# Engineering geology of Lexington and Fayette County, Kentucky

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## Introduction

Knowledge of the physical environment is fundamental to master planning by agencies commissioned to provide guidance to the orderly growth of a community or region. The City-County Planning Commission therefore requested the Kentucky Geological Survey and the U.S. Geological Survey to make an engineering geology study of Fayette County. The study was feasible because geologic mapping of Kentucky undertaken cooperatively by the U.S. Geological Survey and the Kentucky Geological Survey covers Fayette County. It was further requested that the report be integrated with a recently completed soils study by the Soil Conservation Service (Sims, 1965) and contain information on the hydrology of the County. This report is in partial fulfillment of the Commission's request.

A section entitled "Water resources of the Fayette County area, Kentucky" by H. T. Hopkins of the Water Resources Division, U.S. Geological Survey, has been included to relate the geology and hydrology as far as present data and knowledge permit.

The geologic mapping of Fayette County at the scale of 1:24,000 was completed in 1965. Geologic maps of two of the 13 quadrangles that cover Fayette County had been published by March 1966. In order to meet the Planning Commission's early need for the geological data, those parts of the published and unpublished manuscript geologic maps within Fayette County were joined at no change in scale to form three sheets. The geologic map units were grouped according to their engineering properties. Compilation of the preliminary engineering geology map was completed, and many of the necessary field observations were made in the fall of 1965. Additional work required for a final report is planned for the spring of 1966. This report, therefore, is a preliminary one written specifically to provide the Planning Commission with the requested environmental information needed for the master plan now being compiled.

Little work on the physical environment as related to land use of Fayette County had been done prior to that requested or stimulated by the Planning Commission. Probably the earliest was a soil survey of Fayette County by Higbee and Venable (1931) in which agricultural uses of the land were emphasized. Geologic investigations have been carried out in the county and adjacent areas in the past, but none were concerned with land use except for mining and possible exploration for oil. Brief resumés of the geology, soils, and hydrology of Fayette County and their effect on land use are presented in the Planning Commission's own publication "The land conditions of Lexington and Fayette County, Ky." published in 1963.

The stimulating interest of Mr. William H. Qualls, Executive Director of the Planning Commission Staff, in the relationships of environment to land use provided the impetus for the compilation of this report. Mr. Charles E. Pixton of the Planning Commission Staff assisted in defining the Commission's needs and furnishing necessary background on the procedures of land-use planning. The help of

Mr. Robert C. Deen, Assistant Director of Research, Materials Research Laboratory, Kentucky Department of Highways, and Mr. David L. Arnall, Chief Geologist, Division of Materials, Kentucky Department of Highways, is also acknowledged.

Not having participated in the geologic mapping of Fayette County, the author had to rely on the aid of those who had, primarily Earle R. Cressman and Douglas F. B. Black, geologists of the Lexington office of the U.S. Geological Survey. Additional help was freely given by Ernest Dobrovolny and Robert D. Miller of the Denver office of the U.S. Geological Survey, both of whom had mapped the geology of parts of Fayette County.

## Geology

The rocks exposed in Fayette County are limestone and shale of Middle and Late Ordovician age. Their lithology and range in thickness are summarized in the accompanying stratigraphic column and described more fully in the discussion of engineering geology. Geologic mapping was based on rock type and was accomplished by tracing outcrops, by projection of stratigraphic marker beds, by use of certain index fossils and by recognition of distinctive rock types. This necessitated changes in the older, established geological nomenclature, especially the Lexington Group and the Cynthiana and Eden Formations. The revised nomenclature used on the generalized stratigraphic column is discussed in detail by Weir and Greene (1965), Black and others (1965), and Weir and others (1965).

Fayette County is situated on a broad, somewhat elongate, northeast-trending structural dome known as the Cincinnati arch. Erosion of the dome has determined to a great degree the outcrop pattern of the underlying rocks. Gentle subsidiary flexures, minor faults, and the prominent northeast-trending West Hickman-Bryan Station fault which traverses the entire width of the county complicate the structure and the resulting distribution of the various rocks.

Little is known of the erosional history of the area over the past 70 million years, during which time great thicknesses of the rock were removed. Remnants of gravel deposits left by an ancestral Kentucky River can be found high on the bluffs overlooking the present-day stream. Related to the late erosional history, during which the Kentucky River became entrenched in its gorge, are the residual soils that are thickest on the higher and broader hilltops and the solution features such as sinkholes, solution channels, and cavities found in the limestone wherever it is present near the surface.

