CHAPTER 2
GEOLOGY AND PEDOLOGY

2.0 INTRODUCTION

The close relationship between geology, pedology, and engineering should be recognized by all dedicated personnel who are concerned with the design, construction, and maintenance of highways. This association is especially valid in the case of highway engineering where highways are built on, through, above, and of earth materials. Unfortunately, most engineers receive little more than a superficial introduction to pedology and geology.

Geology is the scientific study of the origin, history and structure of the earth. It provides the basis for differentiating the materials comprising the earth's crust and interpreting the earth's history. In highway engineering, the importance of geology is in the interpretation of landforms; their history, the processes that shaped them, and the materials that comprise or underlie their surfaces. While pedology deals primarily with the product of surficial weathering, geology is concerned with the underlying material's character, distribution, and origin. Engineering geology studies outline areas of potential slope instability, buried zones of compressible materials, areas of possible surface subsidence, and areas of undesirable bedrock conditions.

Geologic maps show the distribution of rock formations. Geologic maps of Indiana can be purchased from the Indiana Geologic Survey. In addition, the IndianaMap website (maps.indiana.edu) contains a geographic information system (GIS) data map. The data map is free and made available to the public. It contains many geologic data layers and soil data layers.

Pedology is a branch of soil science focusing on the formation, morphology, and classification of soils as bodies within the natural landscape concerned solely with the earth's surficial materials. Pedology seeks to understand how the properties and distribution patterns of soils worldwide have developed along with broader landforms, biogeochemical environments, and habitats of living organisms.

Applications of geological and pedological knowledge provide the groundwork for delineating types of earth materials and potential problematic areas. Based on the geological and pedological data, various sampling methods and tests from soil mechanics can be used to supply the necessary quantitative data for incorporation into design criteria.

Some of the basic objectives of geotechnical investigations are to define the nature, characteristics, properties, thickness, and lateral extent of bedrock and overlying soils as well as groundwater conditions within a given project area. An understanding of some of the basic geologic processes and how they combined to create the varied landscapes in our state, give us a base line of information from which to begin more detailed studies of the subsurface.

2.1 INDIANA GEOLOGY OVERVIEW

The first half of this chapter provides an overview of Indiana's geology. This chapter focuses on geologic features that could potentially affect highway engineering in Indiana. The geology of Indiana is both complex and diverse. The geologic history includes periods of deposition and subsequent erosion, subsidence and faulting, submersion by epi-continental seas with subsequent deposition of thousands of feet of material to form sedimentary rocks. All of these events took place prior to the start of the Quaternary Period, which began about two million years ago. The bedrock, that was created over time, is buried in most of the northern two-thirds of the state by more recent, unlithified Quaternary deposits.

Most of the present land surface in Indiana was developed during the Quaternary Period, which includes the Pleistocene (Glacial) and Holocene (Recent) Epochs. In light of this, much of the emphasis of this chapter will be on Quaternary geology, including glacial soils and landforms, recent soil types, and hydrogeology. The bedrock geology will be discussed only in generalities because it is too complex and diverse to cover within the scope of this manual.

The second half of this chapter divides Indiana into five natural geologic regions: northern, central, southwestern, south-central, and southeastern. These geologic regions are based on physiographic regions. Physiography is the study of landform features of the earth's surface. There are three factors that determine the appearance of land surface or landscape: (1) rock type and geologic structure, (2) the dominant geologic process that has operated in the region, and (3) the stage or degree to which the geologic process has been able to shape the land surface. Physiographic provinces can be subdivided on a state-by-state basis. Understanding Indiana's physiographic regions can be useful in geotechnical investigations because subdivisions are based on very similar surface geology and landscape appearance. Figure 2.1 shows Indiana's various physiographic regions. Physiographic regions of Indiana may also be viewed on the IndianaMap website using the "Physiography Regions" data layer.

All the topics presented in Chapter two fall under the sphere of geology, and questions or problems in characterizing soils, bedrock, or groundwater conditions should ultimately be directed to the Field Unit of the Geotechnical Division.

2.2 GLACIAL GEOLOGY

The start of the Quaternary Period was marked by cyclic variations in the climate, which resulted in successive advances and recessions of glacial ice sheets across Indiana. This time period, referred to as the Pleistocene Epoch, or the "Great Ice Age", has been subdivided into four major glaciations, with interglacial periods. These are from youngest to oldest:

Present interglaciation
Wisconsin glaciation
Sangamon interglaciation
Illinoian glaciation
Yarmouth interglaciation
Kansan glaciation
Aftonian interglaciation
Nebraskan glaciation

A succession of glacial advances and intervening episodes of soil formation during the Wisconsin, Illinoian, and older glaciations are recognized by various glacial sediment sequences, including glacial till and granular materials. Interglacial periods are recognized by evidence of soil development; fossils and pollen, and from sediments which indicate warmer climate, such as lake deposits, beach ridges, and peats.

During the Pleistocene Epoch, the movement of ice and ice-bound debris was a strong abrasive force, and most of Indiana bears the scars of this force. The final glaciation, the Wisconsin, lasted from about 75,000 to 12,000 years before the present time and was responsible for the majority of the landforms seen in Indiana today. Glacial activity during the Wisconsin glaciation eroded or buried earlier glacial deposits from the Nebraskan, Kansan, and most of Illinoian glaciations, largely obscuring evidence of these earlier deposits.

The Wisconsin glaciation is characterized by advances and retreats of ice lobes that protruded from the main ice sheet that covered most of Canada. The direction in which the ice lobes moved across Indiana was controlled by major bedrock topography. In general, the ice lobes followed lowlands that were developed on the softer sedimentary rocks that flank the rim of the Michigan Basin Regional Structure. In general glaciers change in size by accumulation, by the addition of snow and ice, compaction, and recrystallization. Glaciers lose their mass through processes of ablation, resulting from melting. Glaciers also move to lower elevation under the force of gravity by internal flow and basal sliding mechanisms.

The Wisconsin Age of glaciation brought three main lobes of glacial ice (and unlithified materials) into Indiana. In northwestern Indiana, the Lake Michigan Lobe of ice flowed south into the west central part of Indiana as it carved out Lake Michigan and deposited layers of till and other glacial drift. Similarly, in northeastern Indiana the Huron-Saginaw Lobe flowed southwesterly into Indiana from the Saginaw Bay area of Lake Huron in Northeastern Michigan. Thirdly, the Ontario-Erie Lobe came from the northeast and east and crossed most of the northern half of Indiana. Each of these three lobes brought unique combinations of minerals and rock fragments in the soil material that they deposited as glacial drift.

2.2.1 GLACIAL FEATURES AND TERMINOLOGY

Most landforms visible in Indiana today are the result of the Wisconsin glaciation - the final advance of glacial ice to blanket the state. Many of the landforms and associated glacial sediments, discussed in the following sections, and their major areas of occurrence in the state, can be seen in the 1989 map entitled: "**Quaternary Geological Map of Indiana**" by Henry H. Gray produced by the Indiana Geological Survey. The "Glacial Quaternary Geology" data layer on the IndianaMap website may also be used to view surficial geology of Indiana.

Glacial depositional features are common and are the result of material dumped by the ice as it rode over the land surface or left behind as the ice melted or retreated. All material deposited by glacial action, whether it be directly from the ice or indirectly from meltwater, is classified as drift deposits. Drift deposited directly by glacial ice with no sorting action, include erratics and till.

Erratics: Erratics are boulders or cobbles of a certain rock type carried and deposited by glaciers a sufficient distance from their place of origin so that they are foreign compared to the destination's bedrock. Erratics in Indiana include cobble and boulder size fragments of a large variety of igneous and metamorphic rocks that were brought from the Canadian Shield. As such, they contrast with the sedimentary bedrock in the area of deposition.

Till: Till is unsorted, unstratified glacial deposit composed of a heterogeneous mixture of clay, silt, sand, gravel, and boulders. Soil and rock debris entrained within the glacial ice can be deposited during an advance or retreat of a glacier. Till dropped during the advance of a glacier or deposited by a retreating glacier as a thin blanket marked by low hills and swales is called a ground moraine or a till plain. It is usually unlithified and deposited directly by a glacier without having been reworked by meltwater. Gray, slightly moist, hard, clay loam, with a trace of gravel, is the most commonly described till in Indiana.

Materials that are deposited by waters associated with the glacial ice include; glaciofluvial, which are deposited by a stream or river originating from glacial meltwater, and glaciolacustrine, which are sediments deposited in lakes bordering and/or supplied by the glacier. Deposits from meltwater exhibit some degree of sorting and are often stratified. Also associated with glacial and post- glacial activity are wind-blown or Eolian deposits.

