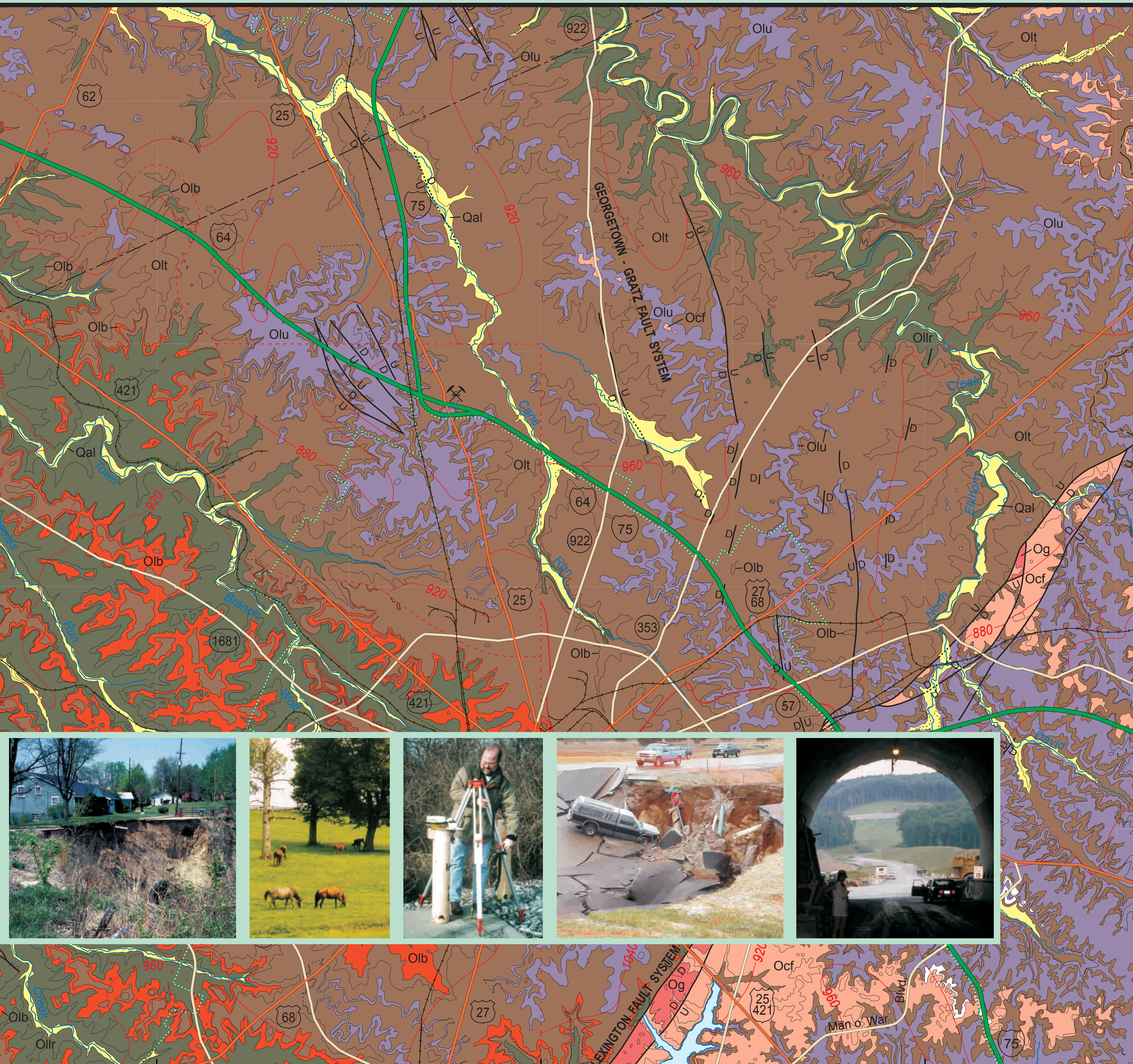
Geologic Maps

And Geologic Issues in Kentucky:

A Citizen's Guide

Carol L. Ruthven, John D. Kiefer, Stephen F. Greb, and William M. Andrews Jr.



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Contents

Our Mission

Our mission is to increase knowledge and understanding of the mineral, energy, and water resources, geologic hazards, and geology of Kentucky for the benefit of the Commonwealth and Nation.

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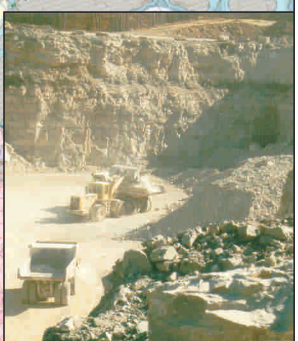
Photo by Richard A. Smath


Photo by Richard A. Smath

Citizens in all walks of life benefit from the information on geologic maps

Geologic maps are used to

- Identify areas prone to natural hazards, such as landslides, erosion, sinkholes, and flooding
- Select locations that are suitable for tunnels, bridges, dams, and quarries
- Identify suitable sites for safe construction of homes and commercial buildings
- Select safe places for building septic systems and landfills to minimize the risk of polluting soils and groundwater
- Help farmers, landowners, and government officials locate groundwater resources and protect water quality
- Help citizens understand geologic features (such as faults, mineral deposits, and impact structures) in the landscape
- Locate and assess the value of resources such as oil, natural gas, coal, and limestone


Photo by Collie Rulo


Photo by Cortland F. Eble


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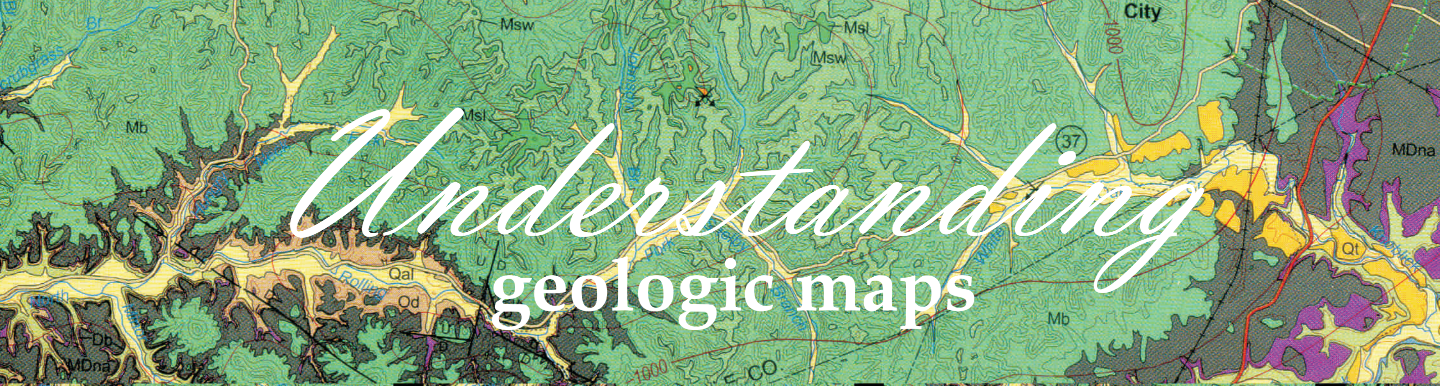
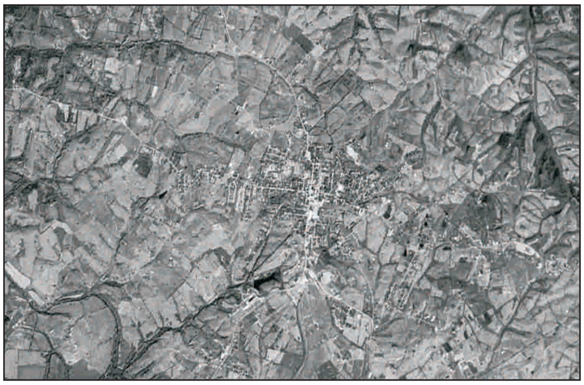


Understanding geologic maps

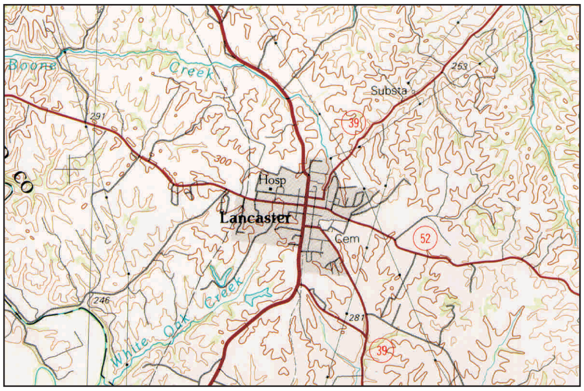
Different maps show different types of information

Photographs taken from airplanes show what the surface of the earth looks like, but the features shown on them are not labeled. To convert the information on these photographs into a more usable format, geologists make a topographic map.



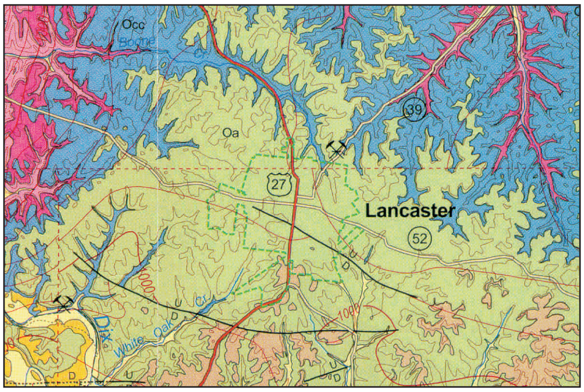
Aerial photograph of the area surrounding Lancaster, Ky.

Topographic maps are representations of the earth that illustrate the shape of the land surface. They show the elevation of hills and valleys and the location of natural and man-made features such as streams, roads, bridges, and cemeteries. They provide an important base for the construction of other maps, such as geologic maps.

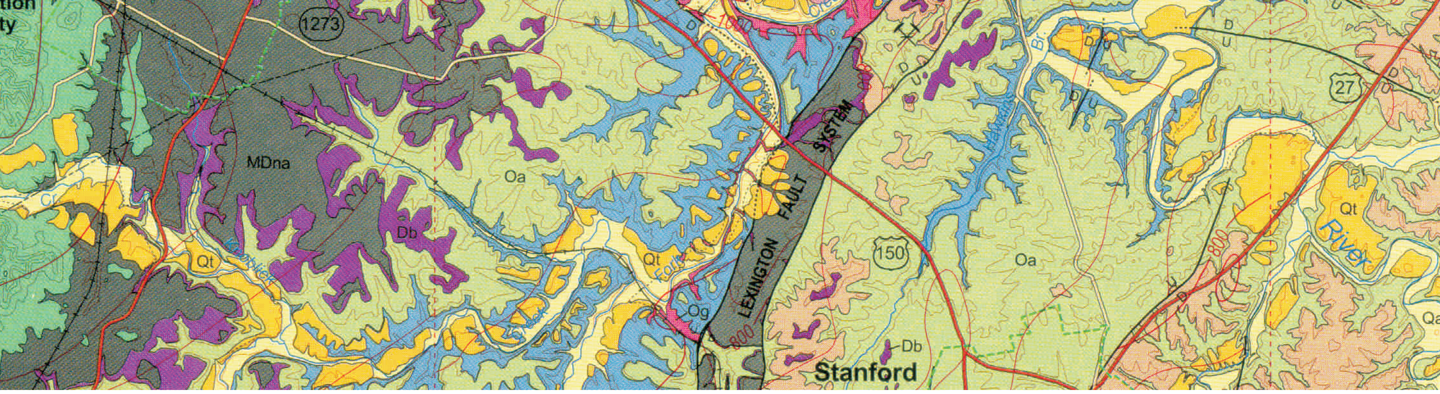


Topographic map of the area surrounding Lancaster.

Geologic maps illustrate the distribution of geologic materials or features on the earth's surface. Different colors are used to represent different rock units. Geologic maps may also show the location of significant geologic features, such as fossils, mines, and economic mineral deposits.



Geologic map of the area surrounding Lancaster (Sparks and others, 2001).