## Engineering geology

Geologic factors of concern to the land-use planners are the same as those of concern to the engineer. These are chiefly slope, topographic relief, physical features and properties of the soils and rocks, and drainage. In Lexington and Fayette County low topographic relief, gentle slopes, good drainage, thick soils over broad areas, and high bearing capacity of the rocks are favorable for urban growth. These more than offset troublesome geologic factors such as thin plastic soils over rock along hillsides and in shallow valley bottoms, faults, and solution features in the widely distributed limestone.

The engineering properties of the soils are presented in the report entitled "Interpretations of Fayette County soils, Fayette County, Kentucky" by Raymond P. Sims, Soil Scientist, U.S. Conservation Service, 1965. Only a few comments concerning the soils are presented here to supplement information in that report. Maximum soil thickness as listed by Sims is 15 feet. Higbee and Venable (1931, p. 39) found the soils on the major hilltops in the central part of the county, and in particular on the drainage divide south of Lexington to be over 20 feet thick and give evidence for its being up to 30 feet thick. Detailed knowledge of the distribution of the thick soil coverings is highly desirable but is not available at this time. Neither the soil maps nor the geological maps contain such information, nor is it possible by comparing the two maps to determine soil thicknesses. Reconnaissance geophysical surveys such as seismic and electrical earth resistivity are suggested means by which the thick soils can be detected and their distribution mapped. Boring through the soil to rock by either auger or hydraulic jet is also feasible but is much more expensive and time consuming.

Wherever limestone is present near the surface, sinkholes, solution channels, caves, and intricate reticulate patterns of pits and pinnacles deeply etched into the limestone can be expected. These vary widely in dimensions from inches to tens of feet. All contain or are drainage channels for water during the spring or extended rainy periods. Some contain permanent flows of water. Sinkholes usually can be detected by the presence of depressions at the surface, but the other features are obscure and are generally found only during excavation of the soil and rock. Solution channels and pit-and-pinnacle surfaces are filled with soil and are the reason for great variations of soil thicknesses over short distances. Caves may be open voids or may be filled with soil or rubble to varying degrees.

For structures less than three stories high, the presence of solution features discussed above presents no great problems for construction of foundations. For larger buildings whose heavily loaded foundations are placed on limestone, solution features can cause unexpected additional costs of construction by requiring extensive subsurface exploration, costly remedial measures, or changes in the foundation design. Occurrence of solution features in the limestones of Fayette County can be generalized as follows. Caves and sinkholes are most common in unit 8, common in unit 9, and present but not common in units 6 and 7. Solution channels and pit-and-pinnacle surfaces are most common in unit 9, common in unit 8, and present but not common in units 6 and 7. Where shaly rocks (map units 4, 5, and 10) are thin and overlie limestone (map units 8 and 9), caves can be expected in the underlying limestone. Sinkholes in the shaly units have been observed where the shale has collapsed into cavities in the limestone beneath.

Geophysical methods of exploring for caves have yet to be fully developed, though much progress is being made on seismic methods. Boring is costly but is still the accepted method for locating underground caverns.

The rocks of Fayette County are nearly flat lying and nearly everywhere appear horizontal in outcrops, roadcuts, and quarries except where they are tipped or tilted near faults and where they border some large sinks. However, they are gently folded into broad, irregular bulges and a few linear folds that are approximately parallel to the main drainage tributaries to the Kentucky River. The folded structures are so low and gentle they have little engineering significance except to the degree they may control subsurface drainage.

Numerous faults are shown on the map. These represent fractures along which the rock has been displaced. Displacement may vary from a few or tens of feet to hundreds of feet. Most faults in Fayette County are steeply dipping or nearly vertical, and, so far as can be determined, displacements have been vertical. None show evidence of movement in recent times. Recurrence of movement along them is not considered likely, but the faults are of much importance for several reasons.

1. Rocks of highly contrasting engineering properties in some places have been faulted into positions opposite one another. This change may be abrupt, occurring over a distance of from a few inches to several feet.

2. The faults may be simple single fractures or complex shear zones with varying amounts of fault breccia or gouge along them and

associated fractures in the adjoining rock. Excavation and over-steepening of slopes parallel to or near the faults can result in rockslides and rockfalls that are difficult and costly to contain or correct.

3. Drainage in many places is concentrated along faults, and solution features such as sinks and caverns are common in limestone along the faults at or below the ground surface.

4. The complex nature of drainage along faults and through associated fractures in adjoining rocks can cause particularly difficult drainage problems for structures built on or across them.

