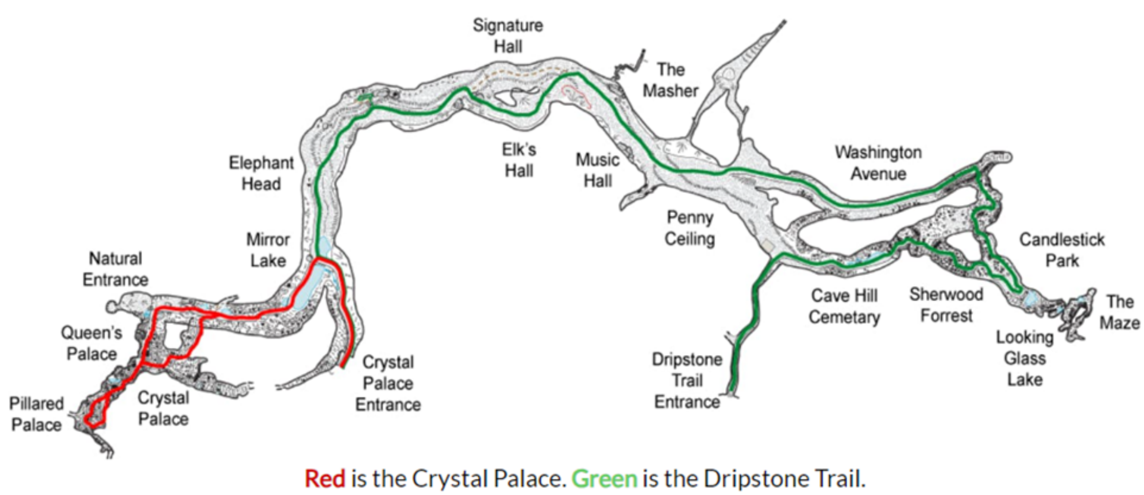


Figure 11. Map illustration of Crystal Palace and Dripstone Trail tours at Marengo Cave (Marengo Cave, Walking Tours, https://marengocave.com/individuals/walking-tours).

STOP 3: Ross Farms Property, Syria, Indiana

Ross Farms is a typical family managed farm sited near the central part of the Mitchell Plateau approximately 5 miles northeast of Paoli, Orange County, Indiana. The farm is owned by Kenneth Ross Farms, LLC and consists of four non-contiguous tracts comprising approximately 480 acres of farmland **(Figures 12 and 13)**. The historic and present use of the property is for row crop production.