Map scales: different maps are designed for different tasks

Map scale refers to the ratio of distances measured on a map to actual distances on the ground. A map can be made at any scale, but certain scales are better for certain purposes. Obviously, it is not practical for a highway map, for example, to be the same length as the highway it represents. So, many highway maps are published at a scale at which 1 inch on the map represents 10 miles on the ground. Scale is always expressed as the ratio of map units to distance on the ground. If 1 inch on a map represents 24,000 inches (or 0.4 mile) on the ground, the scale is 1:24,000. A 1:100,000 map scale means that 1 inch on a map represents 100,000 inches (or 1.6 miles) on the ground. You can determine the scale by looking at the bar toward the bottom of a map. The bar will list scale as a ratio of inches on the ground to inches on the map, and will also show equivalent distances on the map using different units (for example, miles or kilometers), so that you can determine the distance between features on the map.

The level of detail in the features presented on a map varies with scale. A 1:24,000-scale geologic map is an excellent source of information for making site-specific decisions about the construction of houses, subdivisions, commercial buildings, airports, dams, and bridges. A 1:100,000-scale map is ideal when a broader regional or county-level perspective is required for making decisions about the construction of highways, watershed management, wetland restoration, and land-use planning.

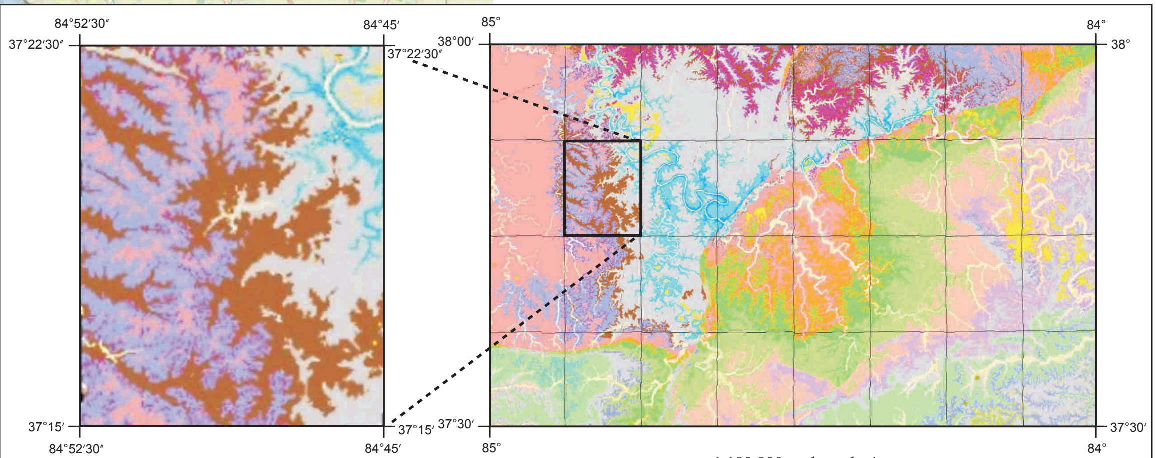
Using Map Scales

	1:24,000	1:100,000
Engineering		
Buildings and foundations	✔	
Dams, dikes, and locks	✔	✔
Pipelines	✔	✔
Railroads	✔	✔
Roads and highways	✔	✔
Utilities	✔	
Environmental Protection		
Industrial applications	✔	
Pollution prevention	✔	✔
Site clean-up	✔	✔
Exploration and Development		
Coal	✔	✔
Groundwater	✔	✔
Industrial minerals	✔	✔
Oil and gas	✔	✔
Hazard Prevention		
Earthquakes	✔	✔
Karst problems	✔	✔
Landslides	✔	✔
Subsidence	✔	✔
Property Valuation		
Land acquisition	✔	
Property tax assessment	✔	
Regional Planning		
Industrial permits	✔	
Transportation	✔	✔
Waste disposal	✔	
Urban Planning		
Building codes	✔	
Landscape planning	✔	
Zoning decisions	✔	

After Bhagwat and Ipe (2000)

Map areas: latitude and longitude

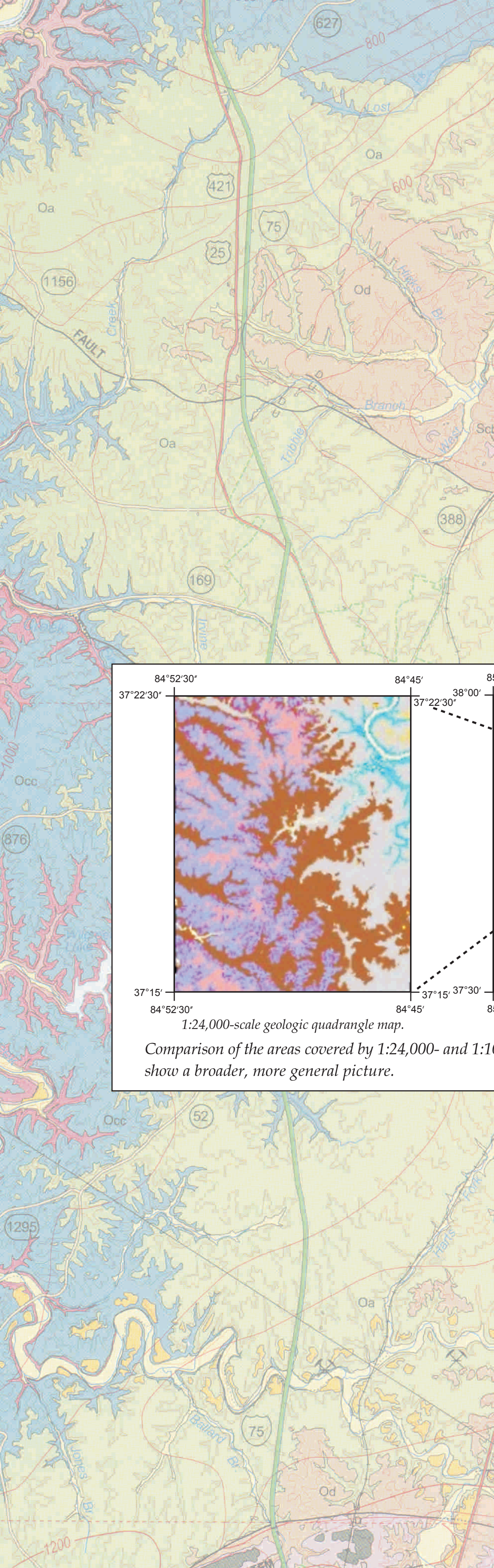
The entire state of Kentucky has been geologically mapped at a scale of 1:24,000—but not all on one map. Since Kentucky is 425 miles wide from east to west, that map would be almost 95 feet wide! The state has been divided into quadrangles measuring 7.5 minutes of latitude and 7.5 minutes of longitude. Latitude is a common radial measure of distance north and south of the equator. Longitude refers to distances east and west of the prime meridian. Units of latitude and longitude are written in degrees, minutes, and seconds (for example, 85°55'00"). Each 7.5-minute quadrangle map covers an area of approximately 69 square miles. There are more than seven-hundred 7.5-minute quadrangle maps for all of Kentucky. These maps are sometimes referred to as “GQ’s.”



1:24,000-scale geologic quadrangle map. *1:100,000-scale geologic map.*

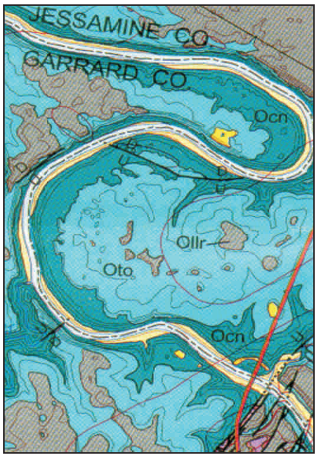
Comparison of the areas covered by 1:24,000- and 1:100,000-scale maps. The 1:24,000 maps show more detail, while the 1:100,000 show a broader, more general picture.

Kentucky has also been divided into larger quadrangles measuring 30 minutes of latitude by 60 minutes of longitude. Each 30 x 60 minute quadrangle covers an area of 1,885 square miles, and there are 34 of them for all of Kentucky. The Kentucky Geological Survey is mapping all of the 30 x 60 minute quadrangles that cover the state, at a scale of 1:100,000. Each of the 30 x 60 minute geologic maps is compiled in a computer from the 32 separate 7.5-minute quadrangle maps that comprise it. A small inset diagram on each 30 x 60 minute map shows which 7.5-minute maps were used to make it.



Rock units

The most obvious feature of a geologic map is the different colors shown in the map area. Each color represents a unit with a specific type of rock or characteristic combination of rock layers. The basic rock unit for geologists is a "formation." Formations are mappable units of rock. At most scales of mapping, identifying every layer of rock is not practical, so geologists combine distinctive intervals of rock layers into units that can be shown on a map. Formations generally consist of layers of rock that are more similar to each other than to the layers above or below them.



The dark teal blue of the Camp Nelson Limestone is quite distinct on the Harrodsburg map where U.S. 27 crosses the Kentucky River near Camp Nelson.

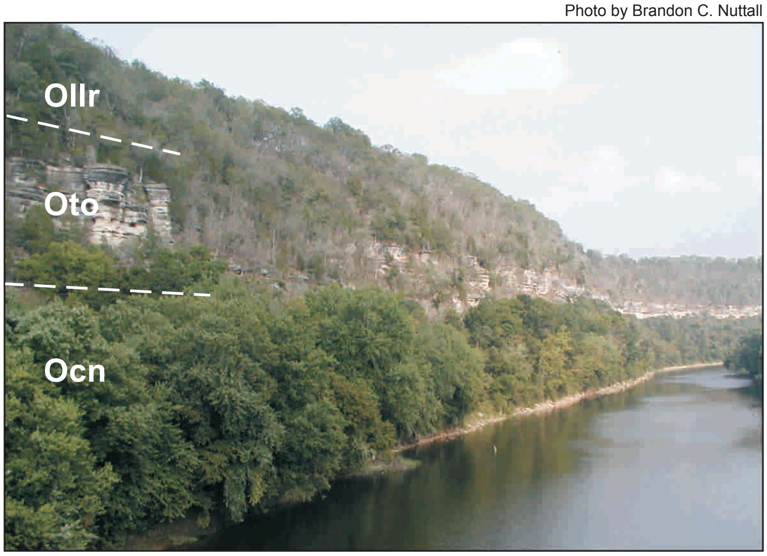
Formations can be mapped together into larger units called "groups." Formations can be composed of smaller units called "members." Individual beds or layers, when important enough to be mapped (such as coal beds of economic importance), can also be shown on geologic maps. Sometimes the main rock type for which the unit is defined is used as part of the unit's name. For example, the Camp Nelson Limestone (right) is a formation composed mostly of the sedimentary rock limestone, so the word "limestone" replaces the word "formation" in the unit's name. Rock units are often named for the geographic area in which they were first defined, or in which they are well exposed. The Camp Nelson Limestone was named for exposures of limestone in the cliffs along the Kentucky River near Camp Nelson. A stratigraphic column (see page 9) provides the name and type of rock units shown on a geologic map.

The locations of rock units shown on a map are determined by measuring natural outcrops and man-made exposures such as highway roadcuts, as well as by analyzing subsurface data from boreholes and mines. The occurrence of a rock unit is then projected between known data points. In many areas, the rock units mapped may be covered by soil, vegetation, or urban development, but are projected to occur beneath these features. In this way, geologic maps provide a powerful tool for predicting what types of rock materials should occur beneath the surface in the mapped area.

Photo by Collie Rulo

Rows of cylindrical-shaped rock core show the layers of the earth where they were drilled.

Photo by Brandon C. Nuttall



The oldest rocks at the surface in Kentucky are limestones from the Middle Ordovician Period (approximately 450 million years old), which are exposed along the Palisades of the Kentucky River. The beds are combined into several distinctive rock units on geologic maps. These rocks are from the Camp Nelson Limestone (Ocn), Tyrone Limestone and Oregon Formation (Oto), and the lower part of the Lexington Limestone (Ollr) as shown on the map above.

Rock types: the building blocks of rock units

Rocks are grouped into three major types according to their origin: sedimentary, igneous, and metamorphic. Sedimentary rocks are the most abundant type exposed at the surface of the earth and cover about 99 percent of Kentucky. They are formed from the weathering and transport of preexisting rocks and the chemical precipitation of sediments. Examples of sedimentary rocks described on Kentucky's geologic maps are limestone, dolomite, shale, siltstone, sandstone, conglomerate, and coal. Limestone, shale, and dolomite are common in central Kentucky. Shale, coal, and sandstone are common in coal fields of eastern and western Kentucky.

