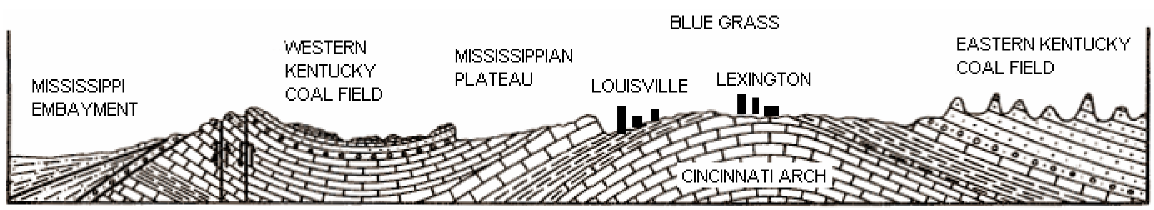
GEM Engineering, Inc.

GEOTECHNICAL ENVIRONMENTAL & MATERIALS SERVICES

Local & Regional Geology: Louisville, Kentucky

Understanding the local geology is a critical first step in the process of geotechnical engineering. Confirmation of the expected subsurface conditions with site specific sampling & testing allows past data to be applied to new projects & can reduce the cost & completion time of the geotechnical exploration. Discovery of inconsistencies often provides advance warning of site specific conditions that can impact design & construction. The local & regional geologic conditions in the Louisville area are complex & include: regional & local bedrock structure, glacial effects, Ohio River effects, karst topography, & problematic shale properties.

Bedrock in central Kentucky primarily consists of limestone & shale that formed roughly 300 to 400 million years ago as sediments on the floor of an ancient ocean. These sedimentary rocks initially were formed in horizontal layers. However, movement of the earth's crust forced the layers to warp upward forming the Cincinnati Arch. As a result, the oldest rock outcrops in the state are found along the crest of the arch which generally runs north to south through Lexington, Kentucky.

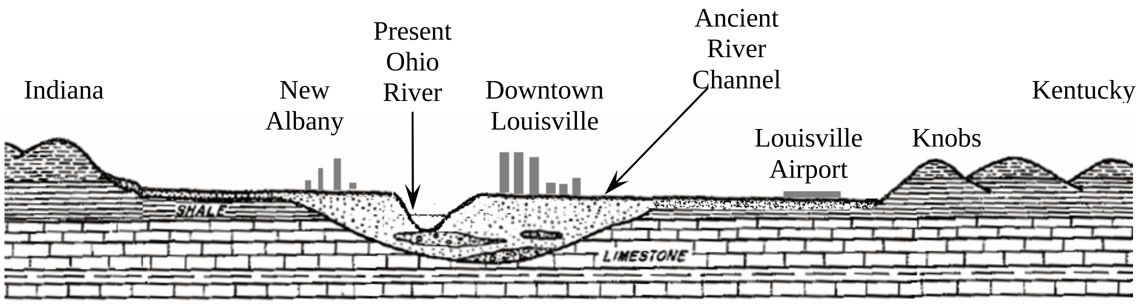


West Generalized East - West Geologic Cross-Section of Kentucky East

The older rock is progressively deeper to the east & west of the crest. Louisville lies on the west side of the Cincinnati Arch. Rock that is near the surface in Lexington is typically several hundred feet below the surface in Louisville. While the layers of rock appear to be horizontal, in the Louisville area they actually slope down gradually to the west on the order of 50 to 100 feet per mile. Erosion & weathering of the rock surface led to the formation of soil & the present day topography over much of the Bluegrass State.

Bedrock in Louisville has been warped in a similar fashion to the Cincinnati Arch, but at a much smaller scale. The Lyndon Syncline basin & the Springdale Anticline dome are parallel features that generally run in an east-west direction through Louisville. Downward warping along the Lyndon Syncline resulted in a natural, relatively impervious, deep, trough-like shale bedrock structure that was well-suited for containment of waste & protection of the groundwater at the Outer Loop landfill.

The Ohio River forms the northern borders of Kentucky & the city of Louisville. The Ohio River generally follows the southern extent of the ice sheets that moved down from Canada during the last period of glaciation. Melt water from the glaciers carved out the Ohio River Valley. Sand & gravel released from the glaciers as the ice melted filled most of the ancient river channel. The sand & gravel is up to 140 feet thick in some parts of downtown Louisville. The sand & gravel is an aquifer & provides a renewable source of groundwater. Drinking water in Louisville is withdrawn from wells installed in the glacial sand & gravel. Some people refer to the aquifer as an underground "river" below downtown Louisville.



