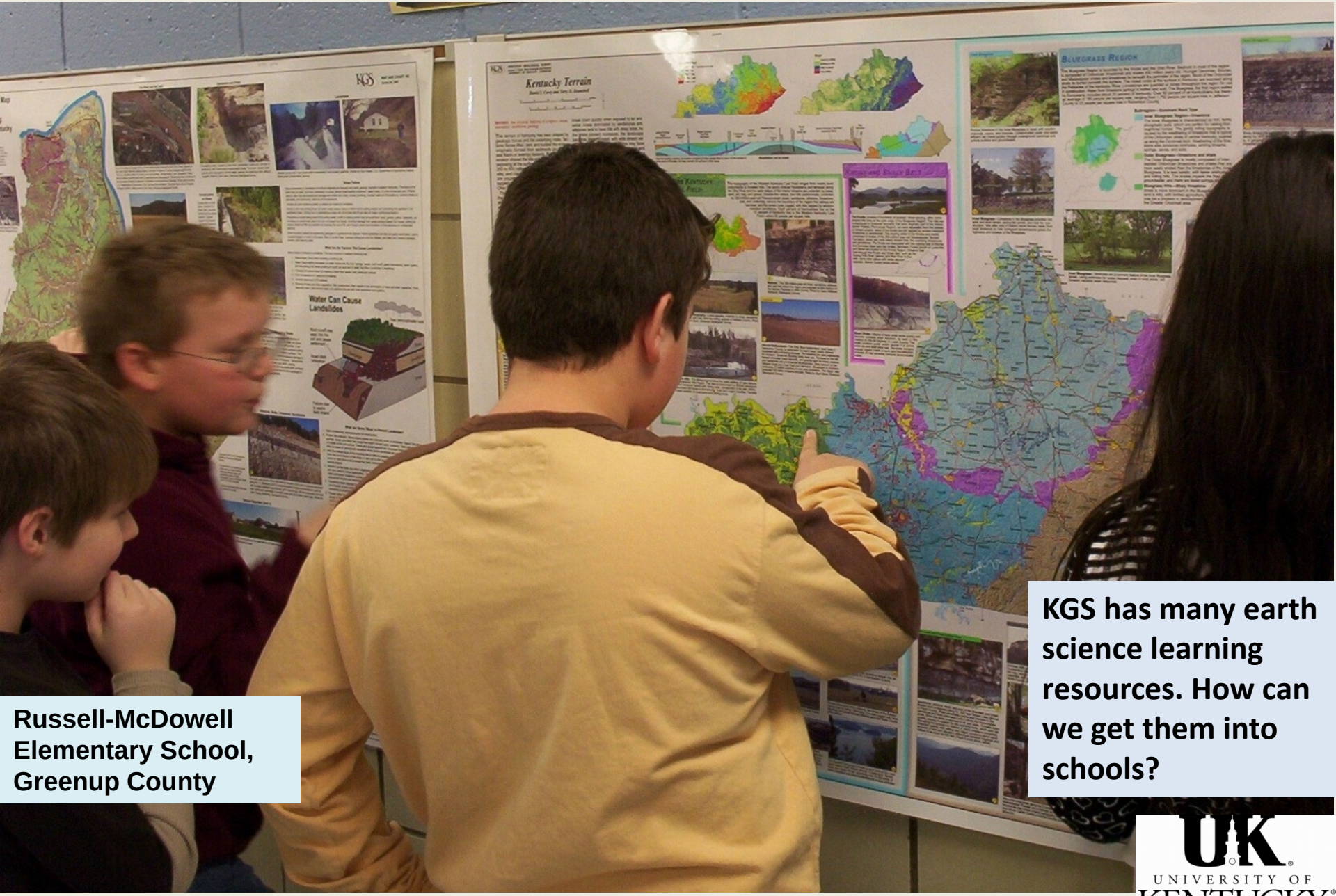
MAPS-TO-TEACHERS: LEARNING ABOUT WHERE WE LIVE



Russell-McDowell Elementary School, Greenup County

KGS has many earth science learning resources. How can we get them into schools?

Earth Science Resources from the Kentucky Geological Survey

UK UNIVERSITY OF KENTUCKY
Kentucky Geological Survey

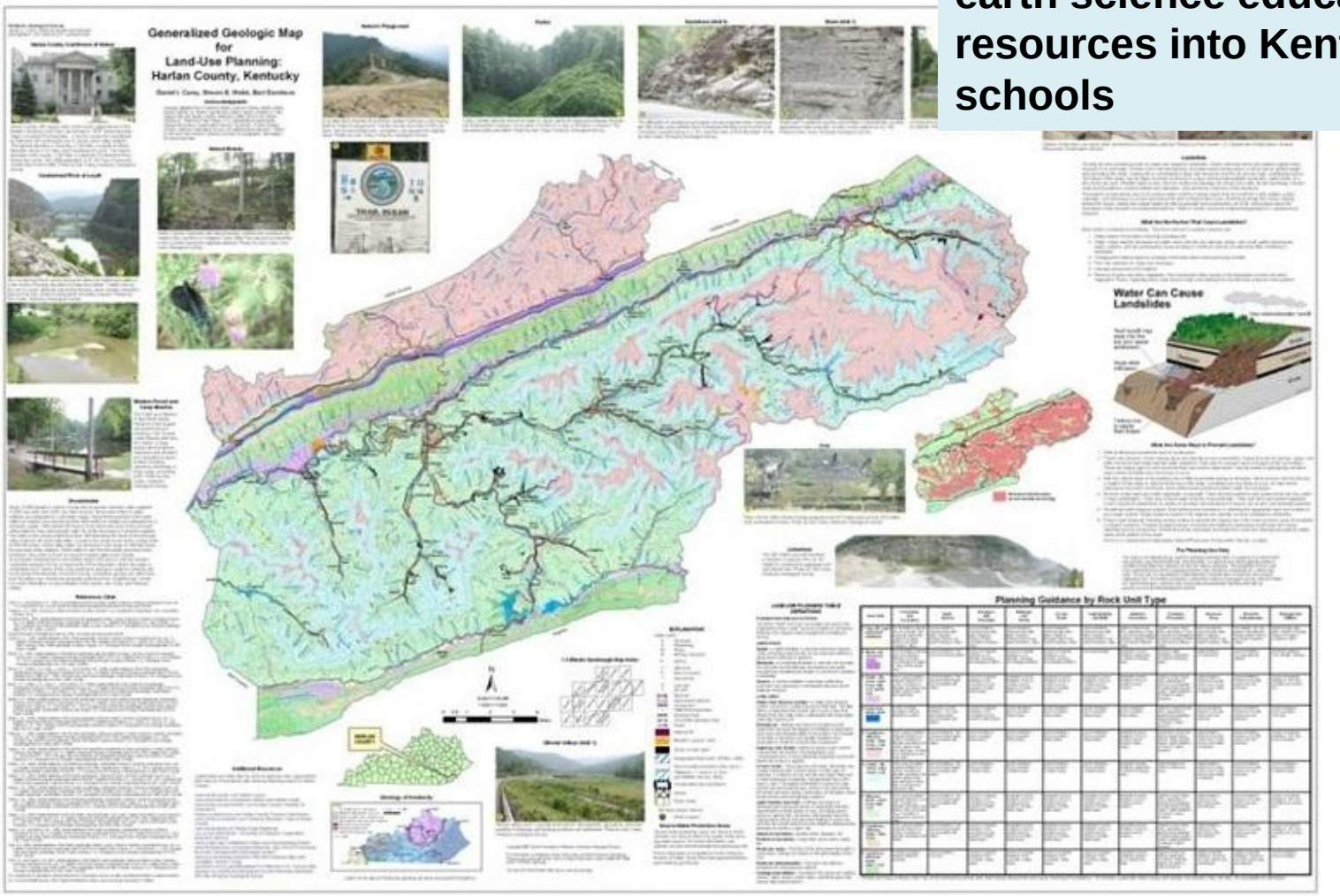
Kentucky Teachers Using Geological Survey Maps in Classrooms

Lexington, KY. (February 22, 2009) Hundreds of teachers across the state have responded enthusiastically to the offer of free county geology maps from the Kentucky Geological Survey (KGS) at the University of Kentucky. Over 1,000 of these maps have been sent to classrooms in over 400 schools in nearly every Kentucky county since November, 2007 through a Maps-to-Teachers service.