Coal

Igneous rocks result from the cooling of molten rock. They are rare at the surface in Kentucky, but the igneous rock lamprophyre has been identified in dikes (a type of geologic feature; see *Glossary*) in Caldwell, Crittenden, and Livingston Counties. Peridodite, another type of igneous rock, has been mapped in Elliott County.

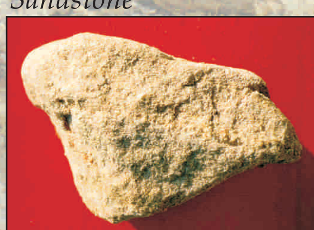
Metamorphic rocks were originally sedimentary or igneous rocks, but have been physically and mineralogically changed by heat and pressure. They are rare in Kentucky, but have been encountered in deep wells, as grains in sandstones, and as isolated cobbles and boulders transported into northern Kentucky by ancient glaciers.

The rock types found within each geologic unit are described in the description of rocks and sediments on a geologic map (see page 8). Additional information about the rocks and minerals in Kentucky and color photographs of them are found in *Rocks and Minerals of Kentucky*, by Warren H. Anderson (1994), and on the KGS Web site (www.uky.edu/KGS).

Sedimentary rock layers

Limestone

Sandstone

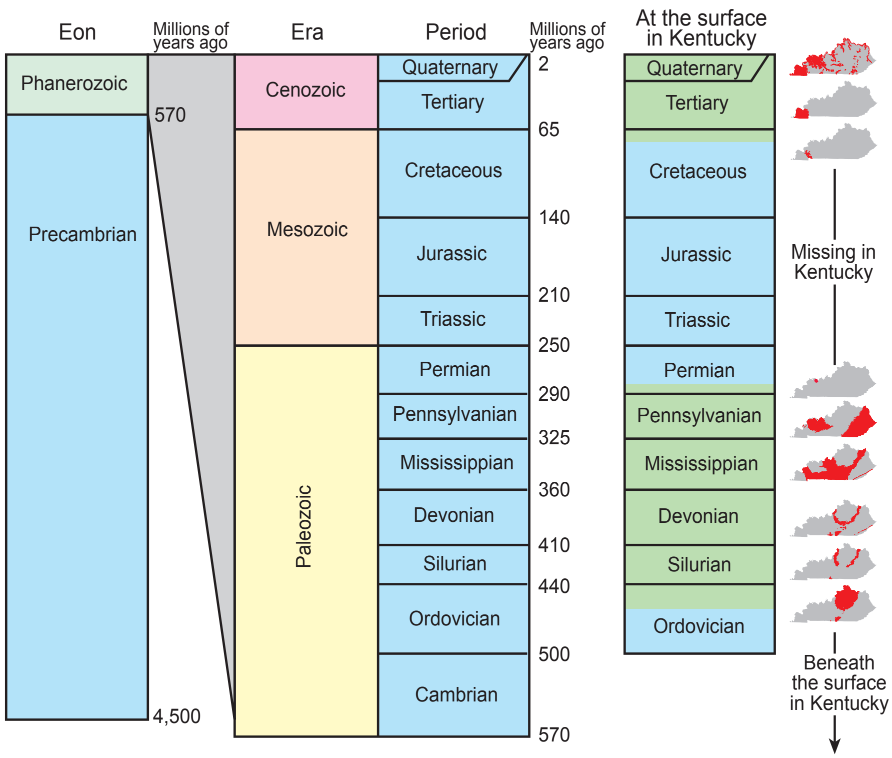


Conglomerate

Black shale

Large photo by William M. Andrews Jr.
Inset photos by Stephen F. Greb.

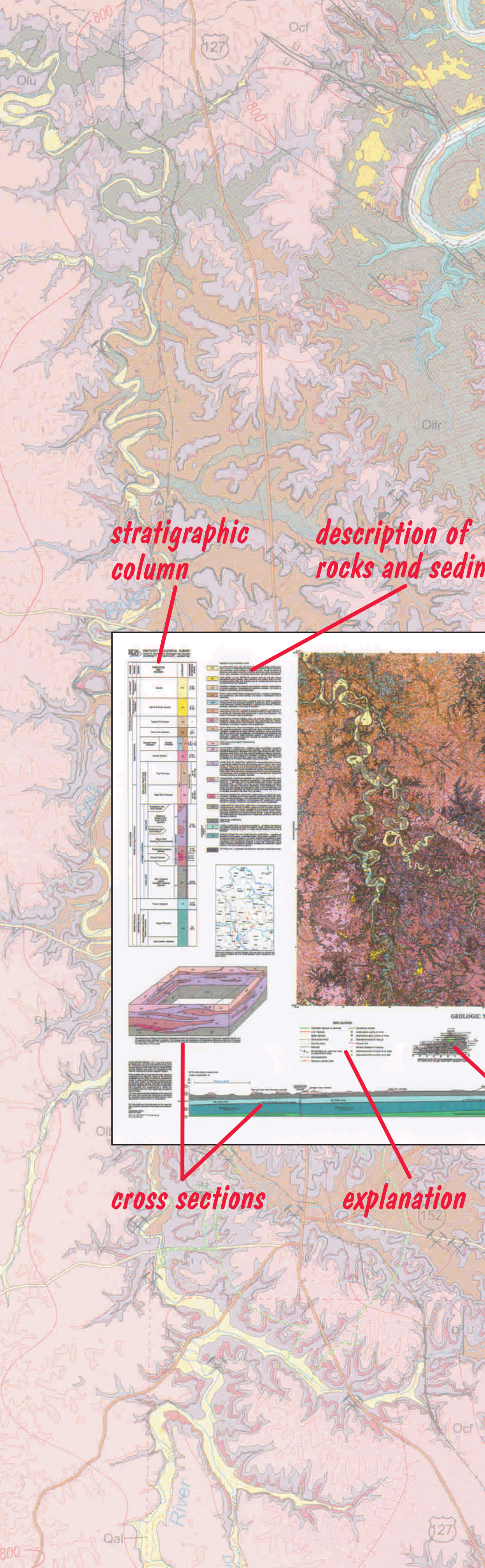
Geologic time: the basis for ordering rock units



This chart is a time scale that shows the names of the geologic periods and how long ago they occurred. Geologists have subdivided the 4.6-billion-year history of the earth into two dominant eons: the Precambrian and the Phanerozoic. All of the rock units found at the surface in Kentucky are from the Phanerozoic Eon, which is in turn divided into three eras: the Paleozoic, Mesozoic, and Cenozoic. The Paleozoic Era has been called the Age of Invertebrates because invertebrate (animals without backbones) fossils are common in Paleozoic rocks. These include brachiopod (seashell) fossils, the official State Fossil. The Mesozoic Era is commonly called the Age of Dinosaurs because dinosaur fossils are found in rocks of this period (although not in Kentucky). The Cenozoic Era is commonly called the Age of Mammals because of the abundance of mammal fossils, including the famous mastodon and mammoth fossils of Big Bone Lick State Park in northern Kentucky.

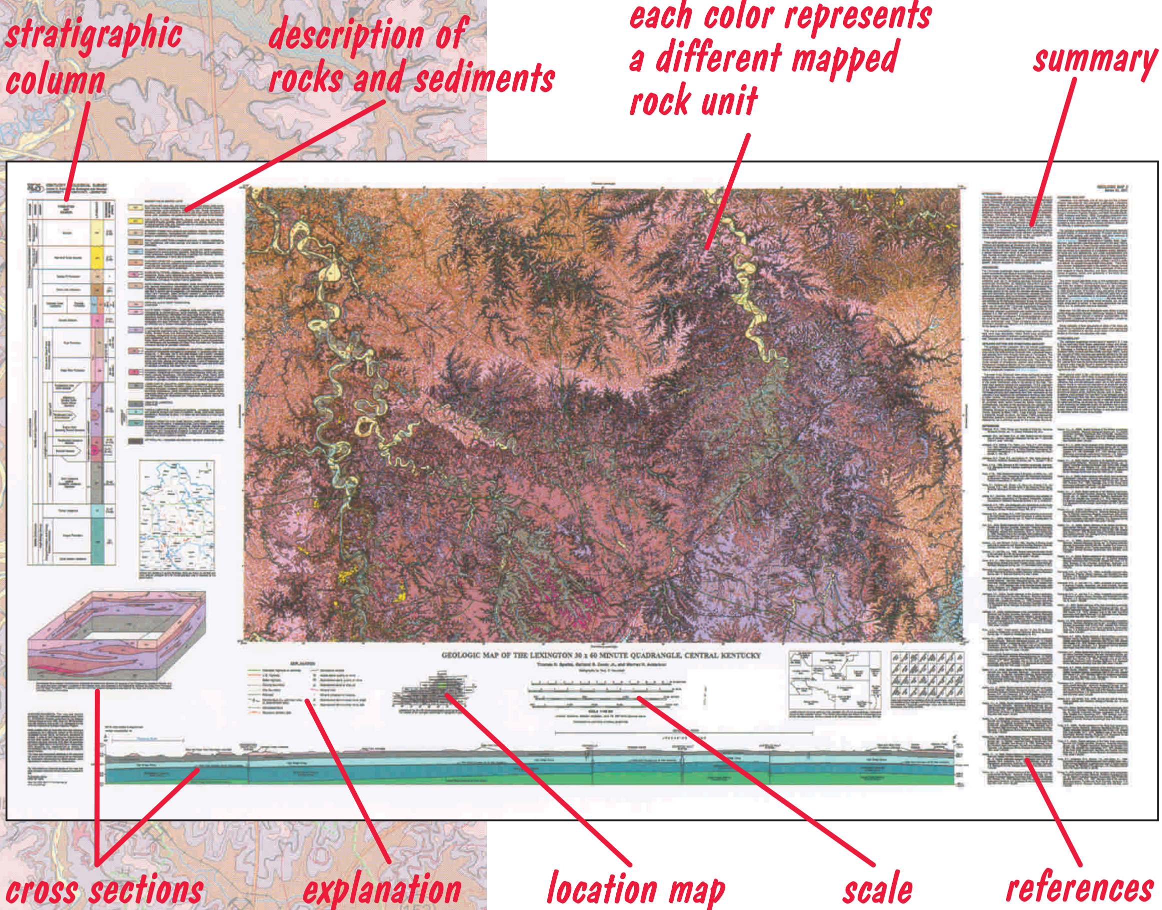
Geologists divide the three eras into periods. Seven periods are in the Paleozoic Era, three in the Mesozoic, and two in the Cenozoic. The word "period" is used to refer to a unit of time (for example, the Ordovician Period of the Paleozoic Era), and the word "system" is used to refer to the rock units deposited during that period (for example, the Camp Nelson Limestone of the Ordovician System). The systems in which rock units occur are shown on the stratigraphic column of a geologic map (for example, see page 9).

Geologic maps are useful for interpreting the stacking of rock units through time. Younger strata are deposited above older strata. By comparing the stacking of rock units across the state, the geologic history of the state can be interpreted. The bedrock in Kentucky does not preserve a complete record of geologic time, and rocks from different periods are not evenly distributed at the surface across the state. The small state map symbols to the right of the time chart show where rocks of different ages occur at the surface in Kentucky. For more information about geologic time and fossils, see the KGS Web site at www.uky.edu/KGS.



Basic elements of a geologic map

A geologic map illustrates the land surface, and records geologic information such as the location, description, and age relationships of rock units; the occurrence of faults and folds in rock strata; the location of economic mineral deposits; and sometimes even the locations of fossils. Information is also provided about the occurrence and trends of rock units beneath the surface.