2.2.1.1 GLACIAL DEPOSITIONAL FEATURES

In considering glacial depositional features, care must be taken to distinguish between glacial deposits (soils) and topographic landforms. The general term that describes glacial deposits is drift. Drift includes all the material ever handled by the ice even if it is subsequently affected by wind or water. Abundant glacial drift deposits, some more than 400 feet thick, cover most of the northern two-thirds of Indiana. Drift from glacial advances older than the Illinoian and Wisconsin glaciations are largely obscured, either by erosion or by burial beneath younger deposits. Even the earliest deposits of the Wisconsin glaciation are difficult to identify because of subsequent advances and retreats of the ice lobes. A map showing the southern limits of the Illinoian and Wisconsin glaciation is shown on the "**Physiographic Map of Indiana**" by Clyde A. Malott (Figure 2.1). The glacial limits of the Illinoian and Wisconsin glaciation may also be viewed on the IndianaMap website through the "Glacial PreWisconsin Glacial Limit" (Illinoian) and "Glacial Wisconsin Glacial Limit" (Wisconsin) data layer. The "Glacial Quaternary Geology" data layer on the IndianaMap website may also be used to view the surficial geology of Indiana.

Topographic depositional features include moraines, drumlins, kames, eskers, kettles, lake plains, outwash plains, and till plains.

Moraines: The type of moraines that can be found in Indiana include ground moraine and end moraines. The term ground moraine is often used interchangeably with till plain. Ground moraines can be composed of both the material contained within the glacier as well as the material being moved along at its base.

Debris accumulates around the margins of glacial ice because melting is most intense along the edges. As a result, this melting of the glacier and continued conveyance of the debris toward the margin, considerable volumes of sediments build up to form terminal moraines. These long, relatively high ridges of till mark the farthest advance of the ice sheet. Recessional moraines form at locations where the glacier "pauses" temporarily, during its final retreat, (where it was melting at about the same rate of advance). The term end moraine is more general and includes both terminal and recessional moraines.

Drumlins: Drumlins are cigar-shaped hills, typically composed of till, that were streamlined by another advance of glacial ice over a rolling till plain. Moraines are transported debris, whereas drumlins are deformed substrate (material that was already there).

Kames: A common feature superimposed on ground moraines is the small, conical-shaped hills known as kames. Kames are formed when a cavity within or on stagnant ice, fills with soil and rock debris. When the glacier melts, this collection of material is left behind as a mound or irregularly shaped hill of crudely stratified sand and gravel. They may appear as clusters or in isolated mounds and contain a wide range of sand and gravel size materials. Kames often occur in groups with kettles resulting in a hummocky topography with variable soil and water conditions.

Kettles: Kettles also known as kettle lakes are pits or depressions in the glacial drift. They can occur in outwash plains or in ground moraines as well as end moraines. Formed by the delayed melting of ice blocks in the drift, these depressions typically range from 30 ft to more than a mile in diameter and may be from 3 to 100 feet deep. Kettle lakes often have a predictable sequence of deposits on a base of hard "loaded ice" ground moraine till: First, a layer of "normally loaded" lake bottom till, usually medium stiff; then often a thin layer of sand; then soft lacustrine clay; then marl, usually very soft; then peat, usually very soft, at the top. Such deposits are commonly found under peat deposits in northern and central Indiana.

Eskers: Eskers are sinuous ridges of stratified sand and gravel formed by meltwater streams at the base of stagnant ice near the margin of the glacier. As the melting glacial ice sheets thin and hydrostatic pressure decreases, water velocity in glacial tunnels is no longer sufficient to transport all of the sediment supplied to the stream. Coarser sand and gravel are deposited with crude bedding, and finer materials are carried beyond the front of the glacier and deposited in lower energy lakes or streams. The subsequent melting of the ice sheet exposed these irregularly stratified and sorted sand and gravel deposits. Due to their coarse-grained nature and length, eskers may provide an excellent source of granular materials. They are steep sided, from 10 to 50 ft high, and may extend for 0.5 to 6 miles in length.

Outwash Plains: The terms, "outwash" and "till" have been used in the literature to describe both topographic landforms and soil types. However, they both possess unique and easily identifiable soil types, and as such, it has been useful to apply them as an adjective to the basic soil type description. To avoid confusion, the term "plain" will be added to the description when a topographic landform is being described in this manual, such as outwash plain or till plain.

Meltwater streams carried sediment out from the toe of the glacial front in large alluvial fans called outwash plains. Large systems of braided streams often carried material in thin sinuous ribbons for distances of many miles from the ice front. The resulting, sorted, granular deposits are mixed sands and gravel with crude bedding and many scour-and-fill structures. Many large areas of northern Indiana are outwash plains, such as the Kankakee outwash plain and the areas around the St. Joseph River and other rivers. Because of their great aerial extent, outwash plains can be sources of abundant water. The high permeability of outwash materials makes them excellent ground water sources.

Glaciolacustrine: Sediments derived from glacial ice, deposited in freshwater lakes, are known as glaciolacustrine deposits. As the glacial ice melts, meltwater runoff is dammed behind morainal deposits and other glacial features creating extensive lakes. During the Pleistocene, such glacial lakes were generally short lived, however, they had a lasting effect on the land surface.

Lake sediment deposits are also common in tributary valleys of the Ohio River, Wabash River and White River in Indiana, south of the Wisconsin and Illinoian glacial boundaries. These tributary valley-lakes are filled with silt and soft clays, due to, outwash sand and gravel filling the main river valleys, causing water levels to rise in the tributary valleys forming lakes.

Lake sediments are characteristically well-bedded silts and clays with occasional fine pebble to boulder size erratics (dropstones) interspersed. These sediments are commonly varved, consisting of pairs of light/dark layers corresponding to summer/winter annual cycles.

Lacustrine deposits tend to have a low shear strength that may cause issues with deep excavations. Some deposits are also frequently saturated and because of their low permeabilities and complicated stratigraphies, they cannot be dewatered prior to excavation. Lacustrine deposits throughout the state can have varying plasticity and natural moisture contents depending on their clay content. Lacustrine deposits can be found throughout the state. One example, the Calumet Lacustrine Plain, a major lacustrine deposit in Indiana, is located along the south edge of Lake Michigan.

Valley train deposits: Valley train deposits are located beyond the glacial margin in the valley of the stream which flowed from the edge of the glacier. The deposit was made during the presence of the glacier by the stream which was then overladen with sediment. A valley train deposit is usually composed of sand and gravel.

Wind deposits: Wind-driven waves created beach ridges or strand lines at the edges of many of the glacial lakes. These old beaches remain visible in many places in the north portion of the state and mark former shorelines. Often elevated above the present topography of lake sediments, lake beaches are visible as linear ridges, 3 to 10 meters in height, 100 meters or more in width, and extending up to tens of miles. These beach deposits consist primarily of sand and/or gravel, with characteristic cross bedding. Some of the more prominent lake beaches (shorelines) are shown on the **Quaternary Geologic Map of Indiana**.

2.2.1.2 GLACIAL EROSIONAL FEATURES

Bedrock outcrops that have survived the abrasive forces of glaciers display distinctive scars. Striations occur as parallel linear scratches on the bedrock, caused by movement over the bedrock surface of individual rock fragments embedded in the base of the ice. Quarrying, or plucking, is glacial erosion on a much larger scale. Bedrock weakened by fractures is pulled away by the overriding ice and removed by the glacier. This process occurs most frequently on the lee side of the bedrock feature.

Tunnel valleys are trenches cut into drift deposits or bedrock by large quantities of flowing subglacial meltwater. They may be many meters deep, over a kilometer in width, and extend for many miles. Typically, they are developed in pre-existing glacial drifts. Tunnel valleys could also be discussed under topographic depositional features, because many erosional valleys are subsequently filled by younger drift sediments. Occasionally, when the quantity of meltwater lessens and the subglacial tunnel chokes with sediments, eskers will develop within the course of the tunnel valley.

2.3 BEDROCK GEOLOGY

The bedrock in Indiana is sedimentary rock. There is no known igneous or metamorphic bedrock encountered in Indiana without first going through at least a half-mile thick sequence of sedimentary bedrock before encountering the Precambrian “basement” igneous rocks. This sedimentary bedrock is from the Paleozoic Era. There are no Mesozoic or Cenozoic bedrock deposits found in Indiana.