## Map Units

The engineering geology map accompanying this report has the dual purpose of providing a simplified geologic map for use by the Planning Commission in classifying the county relative to future land use and by engineers and contractors concerned with excavation and foundation conditions. The rocks are briefly described on the map explanation and generalized stratigraphic column and more fully described and evaluated in the following text. It must be pointed out that the estimates regarding engineering properties made herein are based mainly on field observations. They and the map are intended primarily for use in making preliminary plans and designs and are not intended to take the place of detailed investigations in the field and laboratory.

Map unit 1.--Alluvial deposits of map unit 1 in the valley bottoms are silty fine sand with varying amounts of clay and organic matter. Thickness is variable, 20 feet or more along the Kentucky River and much thinner in the bottoms of tributary valleys. Sediment-filled pits and troughs are to be expected where the streams flow over limestone. No distinction is made on the engineering geology map of alluvial deposits of different textures. References should be made to the soils maps (in Sims, 1965) for a detailed classification of the alluvial soils and to table 2 in the soils report (Sims, 1965) for land-use interpretations. Differences exist between the soils maps and the engineering geology map as to placement of the boundaries of the alluvial deposits. Where location of the boundaries of the alluvium is of concern, reference should be made to the more detailed soils maps.

Map unit 2.--Remnants of gravel deposited by an ancestral Kentucky River occupy a few of the hilltops overlooking the present Kentucky River. The deposits are 0 to approximately 35 feet thick and are composed of an unsorted mixture of clayey sand, gravel, and boulders. The gravel contains a high percentage of chert pebbles and scattered round quartz geodes 0.2 to 1.0 foot in diameter (E. R. Cressman, oral communication). Little is known about this unit because exposures are rare and small. Permeability is expected to be highly variable but in general moderate. Small bodies of water may be present in the deposits, being perched on the impervious underlying rocks of map units 5 and 10.

The gravel can be excavated by hand tools. It is classified as earth relative to excavation.

Foundation conditions are good.

Map unit 3.--About 1 mile northwest of Clays Ferry, U.S. Interstate 75 crosses a small mass of highly brecciated rock between two faults. The breccia, derived from the Ashlock or Drakes Formation is composed of angular fragments of dolomite and limestone in a matrix of unconsolidated silt and clay. Fragments are angular and mostly gravel size but range up to a foot or so in longest dimension. The thickness of the deposit is unknown.

The breccia is permeable.

It can be excavated by hand tools although large fragments would be bothersome, especially in narrow trenches. For excavation purposes, the breccia is classified as earth material. Rock conditions are probably variable over short distances.

The breccia provides good foundations.

Map unit 4.--About 0.3 mile southeast of Walnut Hill the Walnut Hill-Athens road crosses a fault complex. Long, narrow strips of map unit 4 are enclosed by the faults. Map unit 4, the Drakes Formation (D. F. B. Black, oral communication), is composed of interbedded dolomite and shale and is of unknown thickness. The dolomite is brownish to grayish orange, fine to medium crystalline with calcareous matrix; beds are 0.1 to 0.5 foot thick in bedding sets as much as 10 feet thick. Shale separating the dolomite beds is grayish-green clay shale.

The rock has low permeability, though drainage is probably rapid through fractures.

Power tools are required for excavation. Much of the rock can probably be ripped in large broad excavations, but explosives would be required in trenches and pits. Rock conditions are probably uniform.

Foundation conditions are considered good, although locally, especially near the faults, open or clay-filled fractures or large cavities might be encountered.

Map unit 5.--Map unit 5, the Garrard Siltstone, occupies the floor of the northeasterly trending graben (a fault block that has moved down, bringing younger rocks between older) that crosses much of the central part of Fayette County and underlies the upper slopes of the high bluffs within the large southward loop of the Kentucky River. The unit is greenish-gray calcareous siltstone, about 35 feet thick, in even beds a few inches to several feet thick; it contains sparse lenses of gray limestone 1 to 3 inches thick. Contacts with the underlying and overlying shale and limestone of map unit 10 are gradational.

The rock is impermeable with little drainage along the joints which tend to be tight.

Power tools are required for excavation. Locally the upper parts of the rock can be ripped and possibly the entire thickness in large excavations. Explosives probably are required for relatively small and deep excavations such as basements and trenches. Rock conditions are generally uniform, but solution-widened joints and fractures filled with clay, and clay-filled pockets, are present locally.

The rock provides a good foundation.