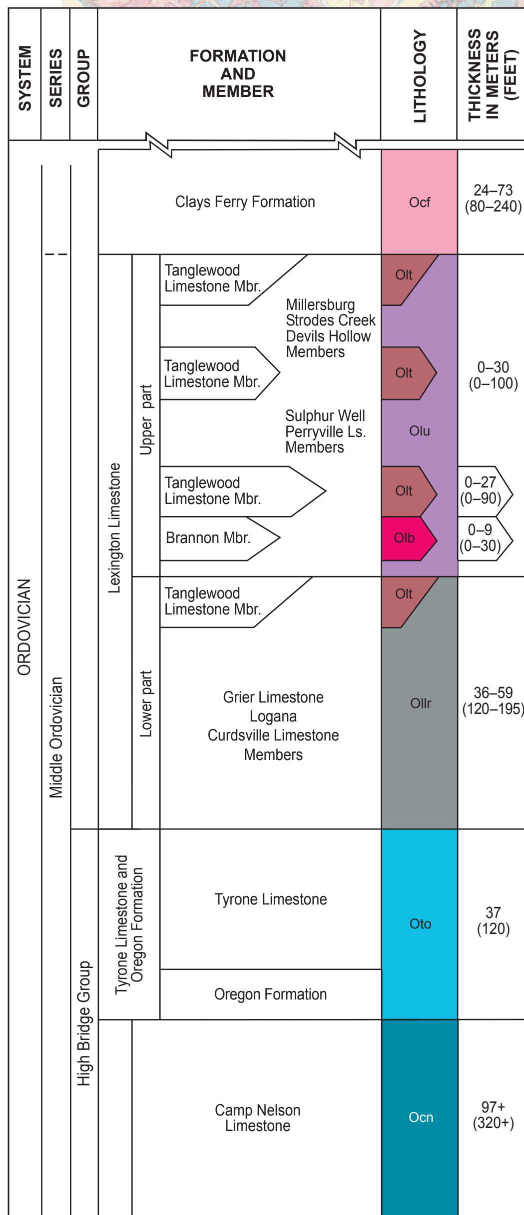
Reduced version of the Lexington 1:100,000-scale geologic map (Sparks and others, 2002).

Stratigraphic column and description of rock units

A stratigraphic column (also called a geologic column) is provided on each geologic map (see page 8). It demonstrates how the rock units shown on the map are stacked from older rocks on the bottom to younger rocks at the top. The color of each unit in the stratigraphic column corresponds to the color of the unit on the map. Each unit also has a two- to four-letter code. This code starts with a capital letter, which represents the system the unit is from, followed by lowercase letters representing the rock unit name. For example, the Camp Nelson Limestone (photograph on page 5) was deposited in the Ordovician System, so its symbol is Ocn: O for Ordovician, cn for Camp Nelson. The range of thicknesses for each rock unit is also shown next to its symbol. This is an important feature of a geologic map because it helps its readers decipher the relative stacking of rock strata in the map area and predict what type of rock units should occur beneath the units mapped at the surface in any area on the map.

The stratigraphic column correlates the systems and the rock units, essentially placing the rock units in their place in time. To fine tune the correlation, systems can be further divided into series, and periods into epochs. For the Paleozoic and Mesozoic, systems are divided using the words "lower, middle, and upper" (for example, the Middle Ordovician Series of the Ordovician System). For the Cenozoic, lower, middle, and upper are not used; instead, unique series names are used (for example, the Pleistocene Series of the Quaternary System).

A description of the rocks, fossils, and sediments in each rock unit shown on the geologic map is also provided. The description includes the color code and symbol for the rock or sediment units shown on the geologic map and stratigraphic column. In some cases, references for additional information or descriptions of outcrop exposures of the rock units in the mapped area are also shown.



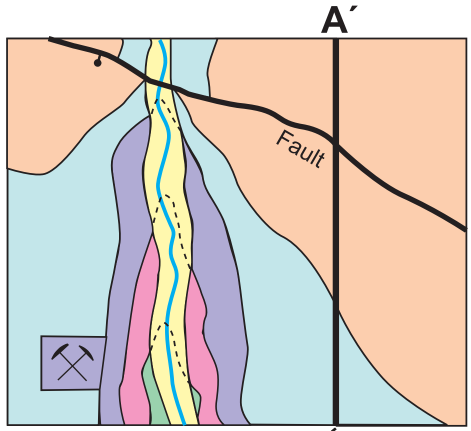
Stratigraphic columns help us visualize the stacking of rock units. This is part of the stratigraphic column from the Harrodsburg 30 x 60 minute map (Sparks and others, 2001).

Photo by Stephen F. Greb

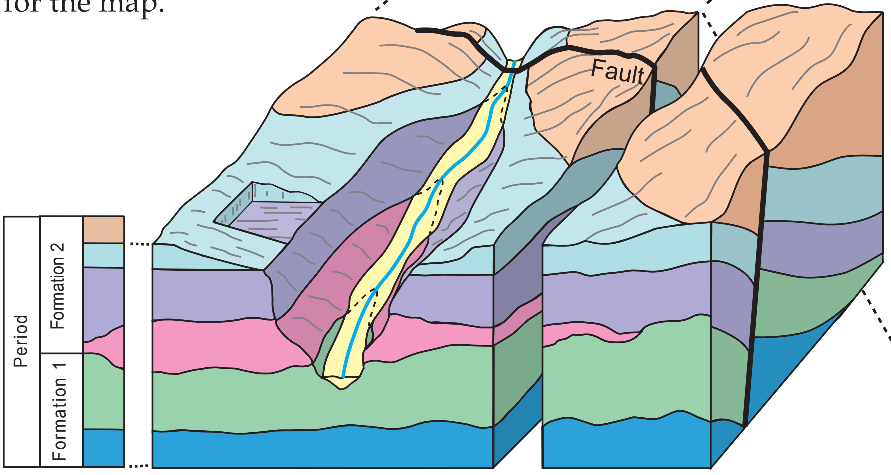
Roadcut exposing the different layers of rock at Pound Gap, Ky.

Faults

Faults, typically shown by heavy black lines on geologic maps, are fractures in bedrock along which movement has occurred. Where there has been significant movement on either side of a fault, the rock units at the surface are generally different on either side of the fault, and are therefore depicted on the map by different colors. The direction and type of motion along a fault are indicated by a symbol, shown in the explanation section for the map.



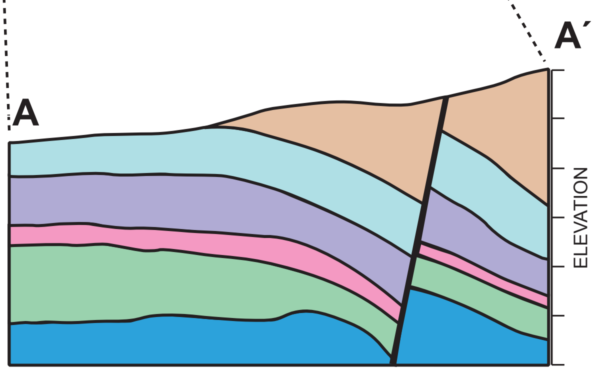
Geologic map.



Stratigraphic column. *Block diagram.*

Cross section

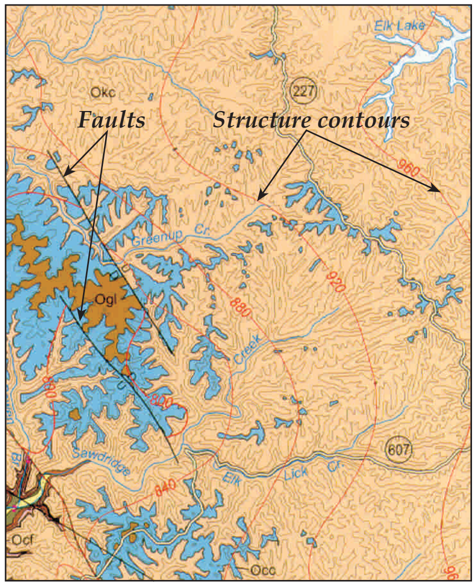
Many geologic maps include a cross section of the area represented on the map (see page 8). A cross section shows a profile of rock units as if a giant knife had sliced open the earth to reveal the relationships and orientations of different rock layers. A scale on the sides of the diagram shows elevation relative to sea level. The top of the diagram shows the topography along the surface of the cross section. The location of the cross section is shown on the map by a bold line. Cross sections show how the dips of different rock units cause them to intersect the modern topographic surface at different locations on the map. Cross sections are also useful for showing the relative movement of rock strata across faults.



Cross section.

Structure contours

All of the geologic maps for Kentucky include structure contour lines. Structure contours are used to visualize, in map view, how rock units are dipping, folded, or faulted beneath the surface. These lines can be thought of as topographic contour lines drawn on a specific rock unit beneath the surface. Data are collected from subsurface drilling to determine the elevation of the specific unit. On 1:24,000-scale maps, a single bed is generally used to illustrate structure. For the larger, 1:100,000-scale maps, many beds are used. A location map for structure is included as a small inset on the 1:100,000-scale maps, and it explains which structural horizons are used across the map.



This section of the 1:100,000-scale Lexington quadrangle map shows both structure contours (red lines) and faults (black lines; see previous page).

Geologic summaries

Many of the 1:24,000-scale maps and all of the 1:100,000-scale maps include some type of summary of the geology of the mapped area. In many cases, the history of mining for economic rock units, the hydrology (groundwater and surface water), the economic geology, and the engineering geology are summarized. References for more information are also included.

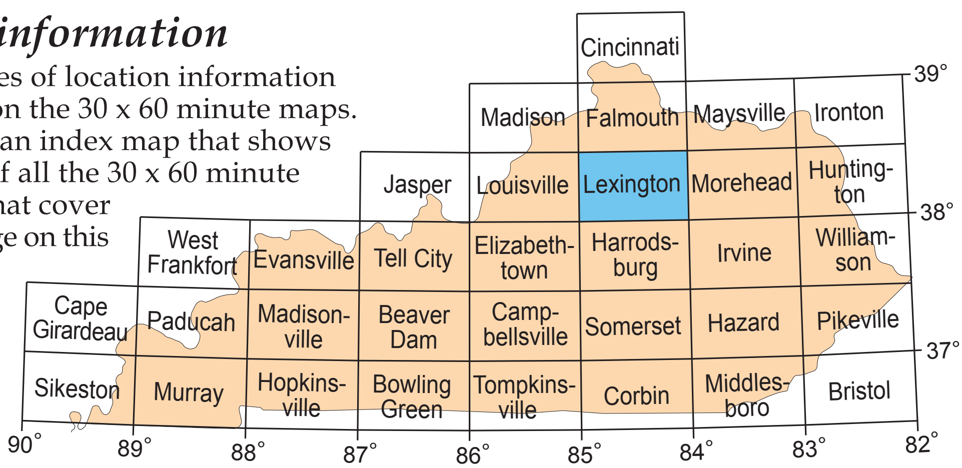
On the new 30 x 60 minute (1:100,000-scale) maps, a summary of the methods by which the map was constructed is provided. An index map also shows the locations and names of all the 7.5-minute quadrangle maps that were compiled to construct a particular 30 x 60 minute map.

Location information

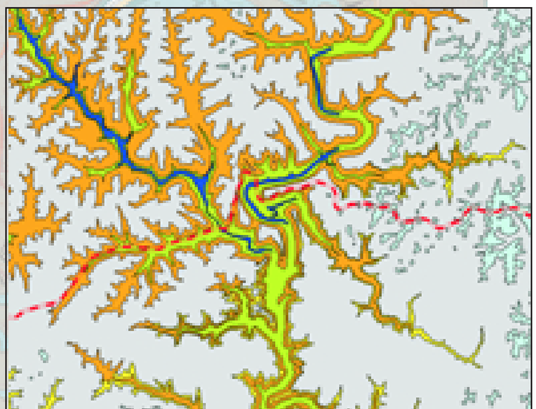
Several types of location information are provided on the 30 x 60 minute maps. Each map has an index map that shows the locations of all the 30 x 60 minute quadrangles that cover the state (orange on this example). The location of the quadrangle shown on a particular map is shaded on the index map (blue). Units of latitude are shown along the right and left sides of the map, and units of longitude on the bottom and top.