Much of the bedrock in the northern two-thirds of the state is covered by thick “unlithified” deposits (up to 400 feet) of glacial drift, but the southern one-third of the state has relatively thinner soil deposits. The southeast part of the state generally has thin, older glacial and residual soils on shale and fossiliferous limestone bedrock of the Ordovician, Silurian, and Devonian systems. The south-central, unglaciated part of the state has generally thin residual clay soil on bedrock of Mississippian siltstone and limestone, and Pennsylvanian shale, sandstone, and limestone. The bedrock in the southwest part of the state is mostly shale, sandstone, limestone and coal of the Pennsylvanian System, which is covered in most areas by glacial soils and residual soils, with some large lakebed clay deposits, and in the southwest part of the state some areas have a surface layer of silty wind-blown loess. The “Bedrock Geology” data layer on the IndianaMap website may be used to view the bedrock geology of Indiana.

2.4 STRUCTURAL GEOLOGY

Structural geology describes the tectonic influence on the rock, such as folding, tilting, cracking, bending, and faulting of the strata. The general attitude of the strike and dip of bedrock strata in Indiana is governed by the following three major regional structural elements: the Illinois Basin, the Cincinnati Arch, and the Michigan Basin.

2.4.1 FAULTS

Displacement along faults occurred millions of years ago. Therefore, the faults in Indiana do not show ground surface differential displacement. A few places show some surface expression where distinctive soil types form due to different weathering characteristics of the individual bedrock types outcropping along a fault, such as along the Mount Carmel Fault in northern Lawrence County, where limestone weathers to residual red clay on one side of the fault and shaley siltstone weathers to yellow silty clay on the other side of the fault.

All of the faults in Indiana are “Normal” type faults, with vertical displacement, rather than “strike-slip” type faults with horizontal displacement. Many of them have anticline, convex upward, structures associated with them usually on the “down-thrown” side. Exposures are scarce or non-existent and most of these faults are known only from drill-hole correlation. The “Bedrock Structural Features” data layer on the IndianaMap website may be used to view the locations of the faults throughout Indiana.

2.4.2 JOINTS AND BEDDING PLANES

Fractures noted in the bedrock wherever it is exposed are classified as joints if no movement of the separated blocks has occurred across the fracture. Joints and bedding planes are the most obvious bedrock structural elements seen in samples and outcrop exposures.

Bedding planes are sedimentary depositional features that are the horizontal planes of separation of the bedrock strata. They are often plains of weakness along which the rock is most easily broken and are especially obvious in core samples of shale. Since rock layers in most of Indiana are nearly horizontal, there is a strong tendency for the rock to fracture at right angles to the bedding surfaces, producing joints that are approximately vertical. Most of the joints in Indiana's rocks are vertical, although other angles are observed. Usually, there are two sets of joints that intersect at nearly right angles, thereby breaking the rock into rectangular blocks.

Joints are usually medium to high-angle fracture planes (cracks) in the bedrock that are commonly seen as angular surfaces in rock cut back slopes along roadways, and as high-angle separations in rock core samples. They are the resultant stress fractures from bending of the rock strata. Joints can be so closely spaced that they severely lower the strength of the rock mass and limit its capabilities with regards to foundations and cut slopes. They also become the main pathways for groundwater flow through bedrock. These pathways often appear as brown weathered zones in otherwise unweathered rock. These zones of accelerated weathering can grow to become large cavities, especially in limestone.

2.4.3 DEPOSITIONAL BASINS

The Illinois Basin and the Michigan Basin are structural low areas, towards which the sedimentary bedrock strata are dipping. In Indiana, the Cincinnati Arch is the relative structural high area that is left after the subsidence that occurred which formed the Illinois Basin and the Michigan Basin. Bedrock strata are generally level along the axial plane of the Cincinnati Arch which runs from southeastern to northwestern Indiana. Bedding planes of the rock strata then dips generally at an increasingly steeper rate as the Illinoian Basin is approached in the southwest direction, towards south-central Illinois, and as the Michigan Basin is approached towards the northeast direction, towards central Michigan. Locally there are broad, open syncline (concave upward), anticline (convex upward), and monocline (step-like) structures superimposed on the regional structure that have more effect on the local dip of strata.

2.5 EARTHQUAKES

Earthquake activity in Indiana, and that of the whole region, is related to the present compressional activity owing to the westward compressional movement of the North American plate. The Wabash Valley Seismic Zone is a tectonic region covering southeastern Illinois, southwestern Indiana, and parts of western Kentucky. South of the Wabash Valley Seismic Zone is the New Madrid Seismic Zone.

Based upon occurrence of epicenters within Indiana, Evansville and Petersburg are the most seismically active cities in Indiana. However, seismic risk in Indiana is related much more to earthquakes outside of Indiana. One potential earthquake concern is the liquefaction of loose, saturated fine sands and silts in areas with alluvial sediments.

2.6 LANDSLIDES

This section reviews landslide hazards in relation to Indiana's highway network. Landslides are defined as downward and outward movement of slope-forming materials composed of rocks, soils, or a combination of these materials. Landslides are under the influence of geologic, topographic, and climatic factors. Landslides in Indiana are considered to be a function of both topography and bedrock geology. Landslides can occur anywhere in Indiana, however, there are two primary landslide clusters in south-central Indiana and southeastern Indiana. There are also a limited number of landslides in southwest Indiana due to cut slope failures. A landslide data layer is not available on the IndianaMap website, however, INDOT has collected and mapped landslide data relative to Indiana's highway network.

Shales and thinly bedded bedrock with alternating rock types are prone to slope failures. Landslide prone rock groups include the Kope, Buffalo Wallow, Stephensport, Sanders, West Baden, Dillsboro, Blue River, Patoka, Shelburn, and Raccoon Creek.

2.6.1 COLLUVIUM

Unsorted, rock fragments and soil materials deposited by gravity or mass wasting are called colluvium. Landslides, mud slides, and talus are all colluvial deposits. These heterogeneous deposits are generally identifiable in the field and typically lie in a slump at the base of a hill or rock outcrop. The presence of such material usually indicates an unstable area subject to debris flow, slides, slumps, or down-slope creep. Highly variable soil conditions should be expected. Variable subsurface conditions or possible boulders may give misleading information as to soil type conditions or possible boulders may give misleading information as to soil type and depth to bedrock.

2.7 KARST

Carbonate rock, which is chiefly limestone, can yield freely to the solvent action of water when the water is charged with carbon dioxide (CO_2), such as from rainfall or organic soils. This weakly acidic (carbonic acid) water reacts with the limestone and slowly dissolves; widening fissures and joints, and weakening the rock. As these joints and fissures grow to cavity size the roof can become unstable and collapse, in near surface areas this results in sinkholes.

The process by which sinkholes form in nature can be aggravated by urban development. Dewatering and alteration of drainage can lower the water table which in turns removes the supporting pressure, reducing the soil's effective stress, needed to hold up the overlying soil and land surface.

The Mitchell Plain, Crawford Upland, Muscatatuck Plateau and Dearborn Upland topographic regions (See Fig. 2.1) are the dominant regions for the surficial expression of karst features in Indiana. Throughout the Mitchell Plain carbonate rocks such as the predominant limestone and dolomite have developed into an extensive system of solution cavities which is expressed topographically as sinkholes, sinking streams and caves. There are areas of buried karst in the Bluffton Till Plain, Newcastle Till Plain and the Tipton Till Plain. Various karst data layers, such as “Karst Sinkhole Areas”, “Karst Springs” and “Karst Cave Density”, are available on the IndianaMap website.

2.8 COAL MINE SUBSIDENCE

Nearly a fifth of the state is underlain at one or more depths by coal-bearing rocks, all of which are Pennsylvanian age. Coal is formed from the compressed and otherwise altered remains of plants that grew in vast swamps during the Pennsylvanian. Deposition beneath the water and later burial with other sediments prevents the decay of organic material and preserves the carbon content.

The Carbondale Group of the Pennsylvanian is a unit commonly mined for coal in Indiana. The most extensive underground mining occurred in Vermillion, Vigo, Sullivan, and Knox Counties. Some mining has also been done in Parke, Clay, Greene, Daviess, Pike, Gibson, Warrick, and Vanderburg Counties.

Indiana coal has been mine through surface mines and underground mines. Areas that have been mined for coal can be seen using the “Coal Mine Surface” and “Coal Mine Underground” data layers on the IndianaMap website.