The map series, Generalized Geologic Maps for Land-Use Planning, was developed to help non-geologists understand the geology of the place where they live, work, and play. Maps have been completed for each of Kentucky's 120 counties. "The maps are ba
that Kentucky carried out in the 1960's and '70's," says map series developer Dan Carey of KGS. "The origina
geologists from KGS, state agencies, federal agencies, and the private sector volunteered their time and exp

"When we first started making the maps," Carey adds, "the idea was to help people avoid the damages of
make the news but cost millions of dollars each year across the state. As we continued to develop the maps,
students and the public better understand how the rocks beneath their feet shape the land and the ways that

Maps-to-Teachers program was created to get KGS earth science education resources into Kentucky schools

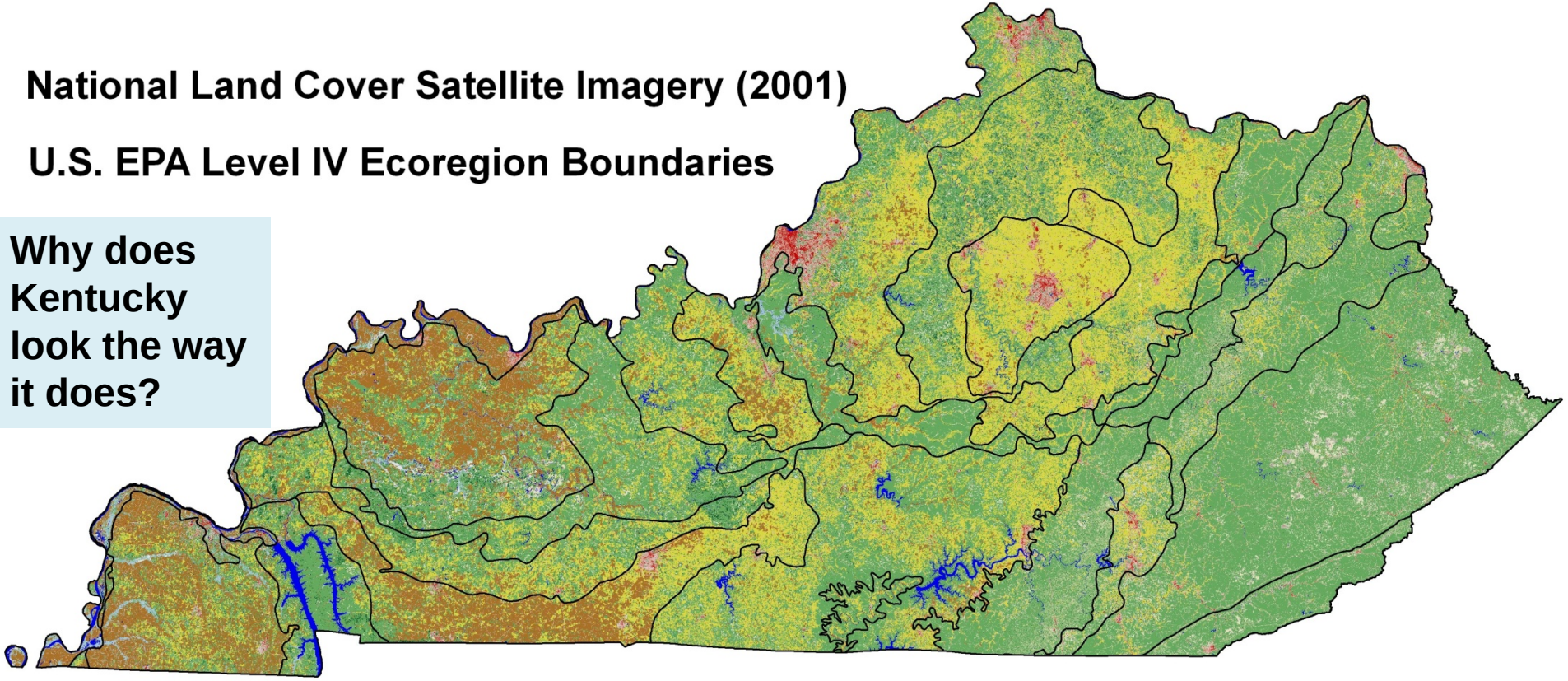


The Harlan County edition (1/32 size) of the Generalized Geologic Map for Land-Use Planning.

Learning earth science from the place where we live. Kentucky as a textbook

Kentucky From Space

Satellite land cover imagery overlain with Level IV eco-region boundaries reveals distinctive regions of Kentucky.



Why does Kentucky look the way it does?

Kentucky contains about 40,405 square miles, or 25,859,200 acres, of land and water. Even from space, the distinct regions of Kentucky can be seen.