Map unit 6.--Map unit 6, the Oregon Formation, crops out along stretches of the Kentucky River and tributary ravines and along the lower half of Boone Creek. It is also exposed in two quarries, the Central Rock Company quarry in the city of Lexington and Lambert Brothers Stone Company quarry about 2$\frac{1}{4}$ miles northwest of Clays Ferry. The rock is dominantly dolomite with lesser amounts of limestone and is about 60 feet thick. The dolomite is light brown to gray, fine to medium grained, with bedding even to irregular and 1 to 18 inches thick. Limestone interbedded with the dolomite is yellowish brown, very fine grained, with scattered small crystals of clear calcite and some brownish streaks of dolomite; beds are mostly even and 2 to 16 inches thick. Locally a 2- to 6-inch bed of green shale (bentonite) is present 15 to 20 feet below the top of the unit. Joints are nearly vertical and spaced 4 to 10 feet apart. Most are tight, but many are open within 10 or 20 feet of the surface, having been widened a few inches to several feet by solution activity of ground water.

The rock is impermeable; there is little movement of ground water via joints but there may be more along faults.

Explosives are required for excavation. Rock conditions are generally uniform, but rare clay-filled cavities or open voids are present locally.

The rock provides excellent foundations.

Map unit 7.--Distribution of map unit 7 in Fayette County is similar to that for map unit 6. Geologic formations included in the unit are the Tyrone Limestone and the Camp Nelson Limestone. The map unit is composed of two sections, an upper 60-foot-thick section and a lower 150-foot-thick section separated by about 60 feet of map unit 6. The rock is pale-brown to light-gray and gray, very fine crystalline limestone and dolomitic limestone mottled brown in part. It commonly contains scattered crystals and veinlets of clear calcite and locally contains some chert beds. Bedding is even, 1 to 4 inches thick and locally 18 to 24 inches thick; shaly beds are rare. Joints are tight with 6- to 8-foot spacing, mostly vertical, and in three sets of directions. Widening of joints by solution appears to be rare.

The rock is impermeable with very little movement of ground water along joints. Most movement of ground water probably takes place along faults.

Explosives are required for excavation. Rock conditions are generally uniform, but rare clay-filled cavities or open voids are present locally.

The rock provides excellent foundations.

Map unit 8.--Map unit 8, the Grier Limestone Member of the Lexington Limestone, occupies the middle slopes and bottoms of the valleys draining the western part of Fayette County and a 1- to 2-mile-wide belt at the south and southeast end of the county. The unit, approximately 180 feet thick, is light-gray to pale-yellowish-brown, fine- to coarse-grained limestone. Most of the grains are broken fossil shells, and the rock is slightly phosphatic; beds are mostly 1 to 6 inches thick and irregular to rubbly and lenticular, especially where shaly partings 1 to 2 inches thick are present. The surface of the limestone beneath the soil cover is nearly everywhere deeply etched by solution into a complex pattern of pits and pinnacles or long, deep channels from a few inches to 10 or 15 feet across. Clay fills most of the widened joints, although locally where the water drains through them there may be open cavities. Sinkholes are common.

The rock is impermeable and locally acts as a confining bed hydrologically. Water moves freely along some joints and faults.

Explosives are required for excavation. Locally the upper few feet of weathered rock might be rippable. Rock conditions are uniform, but clay-filled cavities and open voids are common.

The rock provides an excellent foundation except where solution by ground water has created pitted areas, channels, sinkholes, or caverns which are partially to completely filled with clay. Exploration for such features often proves difficult and costly.

Map unit 9.--Rocks of this map unit, the Tanglewood Limestone Member of the Lexington Limestone, underlie the upper slopes of the broad shallow valleys of the southwestern part of Fayette County and valley sides and divides of the northeastern part. The rock is gray thin-bedded limestone, 5 to 80 feet thick; it has sandstonelike texture and in many places is crossbedded; beds are even, 3 to 12 inches thick, and commonly separated by thin shale beds one-fourth to several inches thick; irregular lenses or streaks of brownish grains of phosphate mineral are scattered throughout the rock. Joints are nearly vertical, 2 to 6 feet apart, and in three sets; they are commonly widened by ground-water solution into vertical-sided clay-filled channels several feet wide and of varying depth. Locally the surface of the rock beneath the soil is a complex of deep pits separated by sharp pinnacles. Sinkholes are common. The clay filling of the channels and pits is phosphatic and has been mined as phosphate ore (Black, 1964) in Woodford County.

The rock with its shale partings is impermeable, but close spacing of joints, many of which have been widened by solution, renders the rock mass relatively pervious, and ground water circulates through it.