Subsidence into underground mines results in the formation of sinkholes, sags, and troughs on the land surface. These features often result in the formation of ponds or swamps. The areas where subsidence is of greatest concern are the areas where coal was mined extensively underground. The problem is most severe where mining was done within 150 feet of the surface, circulating groundwater has weakened the roof layers, where the thickness of surficial deposits is greater, and was mined in a time when the system of mining was haphazard.

2.9 HYDROLOGY

Hydrology is the study of the movement, distribution and management of water, including the water cycle, water resources and environmental watershed sustainability. Various hydrology data layers are available on the IndianaMap website and may be used to view the different aspects of Indiana’s water resources.

2.9.1 ENGINEERING HYDROGEOLOGY

Engineering hydrogeology is the study of groundwater and surface water with emphasis given to the application of the laws of occurrence and movement. It studies the fundamentals of groundwater flow using the principles of dispersion and diffusion in porous soils and rocks.

2.9.2 WATERSHED HYDROLOGY (SURFACE WATER)

A watershed is a drainage basin. All surface waters in Indiana flow either toward the Great Lakes in the north, the Mississippi River to the west, or the Ohio River to the south. Within each of these larger basins, there are smaller tributary rivers and streams that are fed by their own catchments.

The amount of streamflow, or discharge by Indiana's streams is a relatively high amount due to the humid climate. High discharges usually occur in the late winter and spring, and inundated floodplains are likely to occur then. Floods can also occur in the summer and fall, but usually this is the time for minimum flows. The rivers and streams of Indiana also carry large volumes of sediment.

2.9.3 GROUNDWATER OCCURRENCE

2.9.3.1 OCCURRENCE IN NON-INDURATED SEDIMENTS

This refers to the unlithified deposits of alluvium, tills, ice-contact deposits, loess, dune sand, marine sands and clays, colluvial deposits, and lacustrine clays and sands. It also includes residual soils, which have hydrogeologic characteristics in common with colluvium and alluvium. In these soils, permeability coefficients tend to be quite high and close approximations of permeability can be made if the origin of the sediment is known.

2.9.3.2 OCCURRENCE IN SEDIMENTARY ROCK

Sedimentary Rock: Sedimentary rocks in Indiana are predominantly shales, siltstones, sandstones, limestones, and coal. These rock types are bedded in a wide range of thicknesses that often vary greatly within a single unit. In addition to variable bed thicknesses these rock types often grade into other facies. Facies changes within a rock body can create stratigraphic controls on porosity and permeability, the rock's hydrologic properties. Also affecting groundwater movement are the joints and fractures contained within and between strata, they can provide conduits for rapid fluid flow and have the potential for large storage capacities.

Because of the number of variables influencing permeability, including but not limited to, cementation, grain size, compaction, fracturing, and joint placement, it is almost impossible to predict the permeability rate based on porosity alone. In more dense rock (i.e., limestone) fractures and void openings are the main determinants in groundwater quantities and movement.

2.9.3.3 GROUNDWATER SURVEY

Generally, elevations of the water table are determined in boreholes or wells. The depths at which water is apparent is measured three times: during drilling; when the boring is complete, and 24 hours after completion; occasionally additional measurements may be taken. Other subsurface conditions such as artesian flow, a perched water table, or sand-heave conditions should be noted on the boring logs since these can be considered unfavorable to the stability of engineered structures, slopes or subgrades.

Artesian flow: Water flows under natural pressure without pumping to the surface.

Perched water table: Accumulation of groundwater that is above the water table in the unsaturated zone. The groundwater is usually trapped above an impermeable soil layer, such as a clay, and forms a lens of saturated material in the unsaturated zone.

Sand heave: Condition in sand deposits when the water on the outside of the augers becomes greater than the volume of the water on the inside of the auger, the pressure will equalize allowing sand to flow into the auger.

During the initial field survey, any springs in the project area should be noted since this indicates a location where the groundwater table intersects the ground surface, and unusual conditions such as swamps, bogs, gravel pits or lakes which could affect the groundwater should be noted also.

2.10 SOIL PROFILE AND HORIZONS

The soil profile is the result of weathering of the original parent material, which may be unconsolidated materials deposited by glacial, wind, or fluvial processes, or bedrock. The soil profile is divided into **horizons** based on the degree of chemical and physical weathering of the parent material. At any one location, these horizons would always occur, from the surface downward, in the order described below; however, not all of these horizons may be present at any one location.

2.10.1 "O" HORIZON

The "O" horizon is not really a "soil" at all, but merely undecomposed organic debris and black humus (a relatively stable residuum of decomposed organic matter). Naturally, this unit is present only in well-vegetated areas.

2.10.2 "A" HORIZON

The "A" horizon, the uppermost portion of the soil profile, is a mixture of mineral material and partially degraded organic debris. Soils in this horizon crumble easily due to their lack of consolidation. Usually, water percolating through this horizon winnows out the finer silts and clays leaving a sandier lighter textured material. Dark colors are common, due to a high organic content. The mineral assemblage is quite variable.

These materials are generally undesirable for engineering purposes, due to their high degree of compressibility, variability, and high organic content. An increased organic content often makes both the "O" and "A" horizon soils suitable for use as topsoil.

2.10.3 "B" HORIZON

The "B" horizon is often referred to as the zone of accumulation. Here, materials weathered out of the "A" horizon – such as clay, iron and aluminum minerals – are deposited. This results in a fairly uniform, lighter colored, denser soil which may have a blocky structure and may be more brownish or reddish in color than its overlying counterpart.

2.10.4 "C" HORIZON

The "C" horizon represents the parent material of the soil profile – either glacial drift or weathered parent rock (saprolite). "C" horizon materials are generally lighter in color than both the "A" and "B" horizons and remain in essentially the same form as when originally deposited. This material retains its original structure but is leached of more mobile elements, such as calcium or magnesium. Where "A" and "B" soil horizons are thin, the "C" horizon may be encountered during exploration or construction.

2.10.5 "D" HORIZON

The "D" horizon may also be referred to as the "R" horizon. It indicates lithified unweathered bedrock which is not the parent material for the soil, but which may influence the overlying soils by controlling drainage or surface morphology. For the purpose of a geotechnical survey, the "D" horizon is of interest when there are outcrops or when borings indicate that bedrock will be encountered within the roadway section.

2.11 GEOLOGY OF NORTHERN INDIANA

2.11.1 PHYSIOGRAPHIC UNITS

The northern region of Indiana's geology includes the following physiographic units:

- Lake Michigan Border
- Valparaiso Morainal Complex
- Kankakee Drainageways
- Plymouth Morainal Complex
- Warsaw Morainal and Drainageways
- Auburn Morainal Complex
- Maumee Lake Plain

2.11.2 SURFICIAL DEPOSITS AND TOPOGRAPHY

2.11.2.1 GLACIAL FEATURES

The geology of northern Indiana was highly affected by past glaciations and contains many glacial deposits. Refer to section 2.2 for further information regarding Indiana's glacial geology.

2.11.2.2 HOLOCENE FEATURES

Non-glacial sediments began to accumulate as soon as the glaciers had melted from a given area of Indiana. These sediments are of the Holocene Epoch. Holocene sediments include:

2.11.2.2.1 LACUSTRINE

Lacustrine sediments are fine-grained sediments which are deposited in freshwater lakes. These lakes may or may not still be in existence. Wave action in lakes carries the finer grained silt and clay sized particles in suspension towards deeper water. As the water calms, these particles settle out and accumulate in the lakebed to form what is known as lacustrine soil. As mentioned in 2.2.1.1, many lacustrine sediments were formed in glacial lakes. Old lake plains are frequently evidenced by a very flat topography. Remnants of lacustrine terraces are common in southern Indiana valleys that were tributaries to larger rivers that carried outwash sediment.

2.11.2.2.2 PEAT AND MUCK

Peat is formed when organic material is deposited in a predominantly cool and oxygen- deficient environment. These conditions lead to preservation of the plant matter, with leaf and stem materials often remaining identifiable. Peat bogs are dominated by sphagnum moss with stands of black spruce and tamarack and contain highly acidic waters. Fens are dominated by grasses, sedges, and reeds, with waters rich in minerals and less acidic than that of bog waters. These organic sediments typically form as vegetation encroaches into and then totally fills shallow lakes.

Peat is found commonly in the northern lake moraine physiographic regions in the Northern one-third of the state and occasionally in the central one-third of the state. Organic soils contain well-decomposed organic matter with or without some plant fibers of different decomposed states, e.g., "organic soil" has 15% to 30% organic matter. Peat is considered to be greater than 30% organic matter.