North Generalized North- South Geologic Cross-Section of Metro Louisville South

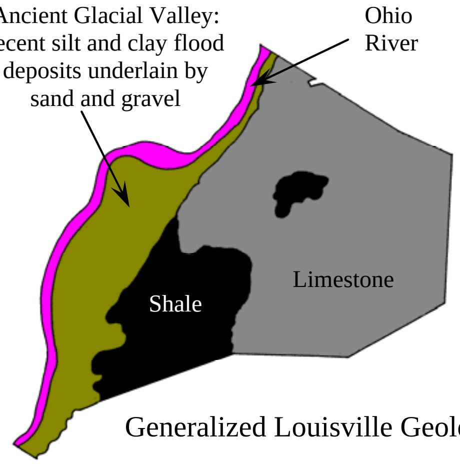
In general, the topography of Indiana just north of Kentucky is relatively flat as a result of the scraping action of the glacial sheets as they moved to the south. Central & eastern Kentucky's landscape was not greatly altered by the glaciers & commonly retains a hilly, rolling quality. However, the ice sheets & transported soils obstructed drainage from Kentucky rivers & streams creating local deposits of lake-bottom sediments where these waterways met the glaciers. The flat topography surrounding the Louisville International Airport was formed in this way. The Ohio River currently occupies a very small fraction of the glacial river channel. The underlying glacial sand & gravel has been covered with more recent clay & silt deposits from flooding of the Ohio River. These deposits commonly are soft & compressible & often contain perched groundwater.

The eastern portion of Louisville primarily is underlain by limestone. Limestone is soluble in mild acid. Rainfall is mildly acidic due to dissolved carbon dioxide from the atmosphere. As rainwater seeps into the soil, the resulting slightly acidic groundwater eventually reaches the limestone. The limestone dissolves in this weak acid, resulting in an irregular upper rock surface & the development of open channels & cavities in the underlying rock.

As the openings widen, the overlying soils may collapse into the rock voids & be carried away by water movement. The collapsing soil progresses upward & outward until the overlying soil arch cannot support the load above it. When the surface soils collapse into the underlying void, the resultant surface feature is termed a sinkhole. Springs result when the water from these subsurface cavities flows back to the surface. The topography formed by these processes is called karst.

Some formations (such as those in the Mammoth Cave area) consist of relatively pure, highly soluble limestone. In this case, large caves & numerous sinkholes have formed. The formations in Louisville typically consist of less soluble limestone & dolomite interbedded with shale. While these conditions reduce the frequency & extent of sinkhole & cave formation, small sinkholes are common in the eastern portions of Louisville.

The southwest portion of Louisville is underlain by shale. A small remnant of shale that overlies limestone also is found in the St. Matthews area. Shale primarily is composed of clay particles that are cemented together to varying degrees. Unlike limestone, shale does not chemically dissolve in water & is more resistant to long term breakdown into soil. The high, rounded, isolated hills ("knobs") in southern Louisville consist of shale remnants that resisted weathering & erosion. However, shale will break down into its component particles when exposed to water.



Generalized Louisville Geology

Many landslides have taken place in the knobs when road cuts or other excavations exposed the shale to the elements. Continued maintenance of slope failures in shale cuts along highways is a common problem. Shale has other detrimental properties that can cause problems with construction. Some shales are expansive & can damage overlying structures. Radon gas from certain shales can cause health problems. The tendency for shale to break down when exposed to water leads to bearing capacity & settlement problems.

Water generally flows through limestone much more readily than it does through shale. In areas underlain by limestone, the overlying soils typically are well-drained, since water can flow down into the pervious rock. Shale bedrock tends to cut off this downward flow of water. Areas underlain by shale typically are poorly drained & the overlying soils tend to be saturated, soft & unstable.

While the bedrock formations in southern Indiana generally are the same as those in central Kentucky, glaciation drastically altered the rock surface and left glacial soil deposits in many areas. Till is the mass of rocks and finely ground material carried by a glacier, then deposited when the ice melted. Till typically is a blend of gravel in a matrix of sandy clay, giving it an appearance similar to that of concrete.

The strength of till typically is high, due to its being compressed under the weight of hundreds or thousands of feet of glacial ice. When the glaciers melted, winds blew away large amounts of the finely ground material from the till surface. When this rock dust fell back to ground, thick layers of soil called loess were formed in many areas. A blanket of loess covers much of the surface in both Indiana and Kentucky.