Physiographic Regions

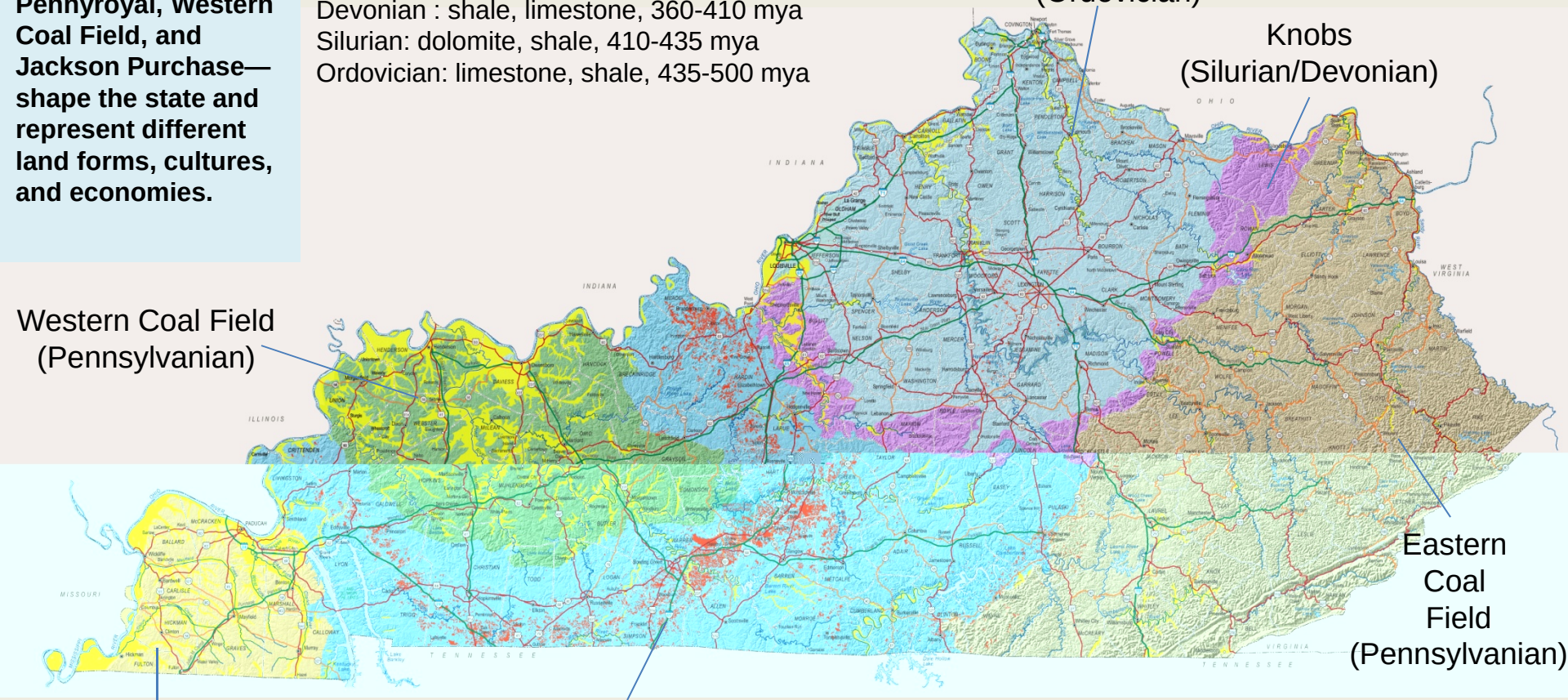
Geology Shapes the Land

The physiographic regions of Kentucky are defined by geology—Eastern Coal Field, Blue Grass, Knobs, Pennyroyal, Western Coal Field, and Jackson Purchase—shape the state and represent different land forms, cultures, and economies.

When the regions were made
Geologic era , rock types, million years ago (mya)

Tertiary/Cretaceous: sand, clay, 2-140 mya
Pennsylvanian: shale, sandstone, coal, 290-330 mya
Mississippian: shale, limestone, sandstone, 330-360 mya
Devonian : shale, limestone, 360-410 mya
Silurian: dolomite, shale, 410-435 mya
Ordovician: limestone, shale, 435-500 mya

Students can use KGS maps, diagrams, and posters to learn how and when Kentucky was formed



Kentucky Geological Survey
James C. Cobb, State Geologist and Director
UNIVERSITY OF KENTUCKY, LEXINGTON

The Building of Kentucky

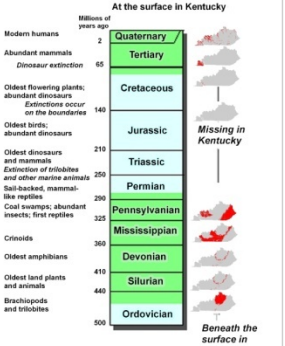
Daniel I. Carey

KGS MAP AND CHART Series XII, 2010

INTRODUCTION

The geologic story of the rocks that form the foundation of Kentucky began a half a billion years ago when the area was covered by water. Deposits of sand, silt, clay, and lime muds in shallow seas, deltas, swamps and river systems accumulated over the next 250 million years, layer upon layer. As each layer was covered by another, the sediments were compressed and solidified into the sedimentary rocks that we see today. Clay became mudstone and siltstone; loose sand and silt became sandstone and siltstone; shells, shell fragments, lime oozes, and chemical precipitates became limestone; peat swamps became coal. The ages of rocks in each region, together with a synopsis of the development of life during the period are shown in Fig. 1.

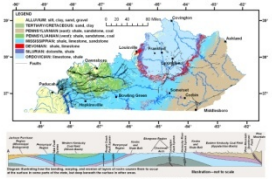
Fig. 1 The Ages of Kentucky



Granites and metamorphic rocks are deeply buried in Kentucky. There is no evidence of local volcanoes. There are only a few instances (Crittenden and Elliott Counties) where deep-seated igneous rocks have been pushed to the surface.

Tectonic forces and erosion bent, folded, and carved the sedimentary rocks into distinctive regions (Figs. 2 and 3).

Figure 2. General Geology of Kentucky



Learn more about Kentucky geology at www.uky.edu/KGS/geoky/

THE LANDSCAPE OF KENTUCKY

Kentucky's natural regions, scenic geologic features, and fossil-fuel, mineral, and ground-water resources are directly related to the underlying rock strata. Most of the areas underlain by sandstone, primarily the Eastern and Western Coal Fields, are either hilly or mountainous because sandstones resist weathering and erosion more than other rocks. Caves, sinkholes, sinking creeks, large springs, and other features associated with underground drainage are found in limestone terranes typical of the Mississippi Plateaus and the Blue Grass Region. The Mississippi Embayment, which was once part of a large coastal plain that extended to the Gulf of Mexico, is the youngest geological region in Kentucky, covered by unconsolidated sand, silt, and gravel.

Figure 3. Physiographic Regions of Kentucky

Physiographic Diagram of Kentucky, Kentucky Geological Survey, series 12, Map and Chart 25, 2001

Stream erosion has been the predominant geological force sculpturing and modifying the Kentucky landscape since the close of the Paleozoic Era. Younger rocks were eroded from the crest of the Cincinnati Arch, leaving older Ordovician rocks exposed at the surface of the Blue Grass region. Away from the Blue Grass, the rocks are progressively younger. The softer or weaker rocks eroded faster than harder, more resistant ones. Thus, we see escarpments such as Muldraugh Hill (knobs area), Dripping Springs Escarpment at the outer edge of the sinkhole plain, and the escarpments at the edges of the eastern and western coal fields. For more about the landscape of Kentucky, see Kentucky Terrain: Kentucky Geological Survey, Map and Chart 187, series 12, 2008.

Acknowledgements

All Paleomap images from Scotese, C.R., 2002, www.scotese.com (PALEOMAP website)

GEOLOGIC HISTORY OF KENTUCKY

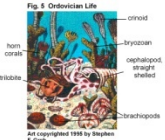
The oldest rocks exposed at the surface of the ground in Kentucky are hard limestones of Middle **Ordovician** age (Fig. 4). They are found along the Kentucky River gorge in central Kentucky between Boonesboro and Frankfort. Older rocks are present in the subsurface but can be seen only in drill cuttings and cores taken from oil and gas drilling and mineral exploration. Later in Ordovician time the seas became relatively shallow. In the clear and warm shallow seas, a profusion of animal life flourished, particularly brachiopods and bryozoa (Fig. 5). These are the rich fossil beds which have attracted amateur and professional paleontologists to the stream beds, rocky hillsides, and roadcuts of the Blue Grass Region.

Fig. 4 The Ordovician World, 440 to 500 Million Years Ago

Ordovician Fossils

During most of the Ordovician, Kentucky was covered by shallow tropical seas. Accordingly, the fossils found in Kentucky's Ordovician rocks are marine (sea-dwelling) invertebrates. Common Ordovician fossils found in Kentucky include sponges (Porifera), corals (Cnidaria), bryozoans, brachiopods, trilobites, snails (gastropods), clams (pelecypods), squid-like animals (cephalopods), crinoids (Echino-dermata), and microscopic animals like ostracodes and conodonts. Straight-shelled nautiloids (squid-like cephalopods), shown below right, are common fossils in the Bluegrass Region. Some have been found that are nearly four feet long. A fully-preserved 450-million-year-old crinoid is shown below. Photo by Rick Schrantz, Kentucky Paleontological Society.