Peat (more than 30% organic content) can be further subdivided as follows:

- **Spongy Peat** is a well-decomposed organic soil that has been subjected to certain consolidation conditions that cause it to appear and feel spongy. It varies in its mineral soil content, and there is little or no fiber content visible.

- **Well-Decomposed Peat** is an organic soil whose organic content has been subjected to a thorough decay process in which most fibers are invisible to the naked eye and which vary in its mineral content.

- **Partially Decomposed Peat** is a short-fibered organic soil that may be fairly well decomposed and may contain mineral soil. Most of the fibers are generally less than three mm in length.

- **Semi-fibrous Peat** is an organic soil whose plant fibers range from approximately one-eighth to one inch in length and are partially decomposed. These fibers may be mixed with some fairly well-decomposed organic matter and have varied mineral soil content.

- **Fibrous Peat** is an organic soil in which plant fibers are mostly one inch or more in length and are partially decomposed. These fibers may be mixed with some fairly well-decomposed organic matter and a small amount of mineral soil. The term "woody" is sometimes used for very coarse organic deposits.

2.11.2.2.3 MARL

Carbonate-rich, light gray to almost white layers of silts and clays formed by the precipitation of calcite in the bottom of lakes or swampy areas are known as marls. The carbonate generally found in marl comes from two sources, high calcium-carbonate groundwater and carbonate – fixing aquatic organisms such as diatoms (one-celled alga) and snails. Identification can be easily made if there are still shells or fragments of shells observed in the samples, otherwise, because of the high carbonate content of the material, the use of dilute hydrochloric acid may be required to test it. This easy field test of a few acid drops will cause marl soils to effervesce when applied and help differentiate it from the fine gray sands which can also be found in swamp bottoms.

2.11.2.2.4 DUNE SANDS

Sand dunes, along with dune formations, both ancient and modern, can be found throughout Indiana. Most are easily recognized by the clean, well sorted, frosted, fine grain-sized particles and crossbedding of the layers. These particularly fine, well-sorted, sands are easily recognizable from the highly variable, mixture of sands deposited by water.

2.11.3 BEDROCK

Generally, bedrock will not be encountered in a geotechnical investigation due to the thick deposit of unlithified material. Bedrock as in much of the area is on the northeastern flank of the Kankakee and

Cincinnati Arches, with the strata inclined to the northeast toward the Michigan Basin. The rocks get younger in that direction, ranging in age from Silurian to middle Mississippian.

2.11.3.1 FAULTS

The Royal Center Fault is about 35 miles long and has about 100 feet of vertical displacement. It runs from northeastern White County in a northeasterly direction and crosses part of Cass County and runs diagonally through Fulton County. It is covered by thick deposits of glacial drift. No exposures are known.

2.11.4 SPECIAL FEATURES

2.11.4.1 KENTLAND DISTURBANCE AREA

Kentland is a small town in northwestern Indiana in the southwestern part of Newton County. Kentland, an area once covered by the Wisconsin ice sheet, the topography is the same flat till plain characteristic of the region. Bedrock plays no role in controlling the topography.

The normal bedrock sequence in the area around Kentland extends from the Precambrian basement upward through middle Mississippian shale, limestone, and siltstone. In places some Pennsylvanian sandstone is preserved in old river channels that were eroded into the underlying Mississippian bedrock. As an important point of reference, the normal depth to the Ordovician St. Peter Sandstone is about 1,500 feet in Newton County.

However, between the towns of Goodland on the east and Kentland on the west, a distance of only about 6 miles, the normal pattern of northern Indiana geology is altered. The Ordovician rocks such as the St. Peter Sandstone have been brought to the surface from their normal position more than 1,000 feet below. More significantly, they are tilted, folded, faulted, and even brecciated in a highly complex fashion. The Kentland disturbance is the only known area of extensive deformation of rocks in Indiana. The disturbance is thought to be an impact by an extraterrestrial body, likely either a meteorite or a comet. This feature is noticeable when using the “Bedrock Geology” data layer on the IndianaMap website.

2.12 GEOLOGY OF CENTRAL INDIANA

2.12.1 PHYSIOGRAPHIC UNITS

The central region of Indiana’s geology includes the following physiographic units:

- Iroquois Till Plain
- Tipton Till Plain
- Bluffton Till Plain
- New Castle Till Plains and Drainageways
- Central Wabash Valley

2.12.2 SURFICIAL DEPOSITS AND TOPOGRAPHY

2.12.2.1 GLACIAL FEATURES

The surficial deposits of central Indiana were highly affected by glaciations and contain many glacial deposits. Refer to section 2.2 for further information regarding Indiana's glacial geology.

2.12.2.2 PEAT AND MUCK

Swamp and lake deposits are common in poorly drained parts of the landscape. Peat deposits can occasionally be found in central Indiana. More information on peat may be found in section 2.11.1.2.2.

2.12.2.3 OTHER SURFICAL DEPOSITS

Stream deposits occur along the Wabash River and its tributaries. These alluvial deposits can be quite thick. Some wind-blown sand occurs in places along the east side of the Wabash River, and patchy thin loess occurs on parts of the Wisconsin glacial deposits.

2.12.3 BEDROCK

The distribution of bedrock beneath the glacial deposits in central Indiana is still controlled by the trend of the Cincinnati and Kankakee Arches. The age of rocks along the crest of the arches ranges from Ordovician to Devonian, depending upon structural position. The Devonian rocks occur where the arch is bowed downward along its trend. Southwest of the crest of the arch the age decreases toward the Illinois Basin, following the same sequence as in southern Indiana.

2.12.3.1 FAULTS

The Fortville Fault is about 50 miles long and has a vertical displacement up to 60 feet. It runs from southeastern Marion County in a northeasterly direction across corners of Hancock County and Hamilton County and diagonally through Madison County and slightly into Grant County. It is covered by thick glacial drift deposits for most of its length. Some exposures may become apparent in future limestone and dolomite quarries for crushed stone aggregate mining in Madison County.

2.12.4 SPECIAL FEATURES

2.12.4.1 TEAYS RIVER VALLEY

An important feature from prehistoric times is the preglacial Teays River which flowed through north central Indiana and was the major source of Indiana's deep deposits of alluvial sediments, which includes extensive boulder and cobble beds, in the now buried Teays Valley. The deep valley extends out of Ohio at a point in southern Adams Counties, where it continues west into Miami and Cass County. At that juncture, the ancient valley tracks almost due west along the Warren and Benton County line and exits Indiana into Illinois. For several miles starting in Wabash County through Tippecanoe County, the valley roughly parallels the present Wabash River.

2.12.4.2 COAL MINING AND MINE SUBSIDENCE

Underground coal mining has occurred in the Central Wabash Valley Region. Refer to Section 2.8 for more information regarding coal mining and mine subsidence.

2.13 GEOLOGY OF SOUTHWESTERN INDIANA

2.13.1 PHYSIOGRAPHIC UNITS

The southwestern region of Indiana's geology includes the following physiographic units:

- Wabash Lowland
- Boonville Hills

2.13.2 SURFICIAL DEPOSITS AND TOPOGRAPHY

2.13.2.1 GLACIAL FEATURES

The far southwestern point of Indiana has not been glaciated. The rest was not reached by the last major advance but was covered by ice during the two earlier advances. The thickness of these deposits increases northward, exceeding 100 feet in some areas near Terre Haute. In that area the landscape is often rather flat because the bedrock is effectively blanketed beneath the glacial deposits. In the rest of glaciated southwestern Indiana, the glacial deposits are thin, and the character of the underlying bedrock is the primary control on the topography.

2.13.2.2 LOESS

Loess deposits in the middle regions of the United States are a result of the thousands of years of the winds blowing the soils of the desolate, vegetation poor, wastelands caused by the retreat of the great Illinoian and Wisconsin Ice Ages. Massive sheets of ice scoured the hilly terrain and left extensive flat beach-like areas, with no plant life. Fast moving northwesterly winds had nothing to slow them, and the lighter soils (silts) were picked up by the winds and scattered all over the central United States, covering the landscapes with a mantle of silt in varying depths.

Most of the thicker deposits have been associated with the Illinoian Stage Glaciation and the subsequent erosion and deposition of the fine particles found between till layers. The Wisconsin Stages, deposited second, are a less thick deposit, but are also widely spread.

In Indiana, a thick mantle of loess deposits are evident throughout most of the state, but are far greater in the southwestern geographical quarter where there may be silt deposits as thick as 40 ft. in some locations. The counties of Vigo, Sullivan, Knox, Davis, Gibson, Pike, Posey and Vanderburg are where the deepest deposits of wind-blown silt occur. Indiana Geological Survey has an excellent map, Quaternary Geologic Map of Indiana, by Henry Gray, 1989, which illustrates where these deposits are located.