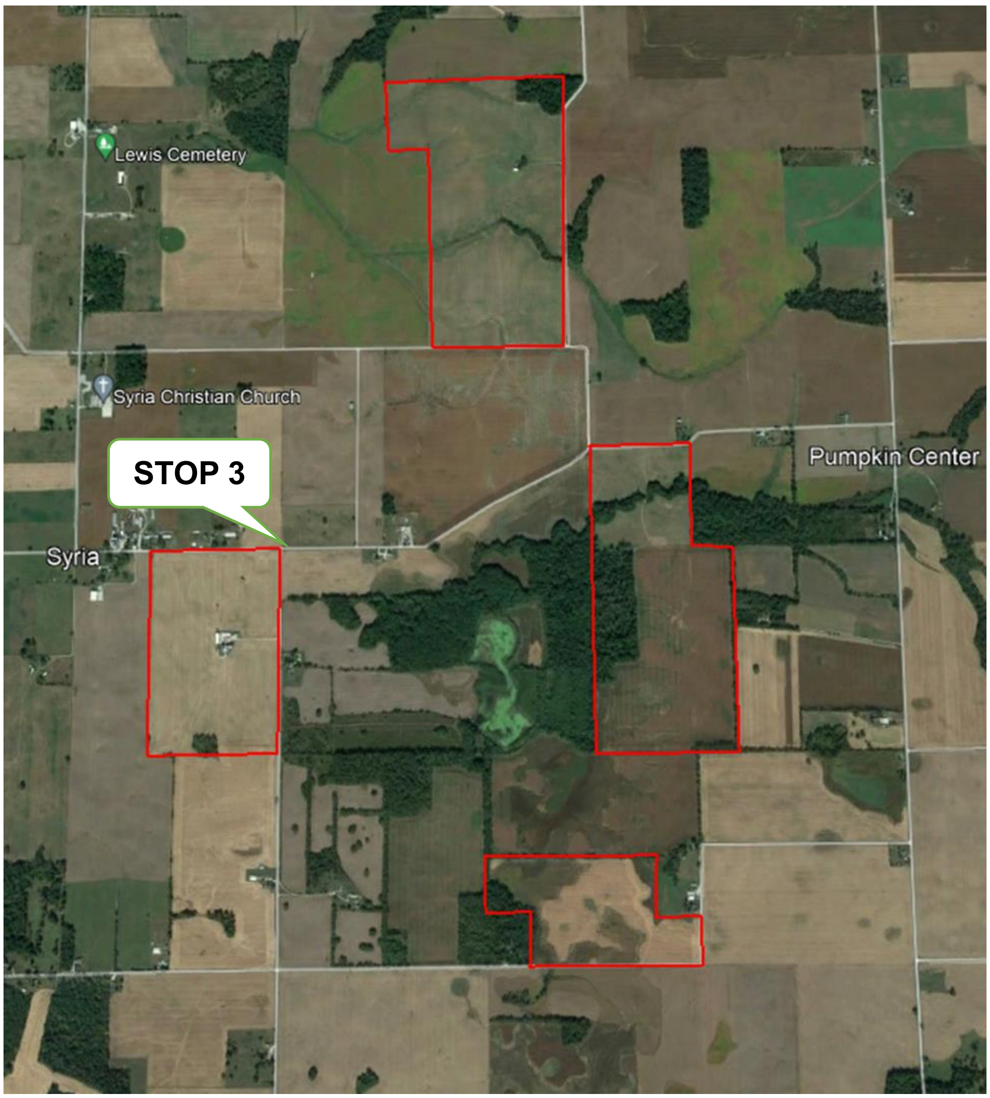


Figure 12. Aerial image of Ross Farms property, showing the location of controlled tracts (red colored polygons) and **STOP 3**. Light tan color denotes corn crop, light and dark brown color denotes soybean crop, and dark green color denotes deciduous woodlands. A west flowing, treelined Stamper Creek drains into the subsurface karst aquifer in the lime green colored water body ("Stamper Sinks") near the center of the aerial image (Image Scale: 1 in. = 0.5 mi.)

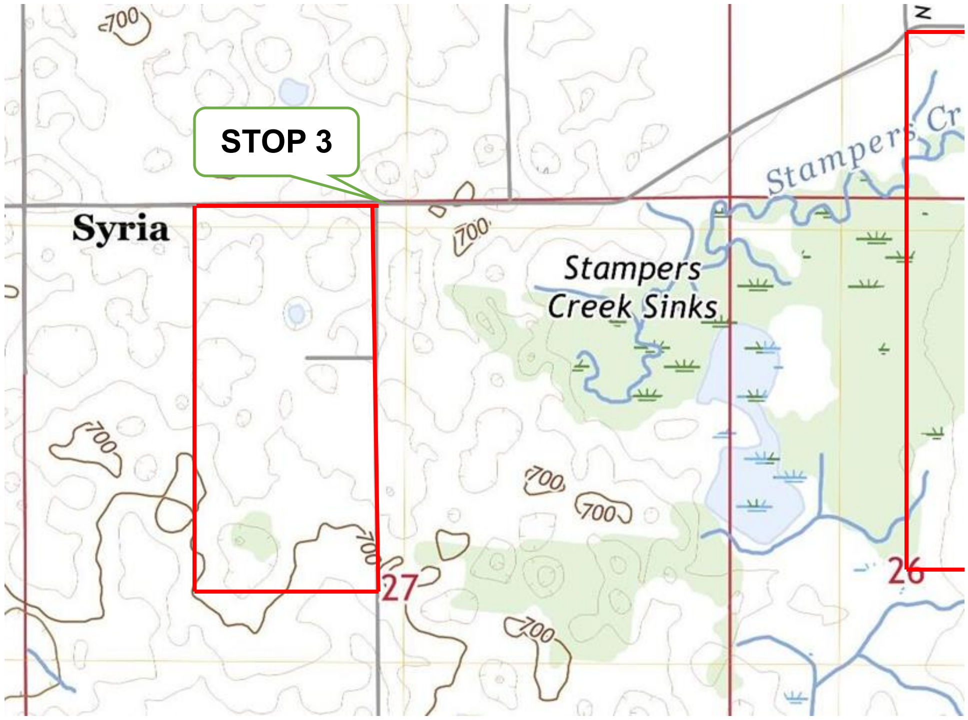


Figure 13. Part of Paoli, IN 7.5' Topographic Map showing the location of **STOP 3** at Ross Farms property (red colored polygons), surrounding sinkhole plain and west flowing Stampers Creek as a sinking stream ("Stamper Creek Sinks"). The highlighted rectangular tract in Section 27 consists of 80 acres (Map scale: 1 in. = 1,800 ft. approx.).