Explosives are required for excavation. Locally the rock is rippable to shallow depths. Rock conditions in the upper 10 feet or so change abruptly from hard rock to clay where channels and pits are encountered. At greater depths the rock is much more uniform laterally.

The rock is a good foundation, but the presence of solution features requires thorough exploration of foundation sites and might impose unexpected costs in excavation and design.

Map unit 10.--Rocks of this map unit crop out in nearly all topographic situations in Fayette County, but in general they underlie the upper valley slopes in the western part of the county and hilltops in the south-central and northern parts. Map unit 10 consists of four geologic rock units; these are the Clays Ferry Formation, and the Brannon and Millersburg Members of the Lexington Limestone and the Calloway Creek Limestone. All are interbedded shale and limestone, less than 30 to as much as 220 feet thick, varying in percentage of rock types but ranging from 30 to 60 percent of shale. The limestone is light to dark gray and fine to coarse grained; beds are even or tabular to irregular and nodular and 1 to 6 inches but locally as much as 3 feet thick; the shale is greenish gray, calcareous, laminated to nodular, and in beds 1 to 6 inches thick; the siltstone is greenish gray, calcareous, and in even beds 1 to 3 inches but locally as much as 3 feet thick; some siltstone beds exhibit contorted internal structure. Joints are inconspicuous and, where present in the limestone beds, generally stop at the contact with the underlying and overlying shale. Solution features are relatively rare in the map unit. Solution channels are present only where the limestone in which they are developed is 2 to 3 feet or more thick. Sinkholes are commonly only where the unit is thin and has collapsed into sinks that developed in the underlying limestone.

The rocks of map unit 10 are almost impervious, but water does circulate within them along joints and other fractures in the limestone. Water moves along the top of shale beds and flows out on the surface as seeps and springs along outcrops on valley sides and in roadcuts. Locally the rocks act as confining beds, causing artesian conditions in underlying water-bearing limestone of other map units.

Mechanical equipment is required for excavation of the rock. Locally, where limestone ledges are thick and persistent or in small confined excavations such as pits and ditches, explosives are required. Most of the rock can be ripped, especially in large excavations. Steep cut slopes tend to weather back rather rapidly as the shale flakes and ravels, allowing slabs of limestone to drop to the base of the cut. Nearly all the shale is calcareous and has a low coefficient of swelling, but when exposed to alternating wetting and drying conditions it weathers away in thin flakes. Rock conditions vary from site to site and within short distances both horizontally and vertically.

Foundation conditions are generally good, the chief concern being solution features in underlying limestone strata.

## Evaluation of map units for land use

Estimated evaluations of the rocks for different classifications of land use are presented in table 1 entitled "Estimated limitations of various land uses and chief causes of the limitations." Column headings for the table were taken from table 2 in the soils report by Sims (1965) at the request of the Commission planners in order to furnish interpretations of the rock for the same land-use categories as were used in the soils report. Anyone studying table 1 should note carefully the definitions of the limitation of land-use terms (slight, moderate, and severe) and should bear in mind that bedrock, not soil, is being evaluated. Otherwise the table may be misinterpreted.

## Mineral construction materials

Fayette County and the adjacent counties have unlimited resources of limestone suitable for use as a construction material. Three quarries are now operating in the County, producing crushed rock for use as aggregate in portland and asphalt cement concretes, agricultural stone, base material for roads, and road metal for driveways.

The Blue Grass Stone Co., 2 miles north of Lexington, quarries rock from map units 8 and 9. Both the Central Rock Company, in Lexington, and Lambert Brothers Stone Company, whose quarry is about 9 miles south of Lexington near Clays Ferry, mine rock from map units 6 and 7. The presence of shale partings and shale beds that vary in thickness laterally cause problems of selective quarrying in rocks of map units 8 and 9, while chert layers and a few thin beds of green bentonitic shale cause problems of rock selection in quarrying rock in map units 6 and 7.

The limestones of Fayette County where free of shale are generally of good quality for use in construction. Some of their physical and chemical properties are shown in table 2.

Many abandoned quarries scattered throughout the county formerly furnished rock for local needs, such as slabs for houses and walls and crushed rock for road surfacing.

Rock suitable for riprap probably could be obtained from the operating quarries as well as from many of the abandoned quarries.

Hard, durable sand is not available in Fayette County or any of the adjacent counties. The nearest source is the Ohio River where sand is dredged and shipped to Lexington. Sand-size limestone chips recovered as a byproduct from the crushing plants are available at the operating quarries.

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