Fig. 5 Ordovician Life



Art copyrighted 1998 by Stephen F. Greb.

Ordovician Sea Life

Ordovician sea-floor trilobites (left) of different sizes. Right, cephalopod chasing trilobites. Illustrations by Stephen F. Greb, Kentucky Geological Survey.

Ordovician brachiopod preserved for 440 million years found in Bath County. Photo by Rick Schrantz, Kentucky Paleontology Society.

Fig. 6 The Silurian World, 415 to 440 Million Years Ago

When sediments that formed the Silurian rocks were deposited 425 million years ago, the seabed that was Kentucky contained algae, eurypterids, worms, shrimp, and early fish.

Silurian Fossils

Art copyrighted 1995 by Stephen F. Greb.

Silurian seas were commonly warm and clear, although the presence of some shale beds suggests that muddy conditions prevailed at times. Numerous corals and brachiopods can be found in the Silurian limestones and dolomites. During the Silurian Period, gentle folding began creating a major upwarp, or arching, of the rock strata, which extends from the Cincinnati, Ohio, area, through the central Blue Grass region, southeastward across the State toward Nashville, Tennessee. This upwarping raised part of the land above sea level and temporarily separated two major geological basins.

Silurian rocks are exposed at the surface in the Knobs Region, which rings the Blue Grass Region. Silurian rocks are absent in the Blue Grass, but occur below the surface in other parts of Kentucky. During most of the Silurian, Kentucky was covered by shallow tropical seas (Fig.6). However, some very low lands may have been emergent in central Kentucky at times. All Silurian fossils are marine (sea-dwelling) invertebrates. Common Silurian fossils in Kentucky include corals (Cnidaria), bryozoans, brachiopods, trilobites, snails (gastropods), clams (pelecypods), squid-like animals (cephalopods), crinoids (Echinodermata), and microscopic animals like ostracodes and conodonts.

Halysites, the chain coral, is common in some Silurian rocks in Kentucky. Photo by Rick Schrantz, Kentucky Paleontological Society.

The 420-million-year-old remains of Silurian Eurypterus lacustris, found near Bardstown, are beautifully preserved by crystalline dolomite (right). Photo by Rick Schrantz, Kentucky Paleontological Society.

Fig. 7 The Devonian World, 355 to 415 Million Years Ago

By the Devonian the early Paleozoic oceans were closing, forming a "pre-"Pangaea". Freshwater fish were able to migrate from the southern hemisphere continents to North America and Europe. Forests grew for the first time in the equatorial regions of Arctic Canada.

Upwarping of the Cincinnati Arch continued during the first part of the **Devonian** Period as evidenced by the absence of outcrops of rocks of Early Devonian age in central Kentucky. The Cincinnati Arch has been a significant feature in the determination of rock-outcrop pattern and regional topography in the State.

Devonian rocks are exposed at the surface in the Knobs Region, which rings the Blue Grass Region. Devonian rocks are absent in the Blue Grass Region, but occur below the surface in other areas of Kentucky. During most of the Devonian, Kentucky was covered by shallow tropical seas (Fig. 7), although some very low lands may have been emergent at times in central Kentucky. During the later part of the Devonian, deep seas covered Kentucky, and the water was poorly oxygenated at depth. Dark organic-rich muds were deposited, producing the Devonian black shales in Kentucky, which contain oil shales and are a potential source for a variety of fossil fuels. Much of the oil and gas found in Kentucky originally came from these Devonian black shales.

All the Devonian rocks found in Kentucky are marine and consequently all the fossils are marine (sea-dwelling) invertebrates and vertebrates. Common Devonian fossils found in Kentucky include sponges (Porifera), corals (Cnidaria), bryozoans, brachiopods, trilobites, snails (gastropods), clams (pelecypods), squid-like animals (cephalopods), crinoids (Echinoderms), and microscopic animals like ostracodes and conodonts.

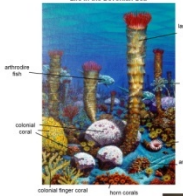
Probably the most common sponge fossils found in Kentucky are the stromatoporoids, or stroms for short. Stroms are calcareous sponges that form mounds 2 to 3 feet across on the sea floor. Stroms still exist today in moderately deep water. Devonian stroms can be seen at the Falls of the Ohio near Louisville.

Fossil bones of giant arthrodires, sharks, and other fish have been found in the Devonian rocks in the Knobs Region of Kentucky. Some giant arthrodires, with sharp cutting beaks, grew to more than 20 feet in length and fed on sharks.

The most commonly found plant fossils in the Devonian black shales of Kentucky are silicified logs (called Callixylon) of the seed-fern tree, Archaeopteris. Several silicified fossil logs from these shales in Kentucky are on display at the Smithsonian Institution in Washington, D.C. Rarely, foliage from these and other plants is found in these Devonian shales.

Perhaps the most famous fossil coral outcrop in the world is the Falls of the Ohio near Louisville. Many solitary and colonial coral fossils can be seen in the rocks exposed in this protected area. Access to the outcrop is best on the Indiana side of the Ohio River (through the Falls of the Ohio State Park), although the exposures are actually in Kentucky.

Life in the Devonian Sea



A large armored fish (arthrodires) swimming among assorted corals and smaller fish in the Devonian sea. Illustrations courtesy of Stephen F. Greb, Kentucky Geological Survey.

Devonian sponge (left) and branching coral (right) lived 385-million-years-ago. Photos by Rick Schrantz, Kentucky Paleontological Society.

Fig. 8 Kentucky during the Mississippian, 325 to 360 Million Years Ago

Mississippian rocks are exposed at the surface in the Mississippian Plateau (Pennyroyal or Pennyrile) Region and occur below the surface in both of the coal fields. Mississippian rocks are absent in the Blue Grass Region and in most of the Knobs.

During most of the Mississippian, Kentucky was covered by shallow tropical seas (Fig. 8), although some very low lands may have been emergent at times in central Kentucky.

Black shale continued to be deposited briefly during the Mississippian Period but soon gave way to a great influx of muds, silts, and sands brought in by rivers and streams from uplands many miles to the northeast and deposited as a great delta. Peculiar markings on some slabs of siltstone are indications of water currents and sea-bottom life.

When Mississippian seas cleared, great thicknesses of limestone were deposited in the warm, shallow waters during the middle part of the Mississippian. Many caves were later developed in these limestones, and this area is now known as one of the world's most famous karst (cave-bearing) areas. The world's longest cave system, Mammoth Cave, is in these limestones.

Periodically, during the later part of the Mississippian, tidal deltas and low coastal plains covered large parts of Kentucky. These periods of coastal environments alternated with periods when the sea came in and inundated the region.

Most of the Mississippian rocks found in Kentucky are marine, and many of the fossils in them are marine (sea-dwelling) invertebrates. Common Mississippian fossils found in Kentucky include corals (Cnidaria), bryozoans, brachiopods, trilobites, snails (gastropods), clams (pelecypods), squid-like animals (cephalopods), crinoids and blastoids (echinoderms), fish teeth (Pisces), and microscopic animals like ostracodes and conodonts. When there was emergent land in the form of low coastal plains, land plants and animals lived. Land plants such as seed ferns, true ferns, scale trees, and calamite trees grew in these coastal areas. Amphibians, such as the one recently found in western Kentucky, lived in estuaries and ox-bow lakes. Insects and other arthropods were probably numerous on land.