This field trip stop, at the "T" intersection of N CR 350 E and E CR 200 N at an elevation of 695 ft. MSL, offers participants an opportunity to observe a classic karst sinkhole plain, and the different agricultural practices applied to karst terrain on non-sloping (0 to 2%), gently sloping (2-6%), and moderately sloping (6-20%) land. The topographic map for this locality indicates small planar hills up to 730 ft. MSL at the extreme southern part of the map area, and intervening sinks and swales as low as 675 ft. MSL such as at Stamper Creek Sinks **(Figure 13)**. Online regional mapping indicates the bedrock is assigned to the Blue River Group (Gray et al., 1987), and probably like the first sinks of the Lost River into shallow subterranean channels developed in the upper part of the St. Louis Limestone (Malott, 1952), the regional structural strike suggests the same fate for Stamper Creek sinks developed in the upper part of the St. Louis Limestone.

Stamper Creek heads at approximately 820 ft. MSL to the southeast near the Orange-Washington County line and meanders 7.7 miles in a northwestward course before submerging at the Stamper Creek Sinks at 675 ft. MSL. The map of Florea et al. (2018, **Figure 7**) indicates Stamper Creek and its sinks are a subbasin within the Lost River Karst Basin and located approximately 3.5 miles to 5 miles south of the surface trace of the Lost River. The map of Florea et al. (2018) shows that a dye injection test at Stamper

Sinks was traced to the Wesley Chapel Gulf located 8.0 aerial miles to the west-northwest. Previous mapping and dye tracing tests by Malott (1952) suggested that Stamper Creek is a "dismembered stream" or former tributary of the much longer Lost Creek, which was captured by swallow holes and diverted underground southward and westward to reemerge at Lick Creek, southeast of Paoli. Subsequent dye tests at Stamper Creek Sinks by Murdock and Powell (1967) traced the dye to the west-northwest to the true rise of Lost River, located 1 mile south of Orangeville Rise and 10 aerial miles to the west-northwest.

Southeast of the "T" road intersection, and mostly obscured from corn crop and deciduous tree foliage, is Stamper Creek Sinks, a non-farmed, low-lying wetland area which is the locus of swallow holes for a sinking stream. Online Federal Emergency Management Agency (FEMA) Flood Hazard Risk mapping indicates Stamper Creek and the area at or below 680 ft. MSL is "Flood Zone A", a regulated floodplain, defined as having a 1% or greater annual chance of flooding in a given year (FEMA, National Flood Hazard Layer Viewer https://hazards-fema.maps.arcgis.com/apps/webappviewer/). Online US Department of Agriculture (USDA) Web Soil Survey mapping indicates these low lying, uncultivated areas that are poorly drained and frequently flooded are mapped as the Wakeland silt loam and the Wilbur silt loam (USDA, Web Soil Survey, https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).

Southwest of the "T" road intersection is a broad, southwest trending coalesced sinkhole of low relief and surrounding upland area planted in soybean crop. The topographic map shows a small circular karst lake approximately 1,000 ft. southwest of the "T" road intersection at an elevation of approximately 675 ft. MSL, and a smaller sink about 600 feet from the "T" road intersection marked by a lone deciduous tree, but the landowner indicated that he backfilled these depressions several years ago to gain more production acreage. The landowner claims he usually produces 60 bushels of soybeans and when he rotates crops 220 bushels of corn per acre on this field. Like most larger farms in the region, the landowner relies on a network of 3-to 4-inch lateral drainage tiles buried 3 feet below the surface, which are connected to 6-inch mains at the property margins and pumped to the surface at an appropriate elevated high point or points for recharge or to a nearby surface drainage culvert or natural stream.