Loess, from an engineering standpoint, is a very interesting soil and can be a challenge for road construction. Loess material is able to stand in a vertical, or near vertical position, in cut sections with few stability problems for long periods, but is subject to rapid erosion when exposed to water or wind in the absence of a protective vegetation cover. Loess may also be subject to settlement problems and the bearing capacity may be affected, by the presence of percolating water. The resulting instability could result in a collapse of vertical soil walls if care is not taken.

2.13.2.3 RESIDUAL SOILS

In places where glacial deposits are thin or absent, or beneath the glacial deposits, is a surficial deposit called residuum, which is the weathered residue of whichever bedrock is present. The principal products of bedrock's in-place weathering are the clay minerals, such as kaolinite and chlorite and often contain remnant minerals of the pre-existing rock structure. Residual soils are present in the unglaciated part of southwestern Indiana, and in places beneath the glacial deposits where it was not eroded by the advancing ice.

2.13.3 BEDROCK

The bedrock of southwestern Indiana is of Pennsylvanian age. This includes a great variety of sedimentary rock, including limestone, sandstone, shale (including carbonaceous shale), conglomerate, coal, and clay. A major unconformity occurs between Mississippian and Pennsylvanian rocks.

2.13.3.1 JOINTS

Joints occur everywhere, but they may be more abundant in the southwestern region of Indiana as part of a greater tendency for fracturing rock in this area. Refer to section 2.4.2 for more information on joints.

2.13.3.2 FAULTS

Most of the known faults in Indiana are located in southwestern Indiana. The New Harmony Fault is about 30 miles long and has more than 400 feet of vertical displacement. It runs through parts of western Posey County and Gibson County in Indiana and into a part of Illinois, trending generally about 20 degrees east of north. It is a zone of overlapping parallel faults. There are many other parallel faults in Posey County and Gibson County which are known in much greater detail due to exploratory drill holes for oil, gas, and coal. These Posey and Gibson County faults are in an area of seismic activity associated with the New Madrid Seismic Region. Because of this, there is a higher degree of seismic risk in southwestern Indiana.

2.13.3.3 SPECIAL FEATURES

2.13.3.3.1 COAL MINING AND MINE SUBSIDENCE

Underground coal mining has occurred in the Wabash Lowlands and the Boonville Hills physiographic regions. Refer to Section 2.8 for more information regarding coal mining and mine subsidence.

2.14 GEOLOGY OF SOUTH-CENTRAL INDIANA

2.14.1 PHYSIOGRAPHIC UNITS

The south-central region of Indiana's geology includes the following physiographic units:

- Norman Upland
- Mitchell Plateau
- Crawford Upland

2.14.2 SURFICIAL DEPOSITS AND TOPOGRAPHY

2.14.2.1 DRIFTLESS AREA

The majority of Indiana experienced periodic overriding by coalescing glacial ice lobes. However, south-central Indiana has escaped modification by glacial ice. This region includes most of the Crawford Upland, the Mitchell Plain, and Norman Upland physiographic units, and much of the southern part of the Wabash Lowland physiographic unit.

While not extensively modified by ice, the driftless area has experienced enhanced topographic development as a result of glacial meltwaters and modern rivers and streams. Surface materials in this area consist predominantly of loess-covered residual soils on bedrock, as well as colluvium and bedrock outcrops.

2.14.2.2 RESIDUAL SOILS

Residual soils are the product of weathered and/ or decomposed shale, limestone and sandstone bedrock and are common in the southern one-fifth of Indiana, in the unglaciated physiographic areas. The principal products of bedrock's in-place weathering are the clay minerals, such as kaolinite and chlorite and often contain remnant minerals of the pre-existing rock structure.

Residual clays are known for their brightly colored hues of green, brown, blue-gray, purple, and red, such as in the well-known "Terra-Rosa" (red earth) clays weathered from the limestone bedrock in the Mitchell Plains and the Crawford Uplands Physiographic Regions near Bloomington and Bedford. The "Terra Rosa" clays are among the purest clays found in Indiana.

2.14.3 BEDROCK

From east to west the rocks of south-central Indiana range in age from early Devonian to Mississippian. This sequence of rocks includes more variety in rock types than characterizes the rocks of southeastern Indiana. The upper and lower parts are represented by a great deal of shale, siltstone, and sandstone, along with some limestone. The middle part is dominantly limestone and dolomite, but also include sequences of chert and gypsum.

2.14.3.1 FAULTS

The Mount Carmel Fault is about 50 miles long and has a vertical displacement of around 200 feet. It runs from northern Washington County, northward through Lawrence County and Monroe County and into southern Morgan County. One of the few places in Indiana where an actual fault surface, and displacement in a bedrock exposure, can be seen, is at an accessory or branch fault of the Mount Carmel Fault on S.R. 446 in Lawrence County at about 2.5 miles south of the Monroe-Lawrence county line. It's near the north end of a long bedrock cut section on the east side of S.R. 446. Shaley siltstone is on the north side of the fault and limestone is on the south side at this exposure.

Other smaller faults include Deer Creek Fault in southern Perry County and some possible faults in southern Spencer County and western Floyd County.

2.14.3.2 SPECIAL FEATURES

2.14.3.2.1 KARST

The Mitchell Plateau is a major cavern and karst region of Indiana. Karst development is in middle Mississippian limestone, mainly the St. Louis Limestone and Ste. Genevieve Limestone. Mitchell Plateau's drainage is mostly underground. Streams disappear into swallow holes. Usually, a sinking stream will have several swallow holes and use them in succession down valley as the stream's discharge increases. The former stream channel down valley from an active swallow hole is called a dry bed because it is only briefly occupied by water only during times of extremely heavy rainfall, and then only briefly, when there is more water than can be handled by the combined underground waters to the surface; it may produce karst springs or rises. All these features of interrupted surface drainage are especially well known from the Lost River area of the Mitchell Plateau between the towns of Mitchell and Paoli. In the Crawford Upland, surface drainage across sandstones and shales tend to be diverted underground when it reaches the underlying limestone. Such valleys are known as karst valleys.

2.14.3.2.2 LANDSLIDES

The Crawford Upland Region contains one of the primary landslide clusters. The Crawford Upland region is composed of the Raccoon Creek, Stephensport, West Baden, Buffalo Wallow, and Blue River bedrock groups. These bedrock groups are composed of alternating layers of shale, limestone, and or dolomite, with shale being a significant constituent.

2.15 GEOLOGY OF SOUTHEASTERN INDIANA

2.15.1 PHYSIOGRAPHIC UNITS

The southeastern region of Indiana's geology includes the following physiographic unit:

- Dearborn Upland
- Muscatatuck Plateau
- Scottsburg Lowland
- Charlestown Hills

2.15.2 SURFICIAL DEPOSITS AND TOPOGRAPHY

2.15.2.1 GLACIAL DEPOSITS

Southeastern Indiana has been glaciated, but not during the major ice advances. In much of the area the glacial deposits are thin, averaging 15 to 25 feet near the Ohio River, thickening northward to about 50 feet.

2.15.2.2 STREAM DEPOSITS

Stream deposits of various types can be found along the drainage of the Whitewater River and East Fork White River systems. However, except along major streams, these deposits are thin, typically less than 10 feet, and some segments of streams in this region flow primarily upon bedrock.

2.15.2.3 RESIDUAL SOILS

In places where glacial deposits are thin or absent, or beneath the glacial deposits, is a surficial deposit called residuum, which is the weathered residue of whatever bedrock is present. The principal products of bedrock's in-place weathering are the clay minerals, such as kaolinite and chlorite and often contain remnant minerals of the pre-existing rock structure.

2.15.3 BEDROCK

The crest of the Cincinnati Arch is near southeastern Indiana along a north-south trend. The Ordovician, Devonian, and Silurian rocks of southeastern Indiana include mostly limestones, dolomites, and shales. In part of the sequence there are a few sandstones. The oldest exposed rocks in southeastern Indiana are the Ordovician Maquoketa Group.