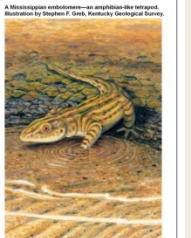
Many types of sharks lived in Kentucky at that time; some had teeth for capturing swimming animals and others had teeth especially adapted for crushing and eating shellfish such as brachiopods, clams, crinoids, and squid-like animals (cephalopods).

Only one amphibian fossil has been found in Kentucky (in 1995). It was found in Mississippian sandstones on the margin of the Western Kentucky Coal Field. This amphibian was about 5 feet long and had a long, streamlined body. It probably lived most of the time in water and ate fish and other small amphibians and reptiles.

Mississippian Sea Life

Art copyrighted 1995 by Stephen Greb.

130-million-year-old shark teeth from the Mississippian. All fossil photos by Rick Schrantz, Kentucky Paleontological Society.



A Mississippian embolomere—an amphibian-like tetrapod. Illustration by Stephen F. Greb, Kentucky Geological Survey.

Fig. 9 Kentucky during the Pennsylvanian, 290 to 325 Million Years Ago

During the **Pennsylvanian** parts of Kentucky were covered intermittently by shallow seas (Fig. 9). The climate was warm, and extensive forests grew in great coastal swamps at the edge of the water. Marine waters advanced and receded many times. Pennsylvanian rocks are both marine and non-marine, with the latter predominating. Giant ferns and trees grew in these luxuriant forests. During times of heavy rainfall, thick accumulations of plant debris (peat) were deposited. Vegetation of all sorts fell into the water and was buried under blankets of deltaic clays, silts, and sands. Clay sealed the vegetation from oxygen, preventing decay. The weight of sediments over long geologic time compressed vegetation into coal. The process was repeated many times, thus accounting for the numerous coal beds in Kentucky's two coal fields.

Pennsylvanian rocks are only preserved in the Eastern and Western Kentucky Coal Fields, although all of Kentucky was probably covered by Pennsylvanian sediments at one time. Erosion has completely removed Pennsylvanian rocks from all areas but the coal fields. The Pennsylvanian Period, often called the Coal Age, was a time of alternating land and sea. When the sea was out, the low coastal plains were covered with luxuriant forests of seed ferns, ferns, scale trees, calamite trees, and cordaite trees.

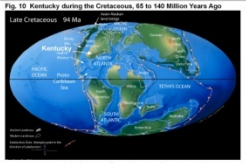
When sea level rose, which it periodically did, it covered the coastal peats and created large inland muddy seas. During these times, which lasted for many thousands of years, many types of marine (sea-dwelling) invertebrates and vertebrates lived in Kentucky. Common Pennsylvanian marine fossils found in Kentucky include corals (Cnidaria), brachiopods, trilobites, snails (gastropods), clams (pelecypods), squid-like animals (cephalopods), crinoids (Echinodermata), fish teeth (Pisces), and microscopic animals like ostracodes and conodonts.

300-million-year-old plant fossils from the Eastern Kentucky Coal Field. Above, horsetail plant, annularia. Above right, another annularia form. Right, seed fern. Photos by Rick Schrantz, Kentucky Paleontological Society.

Peat forming swamps, also known as "mires", formed over Kentucky during the Pennsylvanian. The coal beds are the remains of these swampy landscapes. This reconstruction by Mary Parrish, Smithsonian's National Museum of Natural History, shows a forest dominated by a mixture of lycopsid trees (front right, also with juvenile trees), tree ferns (left, with fronds), and giant rushes (sprouting out from the trunks), seed ferns (center, trees with crowns of broad-like fascicle), and calamites (right edge near foreground, with branches in whorls). The forest is open and includes many vines and low-growing plants.

A millipede (left) fossil was found recently in Pennsylvanian rocks of the Western Kentucky Coal Field. This millipede had large spines all along its body. The first insect fossil found in Kentucky (1980) was an insect wing from the Pennsylvanian rocks of the Eastern Kentucky Coal Field. It came from an animal that had a wing span of about 4 inches, looked somewhat like a dragonfly, (right) and could not fold up its wings. Other insect fossils will probably be found in Kentucky. Illustrations by Stephen F. Greb.

Fig. 10 Kentucky during the Cretaceous, 65 to 140 Million Years Ago



A series of uplifts followed the Paleozoic Era in Kentucky. Seas receded and the land became dry for a long period of time. Much of Kentucky's landscape is a product of erosion which began at that time. No rocks remain in Kentucky reflecting the nearly 200-million-year-old Mesozoic period, which includes the Permian, Triassic, and Cretaceous.

During the latter part of the **Cretaceous**, the Gulf of Mexico inundated much of the southern United States (Fig. 10). A long bay extended northward from the Gulf, covering all of the Jackson Purchase and adjacent portions of the Mississippian Plateaus with sands, clays, and gravels. These geological deposits are a marked contrast to the underlying hard Paleozoic rocks because to this day most of the Cretaceous sediments remain unconsolidated and soft.

Fig. 11 Kentucky during the Tertiary, 65 Million Years Ago

Deposition of marine and fresh- to brackish-water sediments continued in the Jackson Purchase area during **Tertiary** time (Fig. 11). Distribution of deposits indicates that the area was near the northern limit of the Gulf embayment (also called Mississippi Embayment). Portions of the embayment must have been swampy because thin beds of lignite and carbonaceous clays occur in the western half of the eight-county Jackson Purchase area.

Pleistocene glaciations (1.8 million to 10,000 years ago, Fig. 12) played only a minor role in the geologic history of Kentucky as compared to the extensively glaciated states of Illinois, Ohio, and Indiana. The southern margin of the continental ice sheet only reached Kentucky in the vicinity of Covington. It did, however, affect the course of the Ohio Valley upstream from Cincinnati and at Louisville, and glacial meltwaters filled the valley with deposits of sand and gravel. The ice sheet or floodwaters from the melting glacier temporarily obstructed the flow of some northward-flowing streams such as Licking, Kentucky, Salt, and Green Rivers, causing local drainage modifications and leaving remnants of slack-water or lake-bottom sediments various distances upstream.

Fig. 12 Kentucky during the Ice Age, 18,000 Years Ago

Driven by plate tectonics, the face of the Earth continues to change. In another 250 million years—a period shorter than the age of sedimentary rocks in Kentucky—the world will again look quite different (Fig 13).

Fig. 13 The World 250 Million Years into the Future

Where was Kentucky during geologic history, what kind of creatures lived here, and why is the land the way it is?

Where was Kentucky when the rocks were born?