The field southwest of the "T" road intersection has a slope of 0 to 6% and according to FEMA mapping is in "Flood Zone X", or otherwise not susceptible to the 1% annual chance of flooding (FEMA, National Flood Hazard Layer Viewer https://hazards-fema.maps.arcgis.com/apps/webappviewer/). Web Soil Survey mapping indicates the soils at the higher areas with a slope of 0 to 2% that are well drained are mapped as the Bromer silt loam and the Bedford silt loam. Areas with greater slopes of 2 to 12% include the Crider-Frederick-Caneyville silt loam (USDA, Web Soil Survey, https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).

Directly northeast of the “T” road intersection (and not on the Ross Farms property) is a sinkhole of moderate relief, having an overall slope of 6 to 12%, but locally up to 20%. At the time of this writing, the land was uncultivated. The area is considered well drained and mapped as the Crider-Frederick-Caneyville silt loam, but because of the greater slope, this tract is not considered prime farmland.

A densely wooded upland area with a prominent bluff can be observed approximately 2 miles to the southwest of the “T” road intersection. The distant ridge line varies from 770 to 850 ft. MSL, or 80 to 150 feet above the hummocky karst terrain. The bluff is a dissected, steep sloped cuesta and marks the transition of the Mitchell Plain with the Crawford Upland, which is capped by the West Baden Group of alternating clastic and carbonate strata.

A review of online well water records maintained by the Indiana Department of Natural Resources (DNR) Water Survey (https://www.in.gov/dnr/water/ground-water-wells/water-well-record-database/) indicates domestic water supply for the Ross Farms and neighboring farms is derived from wells sourced from a water table depth of 45 to 100 feet in Blue River Group limestone bedrock of variable depth, and pump tests of 5 to 50 gallons per minute **(Table 1)**. A mapping and analysis of Blue River Group aquifers in Orange County indicates most domestic well completion depths range from 80 to 190 feet, and test rates of 50 to 250 gallons per minute (gpm), but most well produce 5 to 25 gpm (Grove, 2003). Water quality data for the wells listed below and for the county is lacking or incomplete.

No.	Indiana DNR Water Well ID No.	Year Drilled	Distance & Direction from STOP 3	Drill Hole Total Depth (ft.)	Description of Surficial Material or Sediment	Depth to Bedrock (ft.)	Depth of Static Water Level (ft.)	Pump Test Result (gal./min.)	Water Quality Comment
1	221371	1965	880 ft. W	125.0	"boulders"	70.0	60.0	5.0	none
2	221361	1966	1,600 ft. E	125.0	clay/brkn lime	15.0	65.0	25.0	none
3	221366	1976	1,670 ft. E	136.0	red clay lime	15.0	n/a	15.0	high iron
4	221376	1962	3,660 ft. NW	130.0	yellow lime	89.0	65.0	10.0	none
5	286930	1995	4,200 ft. WSW	185.0	clay	18.0	100.0	10.0	clear
6	286931	1996	4,200 ft. WSW	165.0	red clay	17.0	50.0	15.0	none
7	308689	1997	4,235 ft. NE	220.0	clay	21.0	n/a	50.0	none
8	308690	1997	4,235 ft. NE	125.0	red clay	30.0	45.0	20.0	none

Table 1. List of domestic water well data for all wells within a 1-mile radius of the “T” road intersection (STOP 3) at Ross Farms property. Wells 5 and 6 and wells 7 and 8 are at the same map location and the latter numbers 6 and 8 are redrills. The depth to bedrock listed for wells 1 and 4 could be inaccurate and much less as the surficial material listed reflects solid or broken bedrock.

STOP 4: Wesley Chapel Gulf Collapse Sinkhole, Orleans, Indiana

Wesley Chapel Gulf is an 8-acre sized, peanut shaped collapse sinkhole located off N CR 350 W approximately 5.5 miles northwest of Paoli and 4.5 miles southwest of Orleans, Orange County, Indiana **(Figure 14)**. The sinkhole is named for the nearby Wesley Chapel Church and was formerly owned by James Elrod who farmed the surrounding property until 1952. Some early reports and maps refer to the property as the Elrod Gulf.

Figure 14. Aerial image of Wesley Chapel (Elrod) Gulf and **STOP 5**, a “hanging valley” of limestone bedrock and entrance of a west flowing surface stream into the collapse sinkhole feature (Image Scale 1 in. = 300 ft. approx.).