2.15.3.1 NEW ALBANY SHALE

The New Albany Shale is a unique shale that is considered for typical rock cuts in the Indiana Design Manual. Therefore, it is described in more detail here than other rock formations. The New Albany Shale is late middle Devonian and early Mississippian in age. The New Albany Shale outcrops or occurs below thin glacial deposits in a belt that extends from Clark County near the Ohio River through southwestern Marion County to the southern part of Newton County in northwestern Indiana. It also extends throughout the subsurface in southwestern Indiana. Equivalent rocks occur in northern Indiana on the north side of the Kankakee and Cincinnati Arches. The thickness of the unit varies from 100 to 130 feet in southeastern Indiana along the outcrop belt to over 330 feet in the southwestern corner of Indiana.

The shale is of two types. The dominant type is hard, black carbonaceous shale. The rest of the shale is softer and greenish gray. Although most of the shale is very thinly layered and splits easily along its layers (fissile), some parts lack well-developed layers and is considered massive. Almost all of the shale is composed of clay and silt grains of quartz and various clay minerals. The carbon is in the form of a solid called kerogen. It varies in abundance and is associated with carbonate minerals such as calcite and dolomite.

The dominant hard, black carbonaceous type of the New Albany Shale may allow for typical rock cut benching as defined by the Indiana Design Manual (Figure 107-6C and 107-6D). The typical soft/weathered rock cut benching as defined in the Indiana Design Manual (Figure 107-6E) should be used for the softer and greenish-gray shale type. The hard, black carbonaceous New Albany Shale is the only shale type in Indiana that can be considered for the typical rock cut bench (Figure 107-6C and 107-6D). All other shale rock cuts should utilize the typical soft/weathered rock cut benching.

In certain parts of the unit there are iron sulfides such as pyrite and marcasite. In roadway projects that expose units with pyrite minerals, acidic runoff may occur after rain events. Proper stormwater management devices may be needed to minimize the effects of the acidic runoff. For example, slopes or drainage ditches may require riprap opposed to seeding because the acidic runoff may not allow for proper plant growth.

2.15.4 SPECIAL FEATURES

2.15.4.1 LANDSLIDES

One of the main landslide clusters occur in the Dearborn Upland Region. Landslides within the Dearborn Upland Region occur primarily within the Kope and Dillsboro Formations, which are composed of mostly shale. The Kope Formation is predominately composed of clay shale about five percent fossiliferous limestone and the Dillsboro Formation is composed of about 30% argillaceous limestone and 70% shale. Landslides within the Kope Formation rarely penetrate the bedrock. Failure within this formation usually occurs along the soil-bedrock interface.

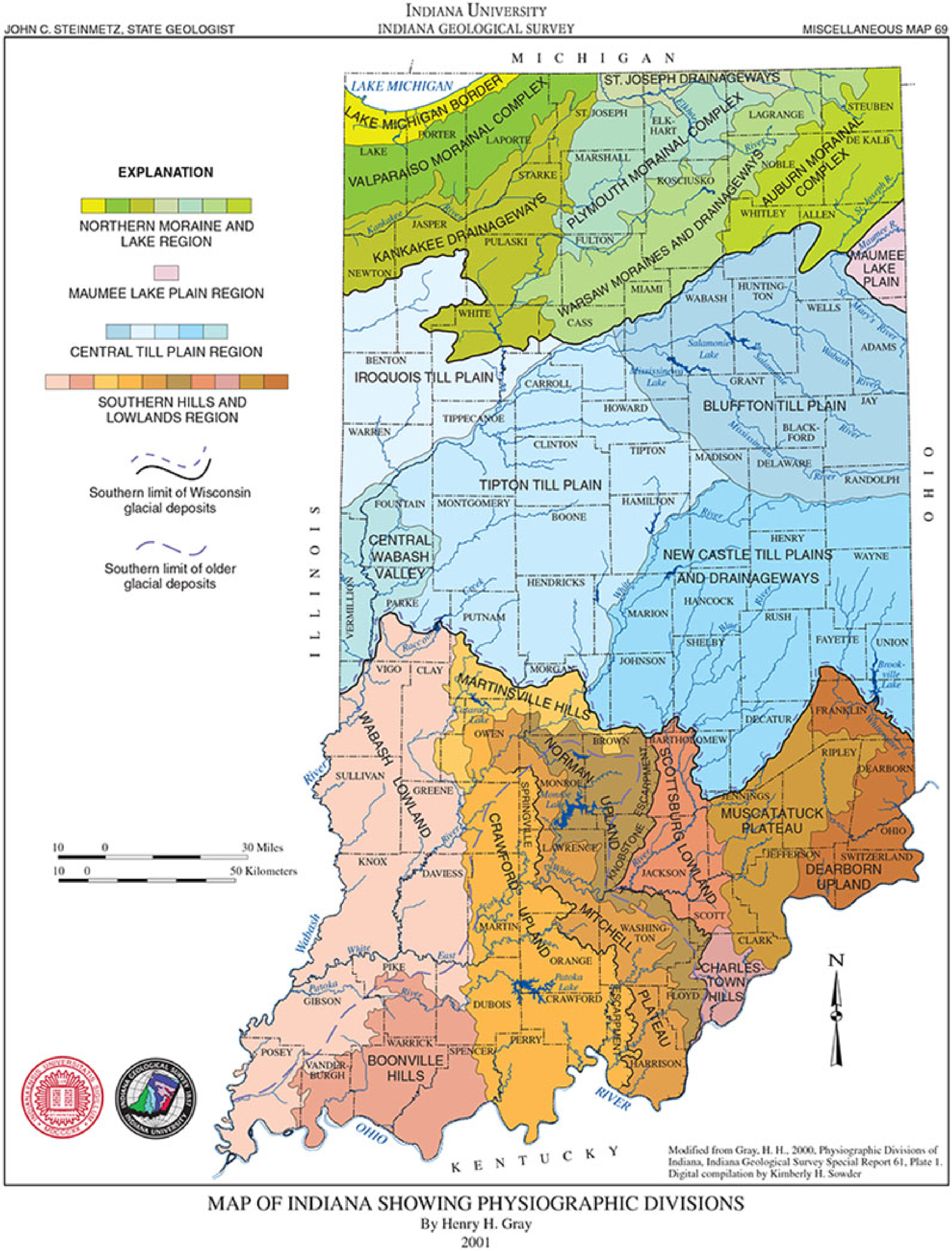

Fig. 2.1: Map of Indiana Showing Regional Physiographic Units Based on Present Topography