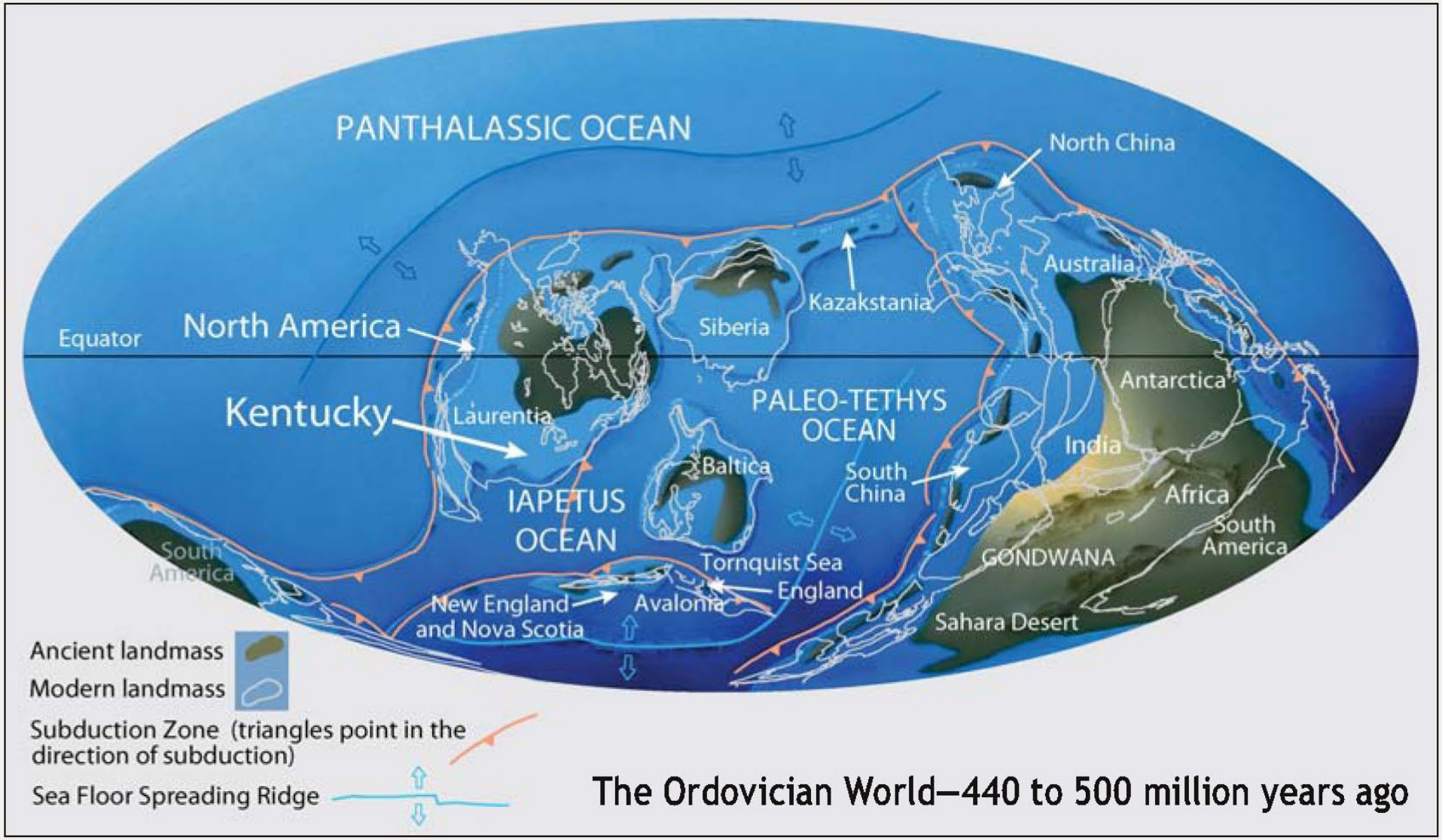
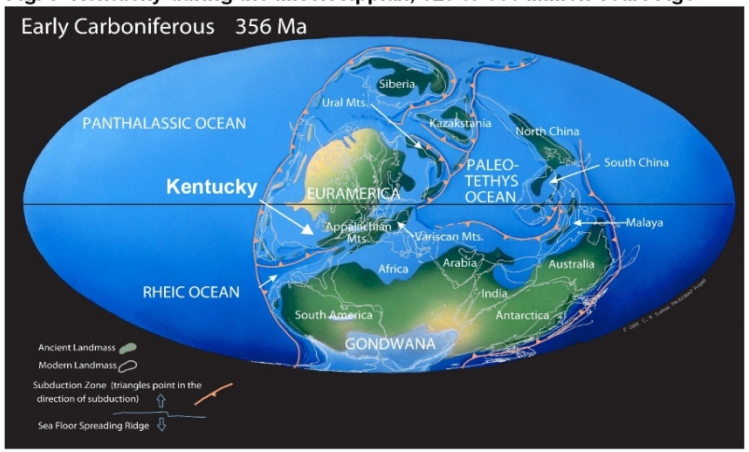


Fig. 8 Kentucky during the Mississippian, 325 to 360 Million Years Ago



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Wher f limestone were deposited in the warr ssissippian. Many caves were later de known as one of the world's most far gest cave system, Mammoth Cave, is

What were the plants and animals?

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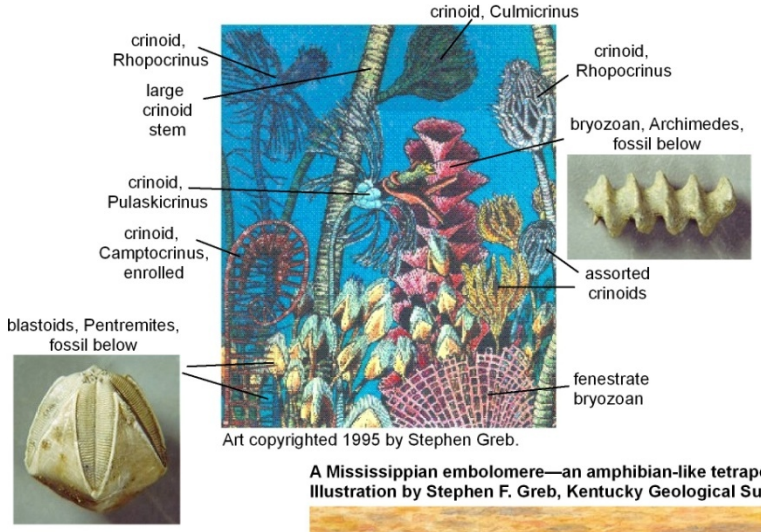
Mississippian Sea Life

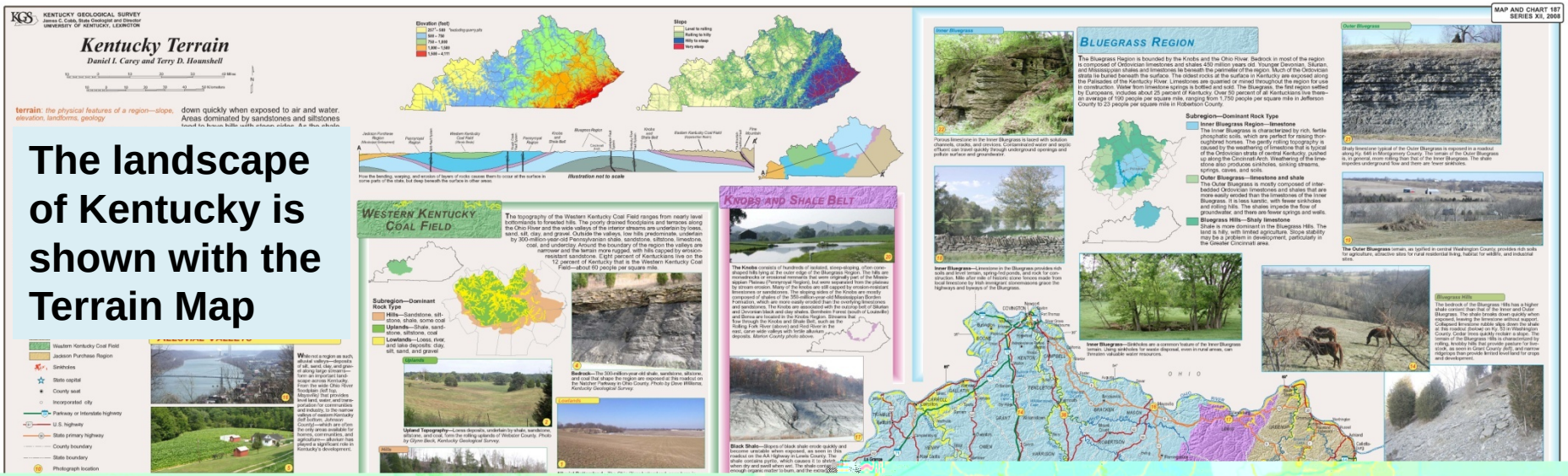


Art copyrighted 1995 by Stephen Greb.