Explanation

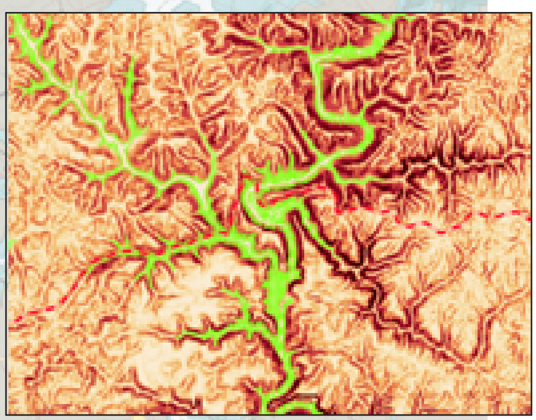
The explanation defines the different symbols and lines on the map. Different types of roads and highways are shown by different colors and line thicknesses. State, county, and city boundaries are shown. Symbols for additional geologic information, such as faults, fault types, fault directions, colors for structure contour lines, mineral and fossil deposits, and the occurrence of quarries, mines, and other man-made excavations are also shown.



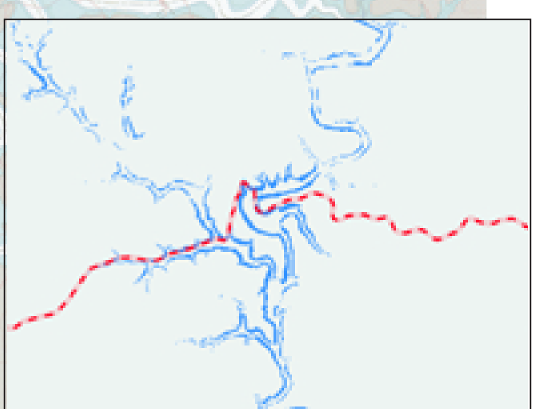
Digital geologic map data



Geology of the I-66 corridor area. The Paragon Formation is shown in green.



The surface slope (shades of brown) is superimposed on the geology.



The intersection of the two themes: the Paragon Formation and slopes greater than 30 degrees.

The Kentucky Geological Survey is publishing digitally vectorized geologic quadrangle data sets (DVGQ's), which contain geologic information digitized from the 707 original 7.5-minute geologic quadrangle maps (GQ's). The DVGQ's are unlike the original paper maps in that each type of data (for example, each rock unit, topography, faults) has been separated into a distinct layer, called a theme, so that individual themes can be used or modified as needed. Check the KGS Web site at www.uky.edu/KGS for information on the availability of individual DVGQ's. The data sets are published on CD-ROM.

DVGQ data sets allow geologic information from the map to be used with other kinds of data—such as agricultural, archeological, biological, engineering, geographical, medical—in geographic information systems (GIS) and other software. Relationships can be visualized and measured, which is useful for urban and rural development, transportation planning, water and resource management, land use, and hazard mitigation. For example, the data can be used in geologic and engineering assessments in which calculations of area, volume, and tonnage are needed. Custom-designed maps can then be prepared to meet company or project requirements.

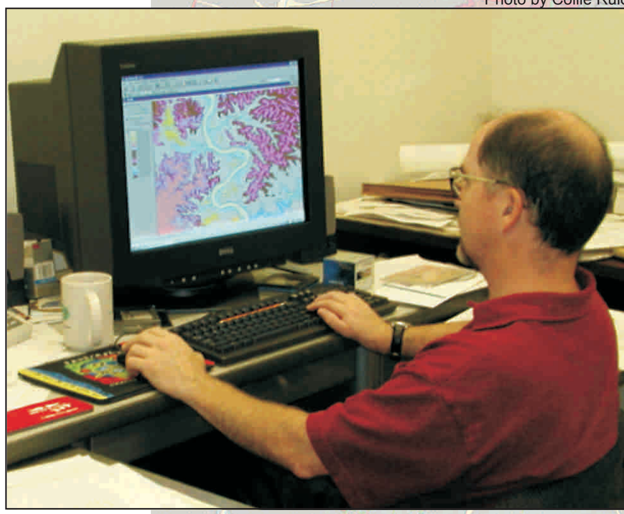
An example of the use of digital geologic map data is planning highway corridors. Geologists at KGS were asked to identify areas along a planned corridor for Interstate 66 near Somerset in south-central Kentucky that might be vulnerable to landslides. First, the geologic map for the area and existing Ky. 80 was constructed. The Paragon Formation, shown in green, consists of clay-rich shales, which can be prone to landslides, especially in areas of steep slope (greater than 30 degrees). Next, the surface slope, in shades of dark brown, was superimposed on the Paragon Formation. Slope was calculated using DVGQ data in GIS software. Finally, areas where the Paragon occurs and the slope is greater than 30 degrees were identified. The final result identified in blue the areas with greatest potential for landslides and associated future highway repair costs.

Newer and more versatile map data

Kentucky was the first state of significant size to be mapped at a scale of 1:24,000, and remains one of the few states in the nation to be completely geologically mapped at this scale. The maps were published between 1960 and 1978, and remain an important resource for Kentucky. They provided the foundation for the new 30 x 60 minute (1:100,000-scale) series.

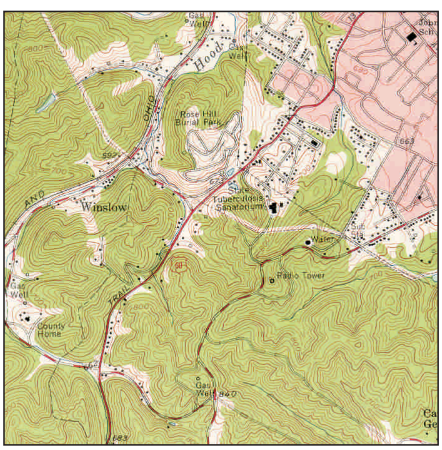
Although no new field mapping was undertaken during the compilation of the 30 x 60 minute maps, the new maps take into account the changes in geologic understanding that occurred during and following the original mapping program. Changes that could be shown appropriately at the 1:100,000 scale of the 30 x 60 minute maps were made, so that these new maps represent the current understanding of Kentucky's regional geology. The new maps also have a more regionally uniform nomenclature than do the 7.5-minute maps.

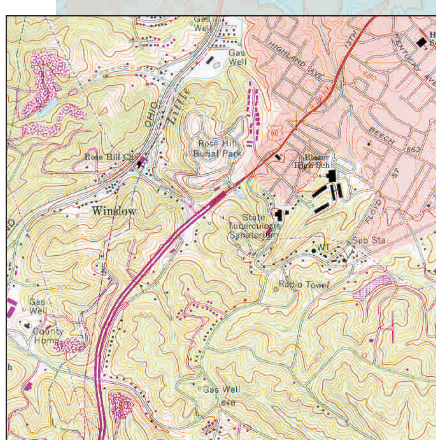
Photo by Collie Rulo



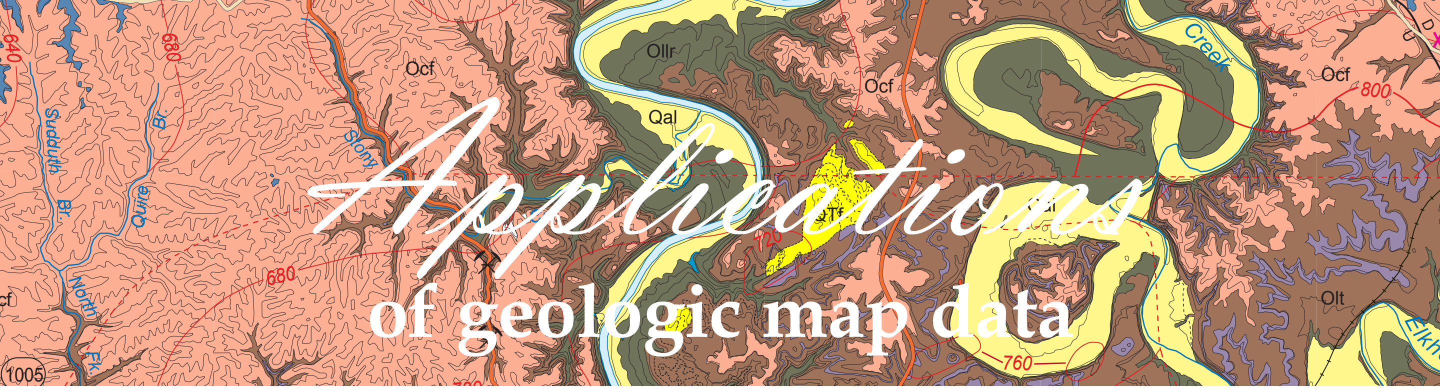
DVGQ's, can make updating map information easier and more economical.

An advantage of the 1:100,000-scale mapping program is that because the maps were compiled digitally, the information can be readily revised in the future (for example, new place names and roads can be added). More important, the DVGQ's can be amended using GIS software on personal computers, to customize map information to meet the needs of an individual user.





On the paper 7.5-minute topographic maps, updates (such as new highways) were shown in purple, but were expensive to make and were not made on any of the geologic quadrangle maps.

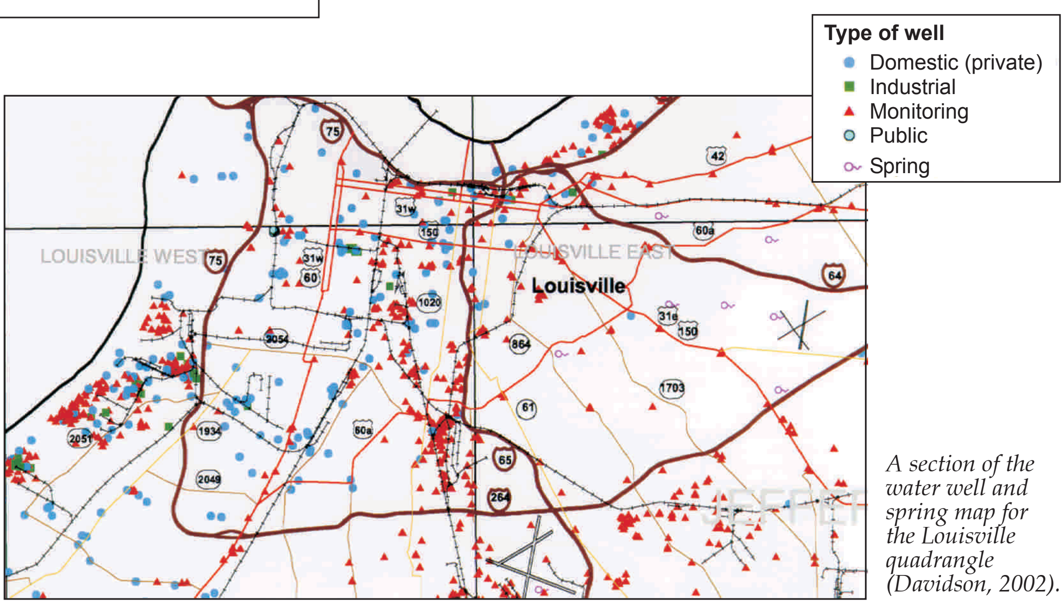


Well and spring location maps

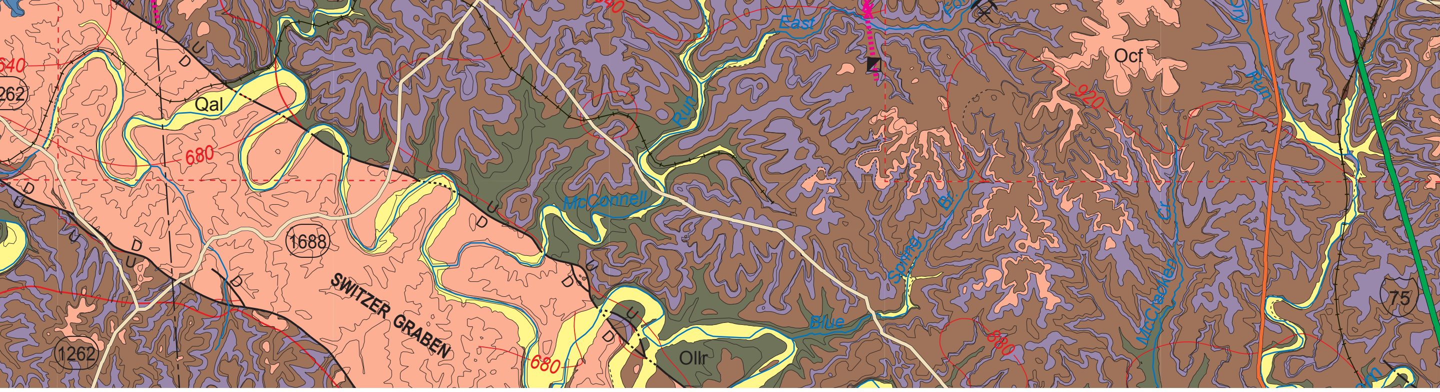
Groundwater, one of our most valuable resources, may also be one of our most vulnerable. Reliable information about water quality is necessary if citizens and communities are to develop plans to protect groundwater resources. Geologic map information can be used to identify areas with specific types of bedrock, or a particular stacking of bedrock, that may be susceptible to groundwater contamination.