Wesley Chapel Gulf is located along a direct line between the main rise (located two miles west) and sink (located 5 miles east) of the Lost River. As a surface feature, the Gulf is entirely within the Ste. Genevieve Limestone. The Lost River chert, a regional marker bed near the base of the Ste. Genevieve, is exposed in places at or just above the alluviated floor of the gulf (US Forest Service, Wesley Chapel Gulf, https://www.fs.usda.gov/detail/hoosier/about-forest/?cid=fsbdev3_017567).

The surface and subsurface gulf features and dimensions were first documented on the Paoli, IN 15' topographic base map by Clyde Malott (1932) and shown below **(Figure 15)**.

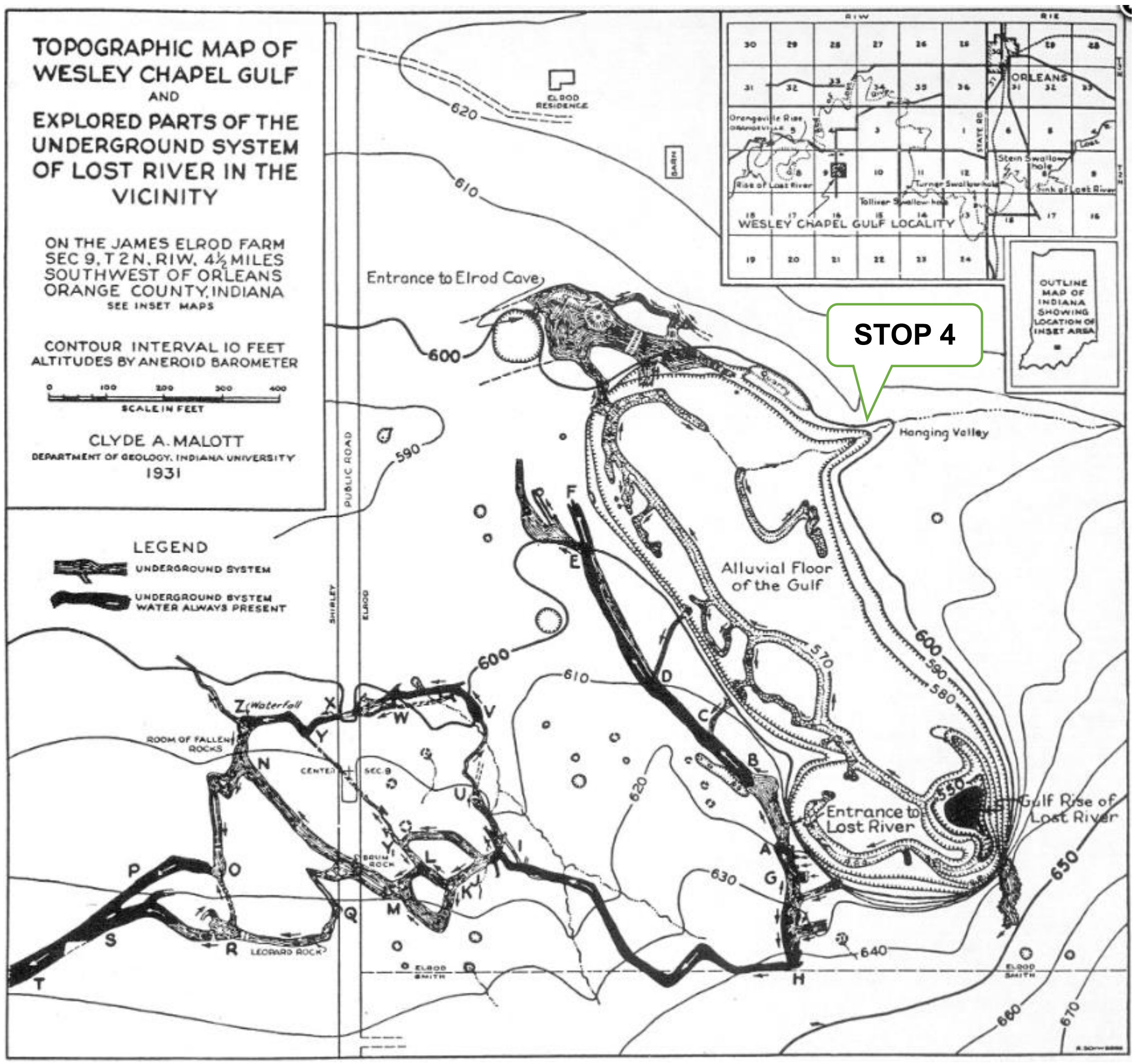


Figure 15. Part of Paoli, IN 15' Topographic Map of Wesley Chapel Gulf and interpretive surface and underground drainage features illustrated by Clyde Malott (1932).