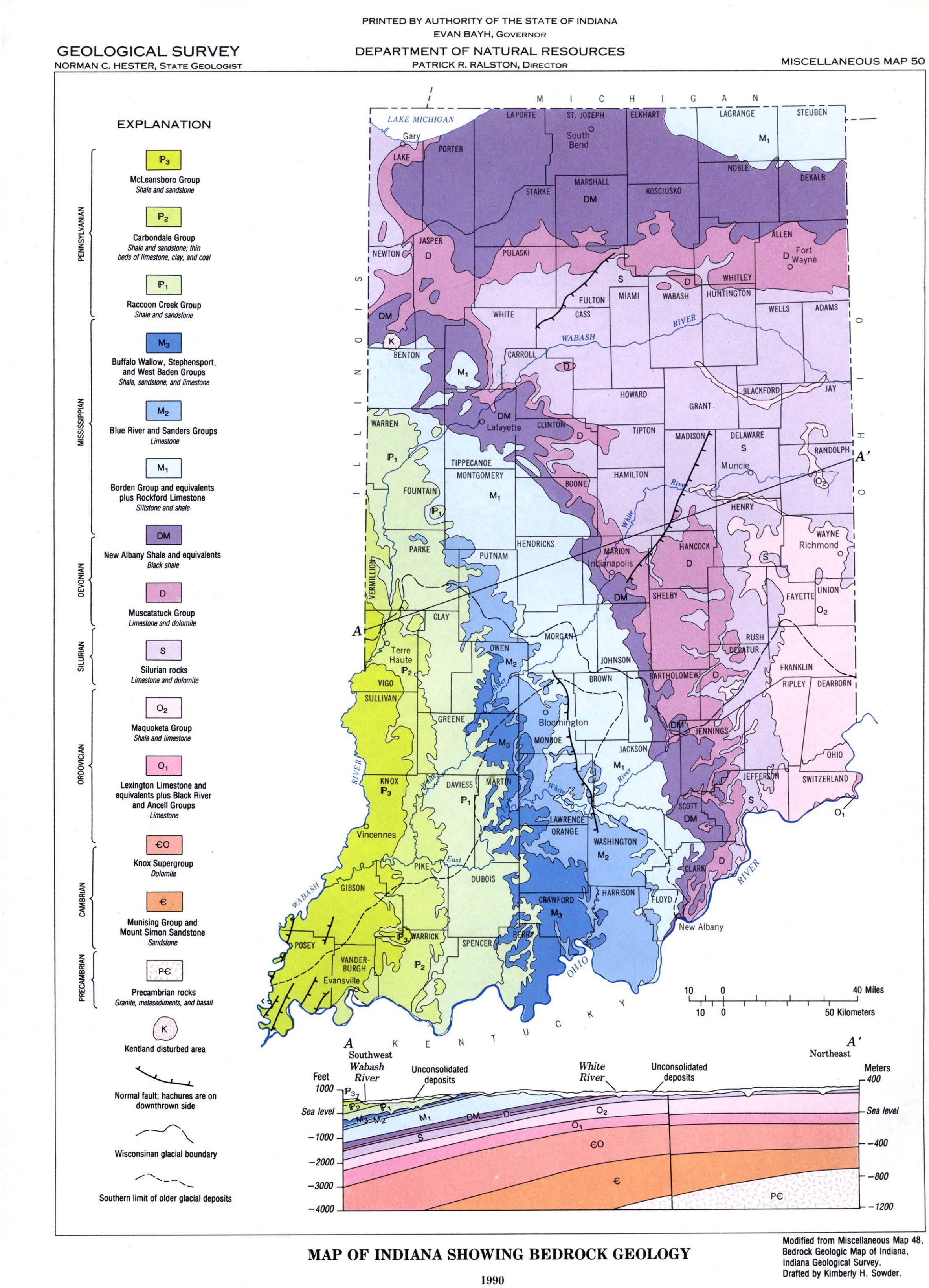

Fig. 2.2: Map of Indiana Showing Bedrock Units in Indiana

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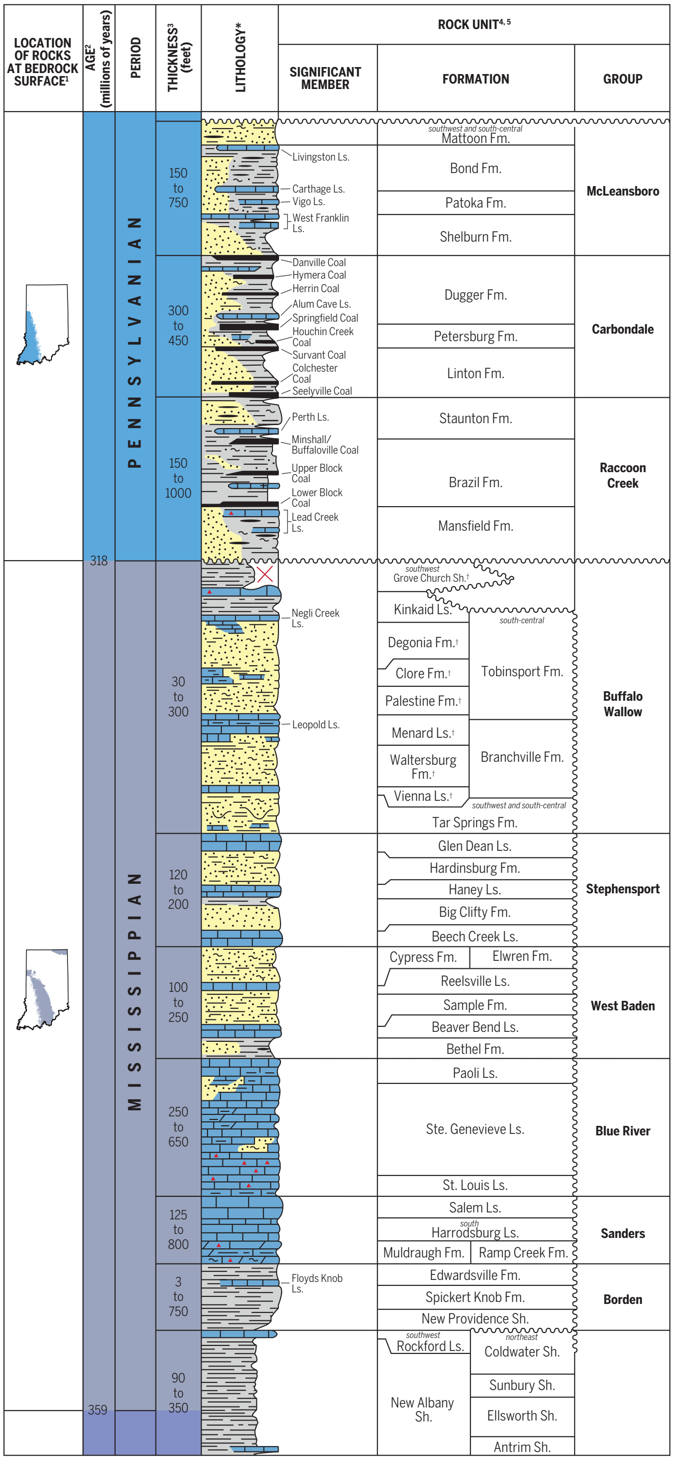
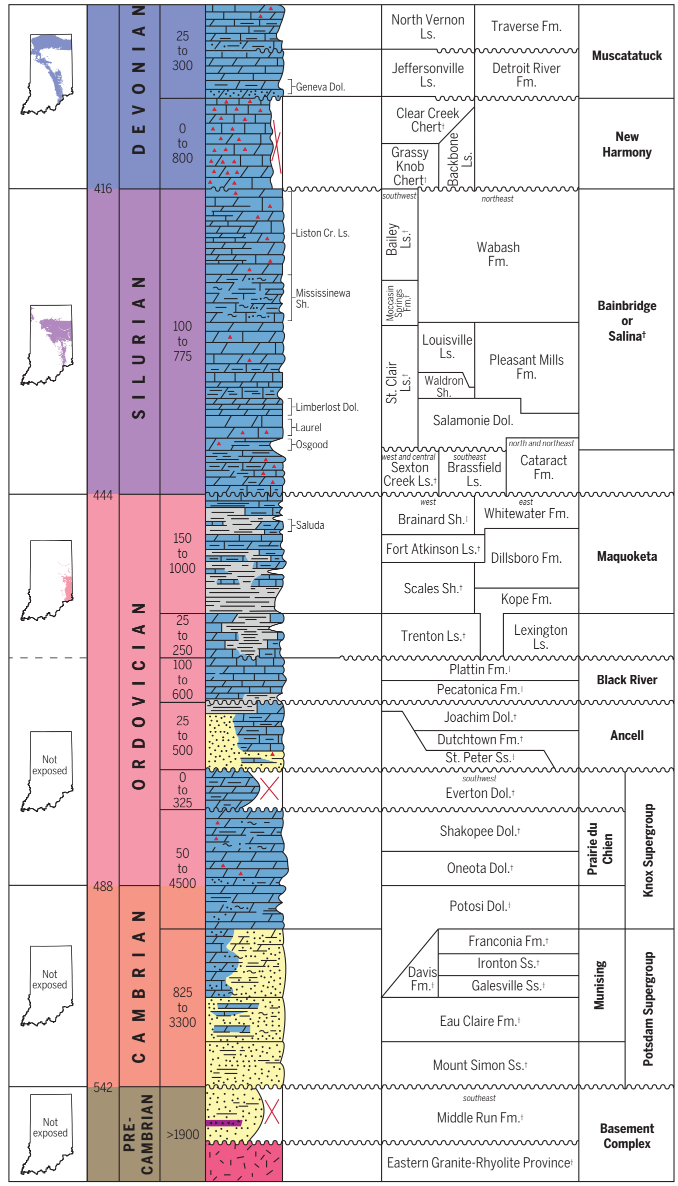
Generalized Stratigraphic Column of Indiana Bedrock

Todd A. Thompson, Indiana State Geologist

By Todd A. Thompson, Kimberly H. Sowder, and Matthew R. Johnson

Bloomington, Indiana: 2010, revised 2016





- sandstone, conglomerate
- shale, mudstone, siltstone
- limestone
- dolostone
- coal
- volcanic rocks
- igneous rocks
- rocks absent
- unconformity
- bioturbation
- chert

Note: Mixtures and interbedding of lithologies can occur.

Italics indicate geographic areas in Indiana where unit names are used.

*Simplified to illustrate common lithologies.

†These units normally occur only in the subsurface. However, some units of Ordovician and Lower Silurian age are exposed at the Kentland impact structure in northwestern Indiana.

Additional information about bedrock stratigraphic units of Indiana can be found at the Indiana Geological Survey Indiana Geologic Names Information System website at https://igs.indiana.edu/IGNIS/.

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