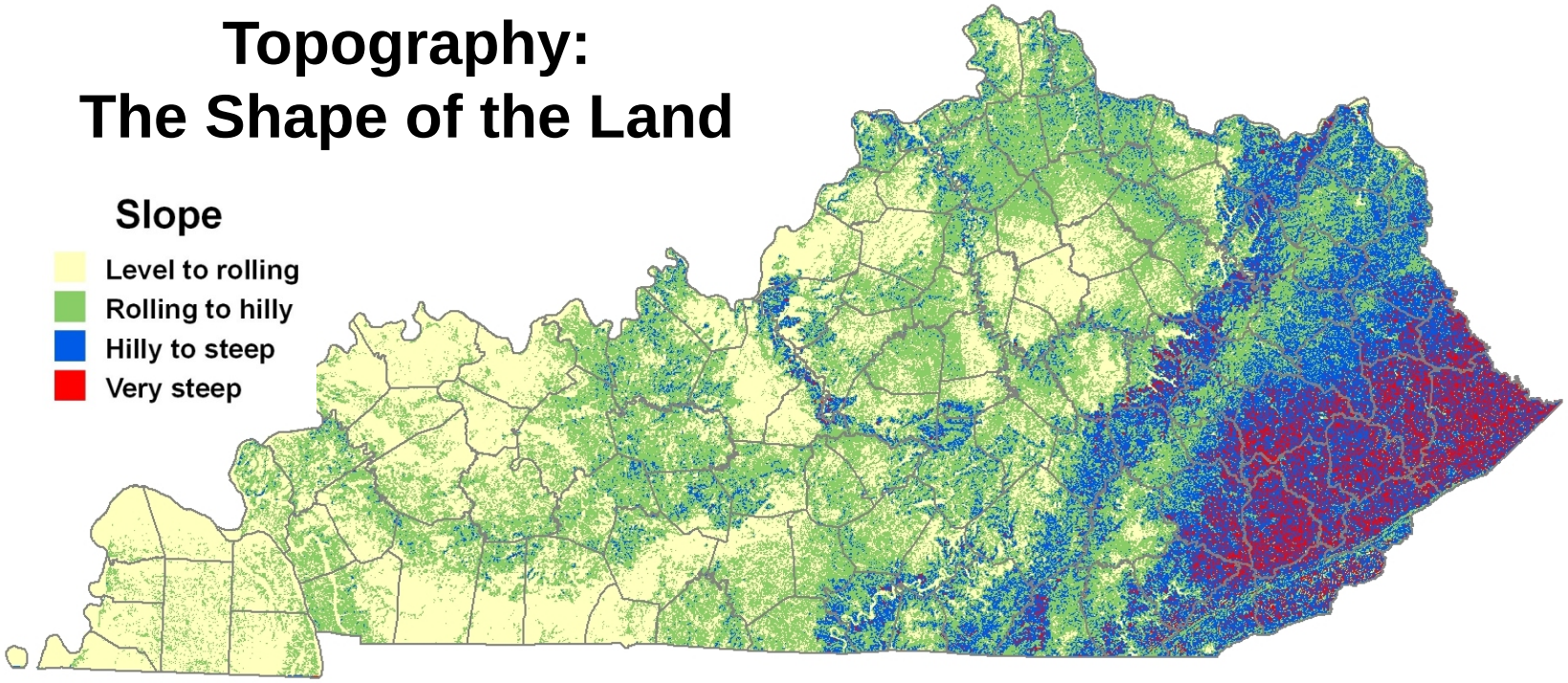
A Mississippian embolomere—an amphibian-like tetrapod. Illustration by Stephen F. Greb, Kentucky Geological Survey.

330-million-year-old shark teeth from the Mississippian. All fossil photos by Rick Schrantz, Kentucky Paleontological Society.

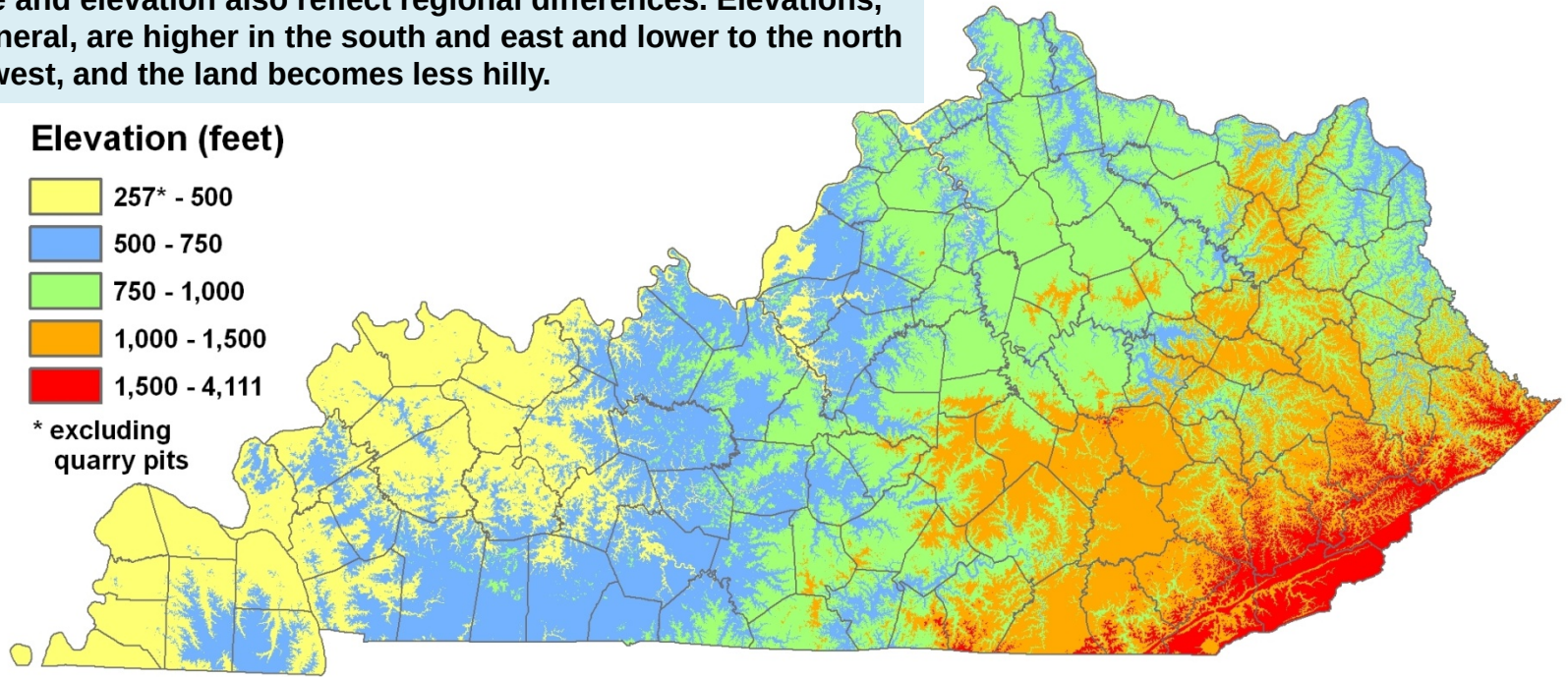
The landscape of Kentucky is shown with the Terrain Map