The gulf and surrounding property was managed as a typical family farm from the 1900's to the 1990's. Wesley Chapel Gulf was designated as a National Natural Landmark by the National Park Service in 1972. The 187-acre property was legally acquired by the U.S. Forest Service in 1996 for public conservation. At that time, most of the sinkholes in the gulf had trash including metal, wood, concrete, glass, and household items, which were cleaned out and restored to natural conditions in 1999. The property has no active management, and currently receives only custodial care (U.S. Forest Service, Wesley Chapel Gulf, https://www.fs.usda.gov/detail/hoosier/about-forest/?cid=fsbdev3_017567).

Wesley Chapel Gulf measures 1,075 feet in length and averages approximately 350 feet in width. It includes an 8.3-acre area as measured from the rim, while the floor of the gulf is 6.1 acres in size. The gulf walls are abrupt and steep sided and vary in height from approximately 25 feet on the northwest side to 95 feet on the southwest side (Malott, 1932; 1952, U.S. Forest Service, Wesley Chapel Gulf, https://www.fs.usda.gov/detail/hoosier/about-forest/?cid=fsbdev3_017567).

The map of Mallot (1932) shows a darkened water body identified as a "Gulf Rise" in the southeastern part of the gulf. The feature was subsequently identified as "Boiling Spring" traced 125 feet deep to the main subterranean course of the Lost River. The rise pit overlies a water-filled opening about 3 feet in diameter that slopes downward to where it intersects a larger passage about 160 feet from the rise pit and 45 feet below normal pool level (Malott, 1932; 1952).

A gulf is always associated with an underground stream, and its development is dependent upon the collapse of the overlying bedrock and the subsequent solution and removal of the fallen rock. When a collapse feature has its steep-walled perimeter enlarged to such an extent that it possesses a distinct alluviated floor in which an underground stream rises and sinks, it may be called a gulf. The alluviated floor is usually marked by stream formed channels which pass from the rise to the swallow hole or series of swallow holes where the water is returned to the underground channel system (U.S. Forest Service, Wesley Chapel Gulf, https://www.fs.usda.gov/detail/hoosier/about-forest/?cid=fsbdev3_017567).

The Wesley Chapel Gulf and its deeply alleviated floor of clays and silts indicate approximately 720,000 cubic yards of limestone have been dissolved and removed. The width of the gulf is far greater than any known section of underground Lost River (Malott, 1952; U.S. Forest Service, Wesley Chapel Gulf, https://www.fs.usda.gov/detail/hoosier/about-forest/?cid=fsbdev3_017567).

Field trip participants will disembark from the small unimproved parking area and walk southeast along a grassy foot path to observe Wesley Chapel Gulf from the top of a "hanging valley" bedrock outcrop at 600 ft. MSL on the northeast side of the gulf. A west flowing intermittent stream which heads approximately 1 mile to the southeast and 100 feet higher in elevation discharges surface runoff from storms into the gulf. The rim area is wooded with a mixture of red cedar trees and deciduous trees, and the floor is wooded with deciduous trees and ground vegetation. The thick summer foliage obscures a complete perspective of the gulf area, and therefore optimum viewing of Wesley Chapel Gulf is during the winter season.

STOP 5: Orangeville (Lost River) Rise, Orangeville, Indiana

The Orangeville Rise of the Lost River is located off N CR 500 W in the unincorporated community of Orangeville, Orange County, Indiana, and 1.9 miles west of Wesley Chapel Gulf **(Figures 16 and 17)**. The feature is in the transitional area of the Mitchell Plateau and Crawford Upland.

The Orangeville Rise issues from a semicircular south-facing rock walled pit composed of planar beds of the lower part of the Ste. Genevieve Limestone approximately 30 feet above its basal contact with the St. Louis Limestone (Malott, 1952). The waters rise some

Figure 16. Aerial image of Orangeville Rise of the Lost River and **STOP 5** (Image Scale: 1 in. = 300 ft. approx.).