- *One-quarter of Kentucky's population depends upon groundwater for its drinking-water supply*
- *Privately owned wells serve more than 500,000 residents of Kentucky*
- *Public water supplies for more than 400,000 Kentucky residents are wholly or partially dependent on groundwater (National Ground Water Association, 2001)*

Regional geologic maps can be used to help people understand regional hydrology (the properties, circulation, and distribution of water on and under the earth's surface), and design measures to protect the quality of groundwater supplies. The Kentucky Geological Survey publishes 1:100,000-scale maps that show the locations of wells and springs in selected 30 x 60 minute quadrangles across the state. These maps are different than the 30 x 60 minute quadrangle geologic maps, but are mapped at the same scale so that data from each can be used together if needed. The well and spring location maps help environmental scientists locate water wells that could be affected by environmental problems, such as chemical spills and underground petroleum storage tank leaks. Homeowners seeking a suitable groundwater supply could use the maps to locate the nearest spring or assess the chances of drilling a successful well.

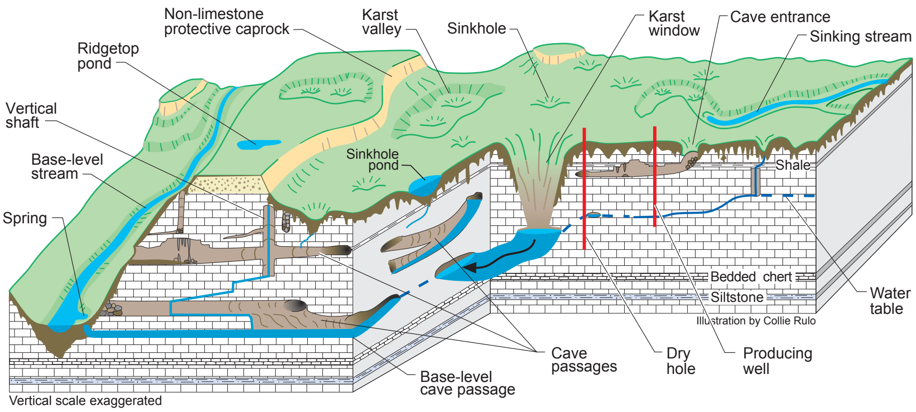


A section of the water well and spring map for the Louisville quadrangle (Davidson, 2002).



Karst groundwater basin maps

Block diagram showing typical karst features found near Mammoth Cave, Kentucky (Currens, 2001). A significant amount of groundwater in Kentucky moves through karst systems (discussed on next page).

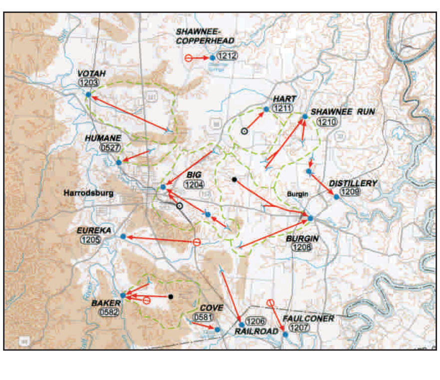


Karst areas are regions in which limestone that is susceptible to dissolving occurs near the surface. Fractures in limestone become enlarged by natural acids in groundwater, leading to the formation of sinkholes, sinking streams, caves, and springs, which are characteristic of a karst landscape. Certain rock units in Kentucky, those containing large amounts of limestone and dolomite, are more susceptible to developing karst than others. Information from the 1:100,000-scale geologic maps can be used to identify areas in which karst topography occurs.

In karst areas, a significant amount of precipitation drains directly through the soil into underground openings rather than flowing at the surface to a creek or river. Runoff water from urban and rural lands, leaking waste from landfills and underground tanks, or chemical spills from vehicle accidents drain into karst passageways below the surface, with little filtration.

Geologists use groundwater dye-tracing experiments to determine the paths groundwater or pollutants travel in karst areas. In these experiments, environmentally safe dyes are poured into a sinking stream. Packets of material that absorb the dye are attached to anchors and are placed in springs at which a geologist expects the dye to reappear.

The results of dye-trace experiments allow geologists to produce a specific type of map called a karst groundwater basin map, which shows the locations of springs, swallow holes, and groundwater flow paths. KGS has published a series of these maps, and information from them can be used by emergency-response personnel to minimize the damage to karst aquifers and drinking-water supplies, if hazardous-waste spills or other accidents introduce contaminants into a groundwater system.



Part of the 1:100,000-scale karst groundwater basin map for the Harrodsburg 30 x 60 minute quadrangle (Currens and Ray, 1998).

Natural hazards: keeping out of harm's way

The exact timing of many geologic hazards such as earthquakes, landslides, and sinkhole collapse cannot be predicted. Geologic knowledge and map information, however, can be crucial in helping people stay out of harm's way, and minimize the risk of damage to property. Steps can be taken to avoid building in areas that are prone to natural hazards, and geologic maps are essential in identifying such areas. The new 1:100,000-scale geologic maps provide valuable information for regional planners and others, which can be related to karst hazards, landslides, earthquakes, radon gas, and bedrock geology and construction.

Photo by Deanna Davis

Typical karst terrain.

Karst hazards

Topographic and geologic maps can be used to identify areas that have limestone bedrock and karst topography, which are vulnerable to hazards associated with karst, such as sinkholes, cover collapse, and flooding.

Photo courtesy of Richard McGehee, Inspector, Field Operations Branch, Kentucky Division of Water

• ***A sinkhole*** is a depression or hole in a karst area. It is circular and often shaped like a funnel. Water drains through it to the subsurface. Large sinkholes may be visible as topographic depressions on 1:100,000-scale geologic maps, but most are of a size that is more easily visible on 1:24,000-scale topographic or geologic maps.

Photo by John D. Kiefer

• ***Cover collapse*** occurs when soil collapses into an underlying crack that has been enlarged as water dissolves limestone. These features are generally not visible on geologic maps, although they can be better interpreted after the collapse by using geologic maps and karst groundwater basin maps.

• ***Flooding*** can result when the outlets of sinkholes are clogged by the accumulation of trash, construction debris, soil eroded from fields, or natural rock falls, and where sinkholes are purposely filled to make a flat area for construction. Natural and man-made obstructions block the natural drainage, and the water has to back up somewhere. This will inevitably cause flooding, either at the site of the sinkhole or somewhere along the flow path.

Photo by James C. Currens

This house in central Kentucky was built in a large sinkhole that has flooded repeatedly since 1989. The sinkhole in which it was built was so large that it was not recognized at ground level as a closed depression. The outlet from the sinkhole cannot accommodate peak runoff from upstream, so during heavy rainfall, it floods. Knowledge of the surrounding area or consulting a topographic map would help a homeowner be alert to such a hazard.

Landslides

Many factors contribute to landslides. Rock units that are rich in shale and occur on steep slopes are most susceptible to landslides. Springs and natural seeps also contribute to decreased slope stability. The 1:100,000-scale geologic maps and DVGQ's can be used to identify bedrock units that contain thick shales, occur on steep slopes, and are associated with springs. On some maps, hazards related to specific rock units are discussed in a geologic or engineering summary. In central Kentucky, the Clays Ferry Formation, Crab Orchard Formation, and shaly units within the Borden Formation are rich in clay, and therefore more prone to landslide than other rock units. In eastern Kentucky, high slopes and thick shales in the Breathitt Group result in many landslides.

Aside from the geological reasons for landslides, poor drainage on abandoned mine lands and construction sites, changes in the natural slope caused by construction, and vegetation being removed from steep slopes may all contribute to landslides. Construction in areas prone to landslides should be avoided to minimize the risk of property damage or loss of life. Swelling of certain types of bedrock after heavy rainfall can result in property damage, pipelines rupturing, masonry and foundations cracking, and expensive road maintenance. An understanding of these factors and the use of geologic maps can help homeowners, real-estate developers, and contractors make informed choices. An example of the use of geologic map information to minimize the risk of landslides occurring along a future state highway is found in the previous discussion of digital geologic map data (see page 12).

Photo by John D. Kiefer

Magnolia Street in Hickman, Ky., was damaged and later collapsed as a result of a landslide.

Earthquakes

Earthquakes occur along faults, which are large fractures within the earth. Most damage from earthquakes occurs near the location of the earthquake, but more distant areas underlain by thick unconsolidated sediments (alluvium) are also at risk of damage because of the unstable nature of the geologic material. Geologic maps are useful for determining areas of thick alluvium at the surface, which might be susceptible to hazards in earthquake-prone areas.

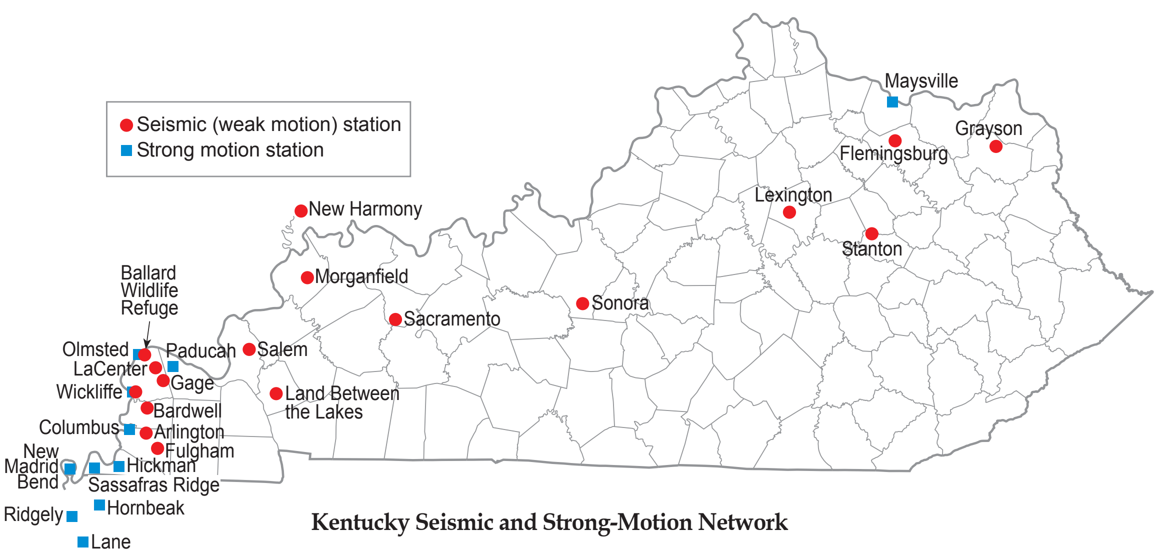

Photo by Richard E. Sergeant

Chimney damage from the 1980 Sharpsburg quake.

Three catastrophic earthquakes occurred near the town of New Madrid, Mo., during the winter of 1811–12, followed by thousands of aftershocks. The main earthquakes are estimated to have been as large as magnitude 8 (see *Glossary*). The New Madrid earthquakes damaged many structures in Kentucky, and were felt as far away as Charleston, S.C., and Washington, D.C. (Schweig and others, 1998).

The strongest recently recorded earthquake in Kentucky occurred in 1980 near Sharpsburg, Bath County, in northeastern Kentucky. The effects of this magnitude 5 earthquake were felt over all or parts of 15 states and in Ontario, Canada. This earthquake was of concern because it occurred in a region that had previously not been considered to be seismically active. It demonstrated that earthquakes can occur in many parts of Kentucky, and that the risk of property damage is not limited to western Kentucky, which is adjacent to the New Madrid Seismic Zone.