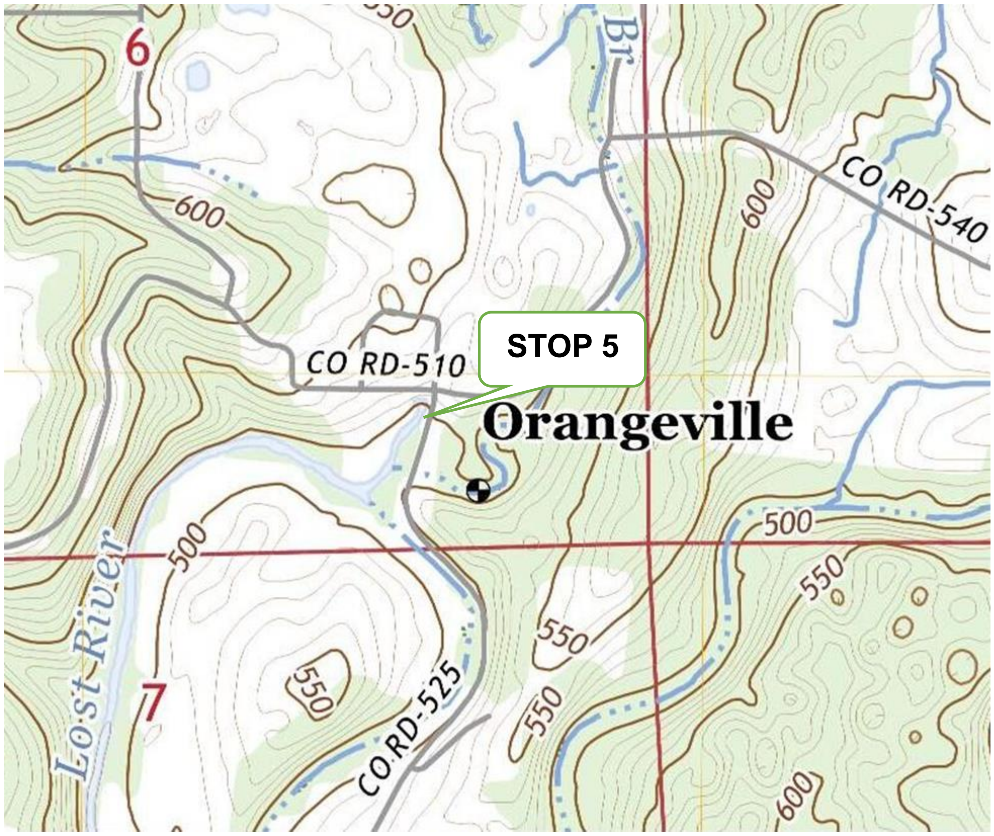


Figure 17. Part of Georgia, IN 7.5' Topographic Map showing the location of the Orangeville Rise of the Lost River and STOP 4 at Orangeville, Orange County, Indiana (Map Scale 1 in.= 1,000 ft. approx.).

15 to 20 feet as an artesian spring from a water filled cavern having a subterranean mouth of approximately 70 feet in width. The Orangeville Rise never goes dry, but in dry weather the flow is reduced to only a few cubic feet per second. After heavy rains, the flow is estimated to reach or exceed 2,000 cubic feet per second, and its lunar shaped, low cliff is submerged and the channel leading to Lost River is filled to overflowing (Malott, 1952).

The waters rising from the Lost River flow southward in a mud-banked channel 15 feet deep and 40 to 50 feet in width for about 600 feet before entering the Lost River dry channel bed. A principal resurgence or "true rise" of the Lost River is regarded to be a deep mud-lined pit about 0.7 miles south-southwest of the Orangeville Rise (Mallot, 1952)

The surface elevation of the Orangeville Rise at "normal pool" is approximately 500 ft. MSL. At its headwaters near Smedley, Washington County, the Lost River is at 880 ft MSL, and at its first sinks the river is at 625 ft. MSL, whereas at its terminus at the East Fork of the White River, the river is at 430 ft. MSL. Over its 86-mile meandering course, the stream gradient of the Lost River is calculated to be 5.2 feet per mile.

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