Following the earthquake near Sharpsburg, the University of Kentucky established the Kentucky Seismic and Strong-Motion Network in late 1980. Data recordings from the seismic network and bedrock information from geologic maps provide information for designing and choosing the locations for buildings, dams, bridges, highways, and pipelines, based on the type and magnitude of possible earthquakes. The network, jointly operated by the Kentucky Geological Survey and the UK Department of Geological Sciences, has 28 stations that monitor seismic activity throughout the state and the surrounding region. Real-time data from the network are available online at the KGS Web site (www.uky.edu/KGS).



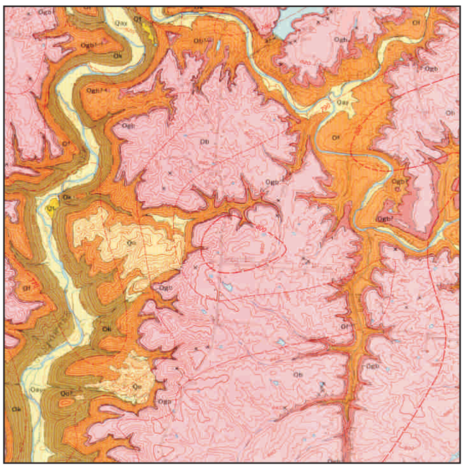
Kentucky Seismic and Strong-Motion Network

Since it began operation in 1980, the Kentucky Seismic and Strong-Motion Network has recorded data for more than 1,000 earthquakes. The Kentucky Geological Survey and the UK Department of Geological Sciences jointly operate the network.

Flooding

Ohio River flooding in Louisville. Photo by Stephen F. Greb

Flooding is a common problem along many streams and rivers in Kentucky. Overflowing streams can damage property and endanger lives. The flat bottoms of many stream valleys, called floodplains, are susceptible to flooding. Floodplains can be distinguished as areas of flat topography (widely spaced topographic contours) on topographic and geologic maps. Most floodplains are composed of sediment called alluvium, which covers the bedrock. Alluvium is commonly shown on geologic maps in shades of yellow. Flooding is also common in karst regions (see page 17), where it is not associated with floodplains.



A floodplain is commonly shown in light yellow on geologic maps.

Flood-prone area maps are specialized maps to show to administrators, planners, and engineers concerned with future land developments in those areas that are subject to flooding.

Radon gas

Homeowners should keep radon in mind when constructing homes and other buildings in some parts of Kentucky. Phosphate minerals in certain rock units frequently contain uranium, which releases radon when it decays. Radon is considered a health risk for lung cancer. The Tanglewood Member of the Lexington Limestone and the New Albany (Ohio) Shale are two rock units that can pose a problem for radon, if they form the bedrock beneath a building and proper precautions are not taken. If buildings are built on these rock units, the buildings, basements in particular, must be well ventilated so that radon gas will not accumulate. A 1:24,000-scale geologic map can be used to determine if these rock units occur beneath a house or other property. The 1:100,000-scale maps can be used to determine broader planning issues related to the extent of these rock units.

Major mineral and fuel resources of Kentucky

Photo by Stephen F. Greb

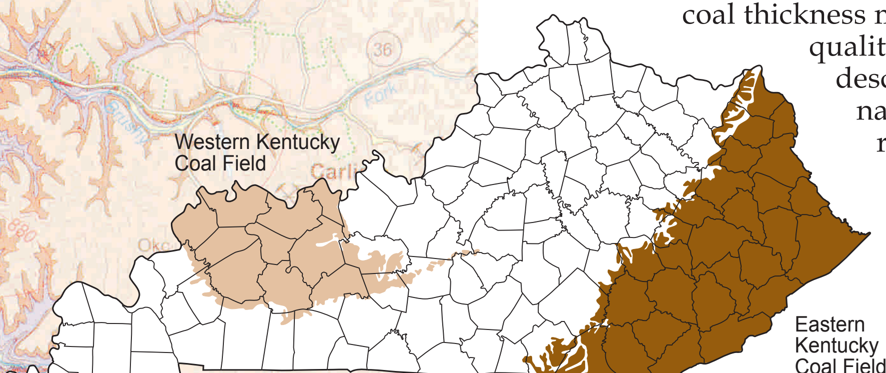
- *For more than 50 years, Kentucky has been one of the top three coal producers in the United States*
- *Kentucky produces more than 140 million tons of coal annually*
- *Ninety-five percent of Kentucky's electricity is produced from coal-fired power plants*
- *Coal is a $3.4 billion industry estimated to create $7.4 billion worth of economic activity in Kentucky (Kentucky Coal Council and Kentucky Coal Association, 2000)*

Coal

Geologic maps show the extent and surface outcrop of the principal coal beds in the state. The 1:100,000-scale maps are useful for visualizing the regional extent of coal beds. The 1:24,000-scale maps are useful for seeing local details, including the locations of mine entrances and areas of surface mining that were known when the original maps were made. Data from both scales of maps and the new DVGQ's can be used to address a wide range of resource and environmental topics related to mining.

Geologic map data can be used to determine remaining coal resources and future availability. KGS researchers used coal outcrop limits from geologic maps to determine the extent of mineable coal seams. Thickness data and mined-out-area data were combined with geologic map data to determine original coal resources. Mined-out areas were subtracted from the original resources to calculate remaining coal resources. Additional data themes have been combined with these data to interpret how much of these resources is available for mining. Coal-availability data and GIS themes are published by KGS in a digital coal atlas, which is available on CD-ROM. More information about the digital coal atlas and other coal information can be found at the KGS Web site (www.uky.edu/KGS).

Borehole records from coal exploration and development in Kentucky may be accessed on the KGS Web site. The Kentucky Coal Resources Information System (KCRIS) contains coal thickness measurements; coal quality analyses; and descriptions from natural outcrops, roadcuts, and mine exposures. These data can be used in conjunction with the DVGQ's for many applications.



Coal occurs in 57 of Kentucky's 120 counties: 20 counties in western Kentucky and 37 counties in eastern Kentucky.

Oil and natural gas

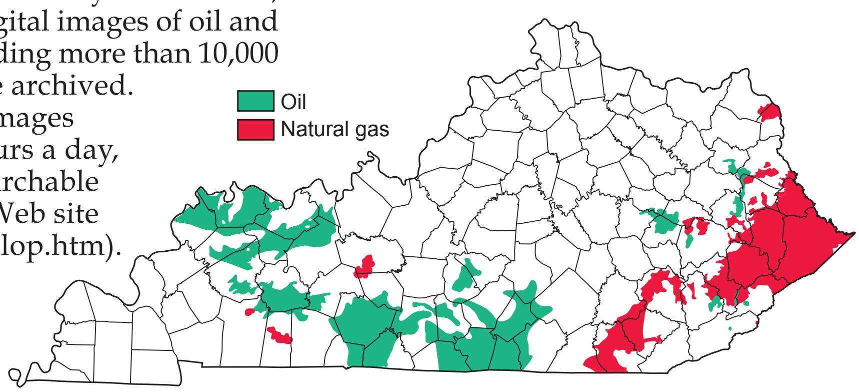
Photo by Brandon C. Nuttall

For decades, oil and gas companies have used traditional paper geologic maps to search for petroleum resources. A geologic map, by providing a graphic representation of rocks at the surface, has information essential in the search for subsurface oil and gas resources. Structure contours show the bending and folding of rock strata beneath the surface. These contours may mimic the shape of deeper rocks, and are useful for locating accumulations of oil or natural gas.

The Kentucky Geological Survey publishes 1:100,000-scale maps that show the location of oil and gas wells in selected 30 x 60 minute quadrangles across the state. These maps supplement the 1:100,000-scale geologic maps. Energy companies use oil and gas well location maps to determine the locations of available drilling data in their search to develop existing resources and discover new energy. In addition, property and royalty owners; residential, commercial, and highway contractors; coal mine and rock quarry operators; and others need to be aware of oil and gas wells for safety, environmental, and financial reasons. Digital well-location data and georeferenced oil and gas pool maps are available, and can be integrated with the digital geologic map data using a GIS software package.

Oil and gas well records archived in the Kentucky Oil and Gas Data Repository are available in digital format. At year-end 2001, more than 1 million digital images of oil and gas well records, including more than 10,000 geophysical logs, were archived. KGS has made these images available online 24 hours a day, 7 days a week, in a searchable database on the KGS Web site (www.uky.edu/pubs/lop.htm).

- *In 2000, Kentucky ranked 18th in volume of natural gas produced in the United States*
- *In 2000, Kentucky ranked 20th in volume of oil produced in the United States*
- *In 2000, nearly $15 million in severance taxes was paid on an approximate gross value of $334 million for oil and natural gas in Kentucky (Kentucky Geological Survey, 2001b)*



Oil and natural gas resources occur throughout much of western, south-central, and eastern Kentucky.

Limestone and dolomite

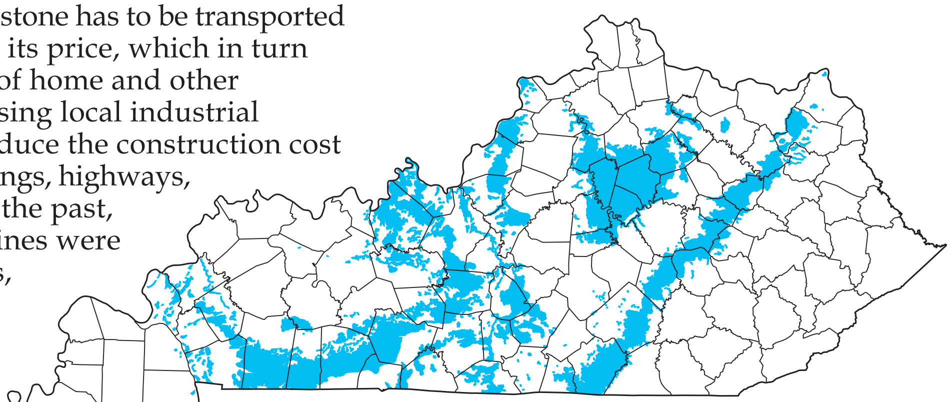
Reed Quarry in western Kentucky. Photo by Garland R. Dever Jr.

Geologic maps show the location of limestone and dolomite resources at the ground surface and the location of stone-producing quarries and mines. Kentucky has more underground limestone mines than any other state in the nation. The Reed Quarry in western Kentucky is one of the largest producers of crushed stone in the United States. Limestone is used in many ways, including as construction aggregate for highways and residential and commercial development, as a component of concrete and asphalt pavements, riprap and jetty stone to control erosion along waterways and shorelines, and as a filter in water- and sewage-treatment plants.

Approximately 10 tons of crushed stone is required annually for each Kentucky resident, and a new subdivision requires an average of 300 to 400 tons of crushed stone per home (Kentucky Crushed Stone Association, 2000). Each year, more than 4,700 pounds of concrete is produced for every person in the United States, and more than 47,000 pounds of new minerals must be provided for every person to maintain our standard of living (Mineral Information Institute, 1999, 2001).

The distance stone has to be transported largely controls its price, which in turn affects the cost of home and other construction. Using local industrial minerals can reduce the construction cost of homes, buildings, highways, and bridges. In the past, quarries and mines were more numerous, and local supplies of crushed stone kept construction costs low. With increased urban expansion and environmental sensitivities, however, fewer quarries and mines are being opened. As urban development expands, areas that could be used to mine limestone are being covered by new housing and commercial developments. Prudent long-range planning and zoning regulations should take into account current and future community needs for crushed stone, sand, and gravel, and balance them against environmental and public concerns. The 1:100,000-scale geologic maps can be useful for showing the regional surface distribution of potential limestone and dolomite resources. The DVGQ's can provide data so that knowledgeable decisions about land and resource use can be made.

- *In 2000, Kentucky ranked 13th in stone production in the United States*
- *In 2000, Kentucky produced 61.6 million tons of limestone and dolomite*
- *Kentucky is annually among the top four producers of lime in the United States*
- *In 2000, Kentucky's stone production had a value of $295 million (Kentucky Geological Survey, 2001a)*



Stone is produced from 62 of Kentucky's 120 counties.

Bedrock geology and construction

The geology of a building site, whether for a house, manufacturing plant, bridge, road, or dam, needs to be carefully considered before construction begins. Potential problems related to foundations, slope stability, drainage, and flooding can be avoided if geologic maps are used to identify suitable locations that minimize the risk of geologic hazards.

Swelling shales

Geologic maps can be used to locate rock units with shale that have the potential for swelling. In central Kentucky, the Crab Orchard Shale, the New Albany Shale, and some rock units with bentonite layers are prone to swelling when wet. When these shales are wet or occur on steep slopes, they tend to slump and slide in highway cuts, so they are unstable for highway construction. These tendencies also make them an unstable material for fill. Swelling shales may result in cracking of walls and foundations.

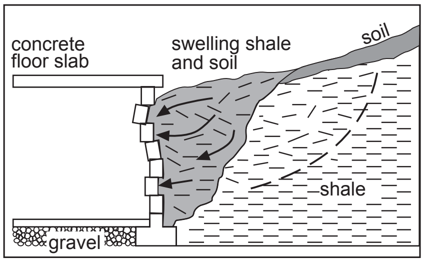
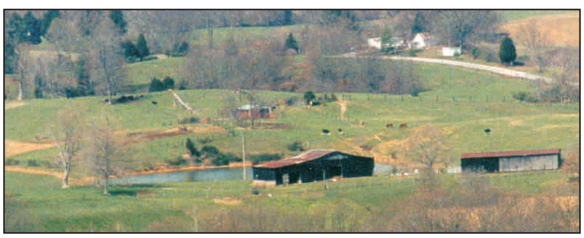


Photo by Deanna Davis



Farm ponds

Geologic maps can assist landowners in choosing a location for building new farm ponds and understanding the reasons for the success or failure of existing farm ponds. For example, in central Kentucky the Brannon Member of the Lexington Limestone, the Clays Ferry Formation, and the Crab Orchard Shale are well suited for ponds because they are clay-rich and therefore poorly permeable (in other words, water will not readily leak through them) (Smith, 1966).

Building stones

Many of the houses, churches, and public buildings of Louisville, Frankfort, Lexington, and other Kentucky communities were constructed with blocks of limestone and dolomite cut from local quarries. The famous stone fences of the Bluegrass Region are constructed from limestone cleared from the fields of central Kentucky. In western and eastern Kentucky, sandstone was used as building and facing stones in many public buildings. Geologic maps can be used to determine the source of building stones in historical houses, for identifying sources of facing and building stone for new construction, or for refurbishing historical buildings.

Photo by Collie Rulo

Photo by Stephen F. Greb

Quarried stone is used in many of our buildings and picturesque fences.

Photo by Brandon C. Nuttall

Distinctive Kentucky industries

Geologic maps help explain why many of Kentucky's industries and resources occur where they do.

Geologic maps can be used to identify the locations of springs and the characteristics of rock units at the surface that enrich the soil and enhance agriculture in Kentucky. In fact, soil and agriculture maps rely on information from the geologic maps, because soils are natural products of the bedrock. For example, the Curdsville, Grier, and Tanglewood Members of the Lexington Limestone in central Kentucky contain phosphate minerals (apatite or calcium phosphate) that are natural fertilizers. Areas in central Kentucky where these rock units occur at the surface have rich soil suitable for growing corn, burley tobacco, and other crops. The combination of fertile soil and spring water containing dissolved calcium and phosphate from the limestone contributes to a unique environment for strong bone growth in grazing animals (calcium phosphate is the dominant inorganic component of bone). The bedrock geology, as illustrated on the geologic maps, indicates why the world-famous thoroughbred race horse industry is centered in this part of the state.

Photo by Stephen F. Greb

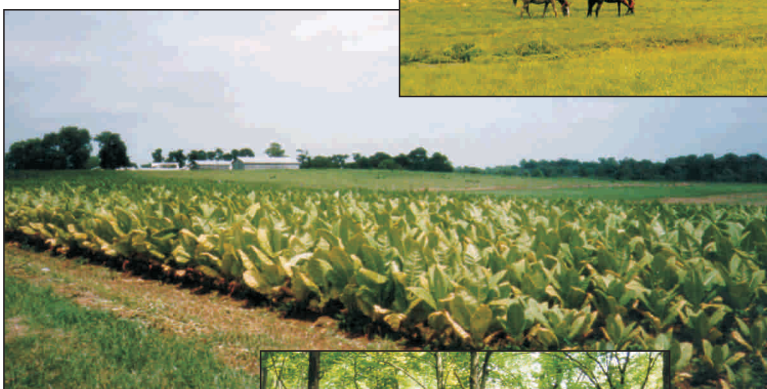


Photo by William M. Andrews Jr.

Photo by Douglas W. Reynolds Jr.

The fresh spring water and rich soil suitable for growing corn, wheat, and rye contribute to the renowned Kentucky bourbon industry. Highbridge Springs bottled natural spring water is also produced from a former limestone mine in central Kentucky.

Tourism is another important industry. Kentucky is famous for its many caves, including Mammoth Cave, the world's longest cave. The natural arches of the Red River Gorge area, the waterfall and gorge at Cumberland Falls, the cliffs atop Pine Mountain, and many of the natural, distinctive features of Kentucky's state resort parks are related to bedrock geology. Cross sections, rock unit descriptions, and summaries on geologic maps can be used to better understand these scenic attractions.

Summary

Geologic maps are not common household items, but the problems that can be addressed by using them are common. Problems such as landslides, sinkholes, flooding, and groundwater supply and protection can be assessed using geologic maps. The new 1:100,000-scale map series being published by the Kentucky Geological Survey provides information to allow visualization of the surface geology of broader areas, not easily seen on the previously published 1:24,000-scale geologic quadrangle maps. The new maps are ideal for regional and county-level planning. They will be useful for private and public decision-making in the construction of highways, watershed management, wetland restoration, land-use planning, and for making other decisions that require geologic information. The new digitally vectorized geologic quadrangle data sets (DVGQ's) published on CD-ROM provide added convenience and utility. The DVGQ's allow users to combine geologic information from the 1:100,000-scale maps with other kinds of data (for example, agricultural, archeological, biological, engineering, and geographical) in GIS and other software. Users will then be able to create custom-designed maps that meet company or project requirements.

Kentucky was the first state in the nation to be topographically mapped at a scale of 1:24,000. Kentucky was also the first major state to be geologically mapped at a scale of 1:24,000. Now Kentucky is on the verge of becoming the first state to be digitally mapped at a scale of 1:100,000. The geologic information gathered from these maps can be used to address many issues and prevent many problems that affect our daily lives. It is the authors' intention that this citizen's guide contribute to a better understanding of the information on geologic maps, as well as the value of geologic maps. This will allow citizens to understand how the information on geologic maps can help them address issues and problems of interest in their communities, for the benefit of the Commonwealth of Kentucky.

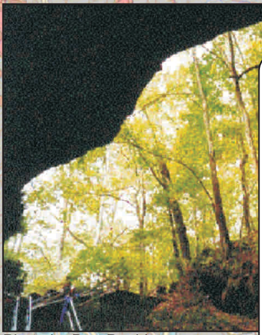
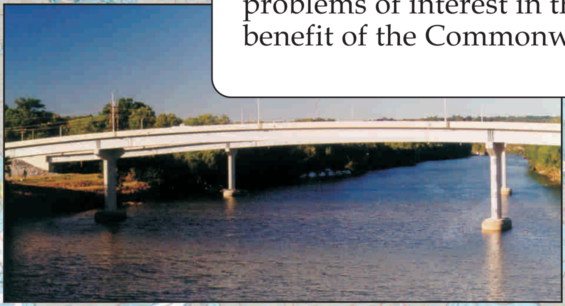


Photo by Bart Davidson


Photo by Collie Rulo


Photo by Brandon C. Nuttall


Photo by James C. Currens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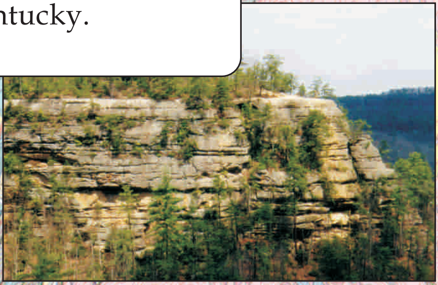
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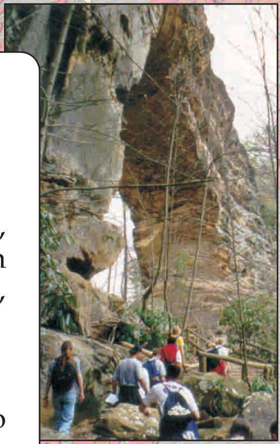
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Glossary[1]

Clay—An earthy, extremely fine-grained sediment or soft rock composed primarily of clay-size particles (less than 0.002 mm). The materials are very plastic (“squeezable,” as in modeling clay).

Coal—A rock that burns, which is formed from the alteration of plant deposits (peat) by heat, pressure, and time.

Dike—A tabular igneous intrusion that cuts across the bedding of the surrounding rock.

Dolomite (do´-lo-mite)—A sedimentary rock composed of carbonate rock with high magnesium content. It is also a common sedimentary mineral composed of a calcium and magnesium carbonate, $CaMg(CO_3)_2$; it is similar to the calcium carbonate mineral calcite, but with the addition of magnesium. Dolomite is white, colorless, or tinged yellow, brown, pink, or gray. It is also a common vein mineral.

Fault—A surface or zone of surfaces separating two rock masses across which one mass has been offset relative to the other.

Formation—A body of rock strata that can be mapped, consisting generally of a certain lithologic type, combination of types, or bedding types that are distinctive from overlying and underlying rock strata. Formations may be subdivided into members and beds.

Gravel—A sedimentary deposit composed of particles (greater than 2 mm or 1/12 in.), such as boulders, cobbles, pebbles, granules, or any combination of these fragments larger than sand.

Group—A named sedimentary unit or package composed typically of several named formations (see formation above).

Karst—A type of topography that is formed on limestone, gypsum, and other rocks, primarily by dissolution. It is characterized by sinkholes, caves, and water draining underground. It is a German word from the Yugoslavian territory Krš, a limestone plateau in the Dinaric Alps of northwestern Yugoslavia and northeastern Italy.

Landslide—A general term for a wide variety of processes and landforms involving the movement downhill, under gravity, of masses of soil and rock material. Examples include soil creep, earth flow, mudflows, slumping, rockslides, and rockfalls.

Latitude—A common radial measure of distance north and south of the equator. Units are measured in degrees, minutes, and seconds (for example, 85°55'00").

Limestone—A sedimentary rock composed largely of the calcium carbonate mineral calcite. Limestone commonly contains fragmented seashells (also composed of calcite).

Longitude—Distances east and west of the prime meridian. Units are measured in degrees, minutes, and seconds (for example, 85°55'00").

Magnitude—A measure of the strength of an earthquake, or the energy released by it. Earthquakes with a magnitude less than 3.5 are usually not felt, but are recorded by instruments called seismographs. Magnitude 6 earthquakes can cause damage over small areas. A magnitude 8 earthquake causes serious damage over several hundred miles.

Member—A subdivision of a formation (see *formation* above).

Quadrangle—A rectangular area bounded by parallels of latitude and meridians of longitude, used as a unit in mapping. The dimensions of a quadrangle are not necessarily the same in both directions, and its size and the scale at which it is mapped are determined by the prime purpose of the map.

Sand—A sediment composed of grains between 0.05 and 2 mm in diameter.

Sandstone—A sedimentary rock formed by the natural cementation of grains of sand. The sand particles usually consist of the mineral quartz.

Shale—A fine-grained sedimentary rock, formed by the compaction of clay, silt, or mud. The rock readily breaks into thin layers, especially on weathered surfaces. It may be red, brown, black, or gray.

Siltstone—A rock formed by the cementation of silt-size grains (0.002 to 0.05 mm in diameter), excluding calcite silt.

Sinkhole—A depression in the surface of the earth in an area with karst. At the surface it is commonly circular and can measure yards or tens of yards in diameter. It drains below the surface and is commonly funnel-shaped.

Swallow hole—A closed depression into which all or part of a stream disappears underground.

Topography—The position of natural or physical and man-made features of any part of the earth's surface, including its relief (highest point to the lowest point on the surface).

[1]For more information, please refer to *Glossary of Geology* (4th edition), edited by Julia A. Jackson (1997, American Geological Institute, 769 p.).