Topography:
The Shape of the Land

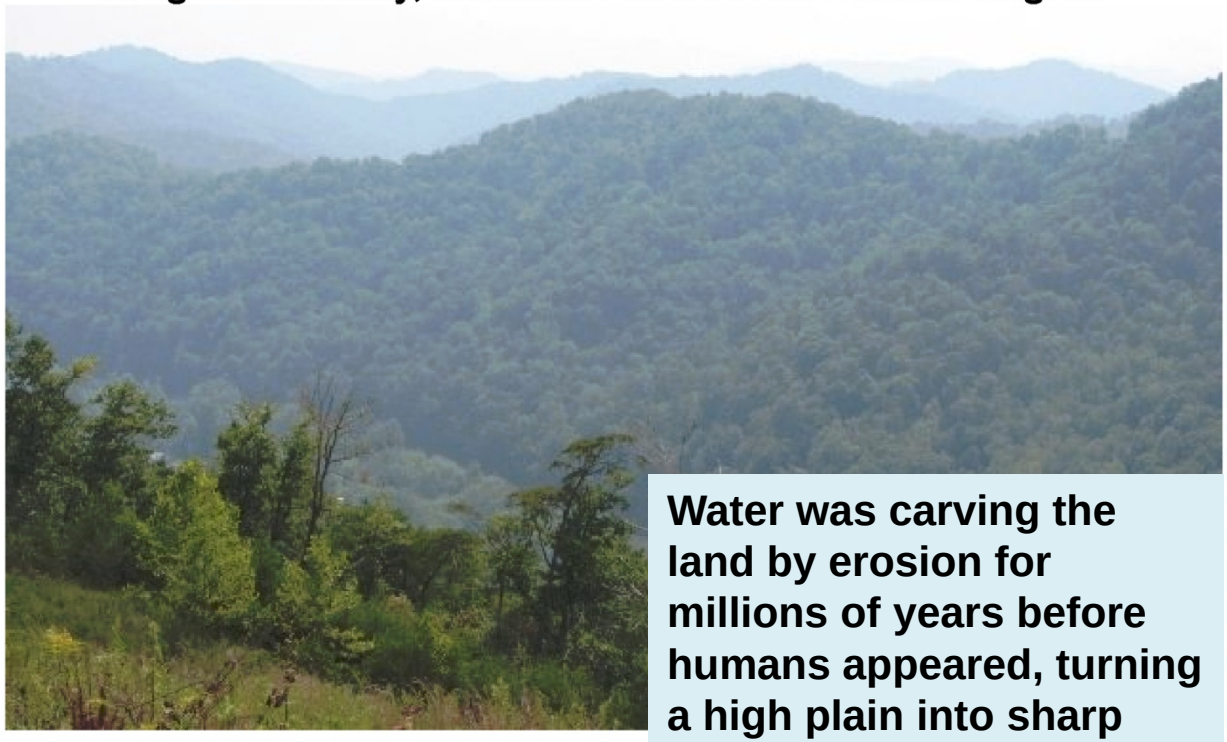


Slope and elevation also reflect regional differences. Elevations, in general, are higher in the south and east and lower to the north and west, and the land becomes less hilly.



Ridge and Valley, Mountain and Creek Bottom Region

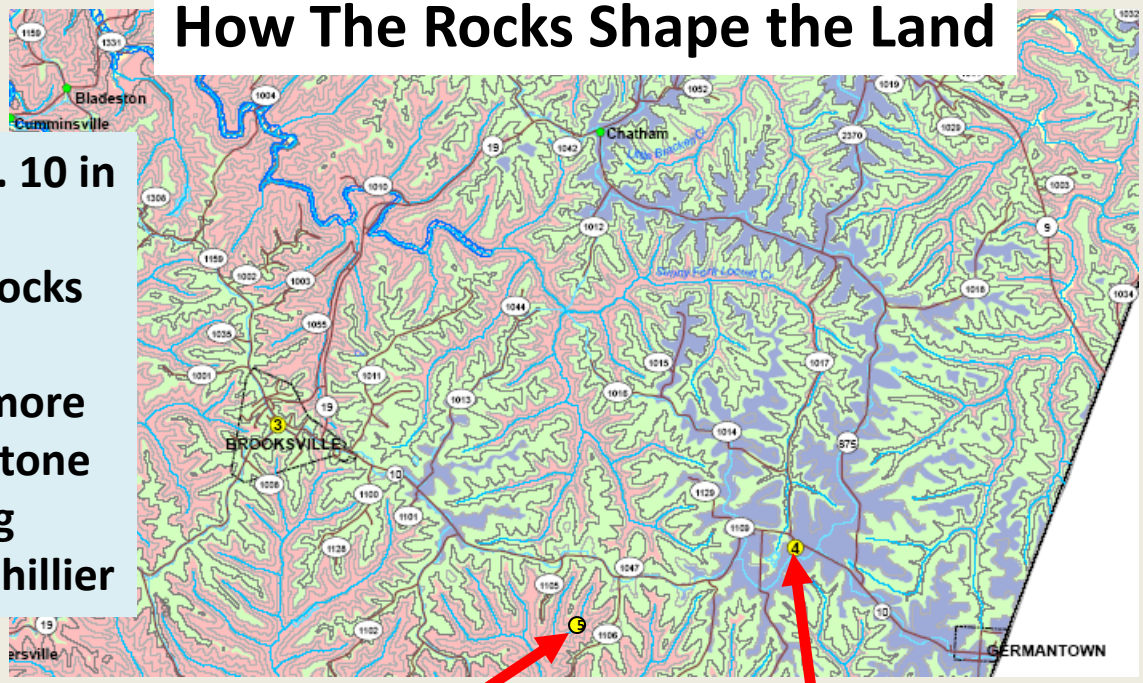
Millions of years of erosion were required to reduce an ancient plateau to the ridges and valleys we now see. Floyd County (right) is completely dissected upland, with valleys and ridges occupying about equal amounts of land and elevation differences between ridge tops and valleys of as much as 900 feet. In Knott County (below right) the ridges are rounder and the hills float like humpbacked creatures in a vast sea. Photos by Dan Carey, Kentucky Geological Survey.



Water was carving the land by erosion for millions of years before humans appeared, turning a high plain into sharp ridges and narrow valleys,

How The Rocks Shape the Land

A drive down Ky. 10 in Bracken County illustrates how rocks shape the land. Where there is more shale than limestone in the underlying rock, the land is hillier



Where limestone dominates, the land is flatter and better for agriculture

Shaly Limestone Terrain

Limestone Terrain

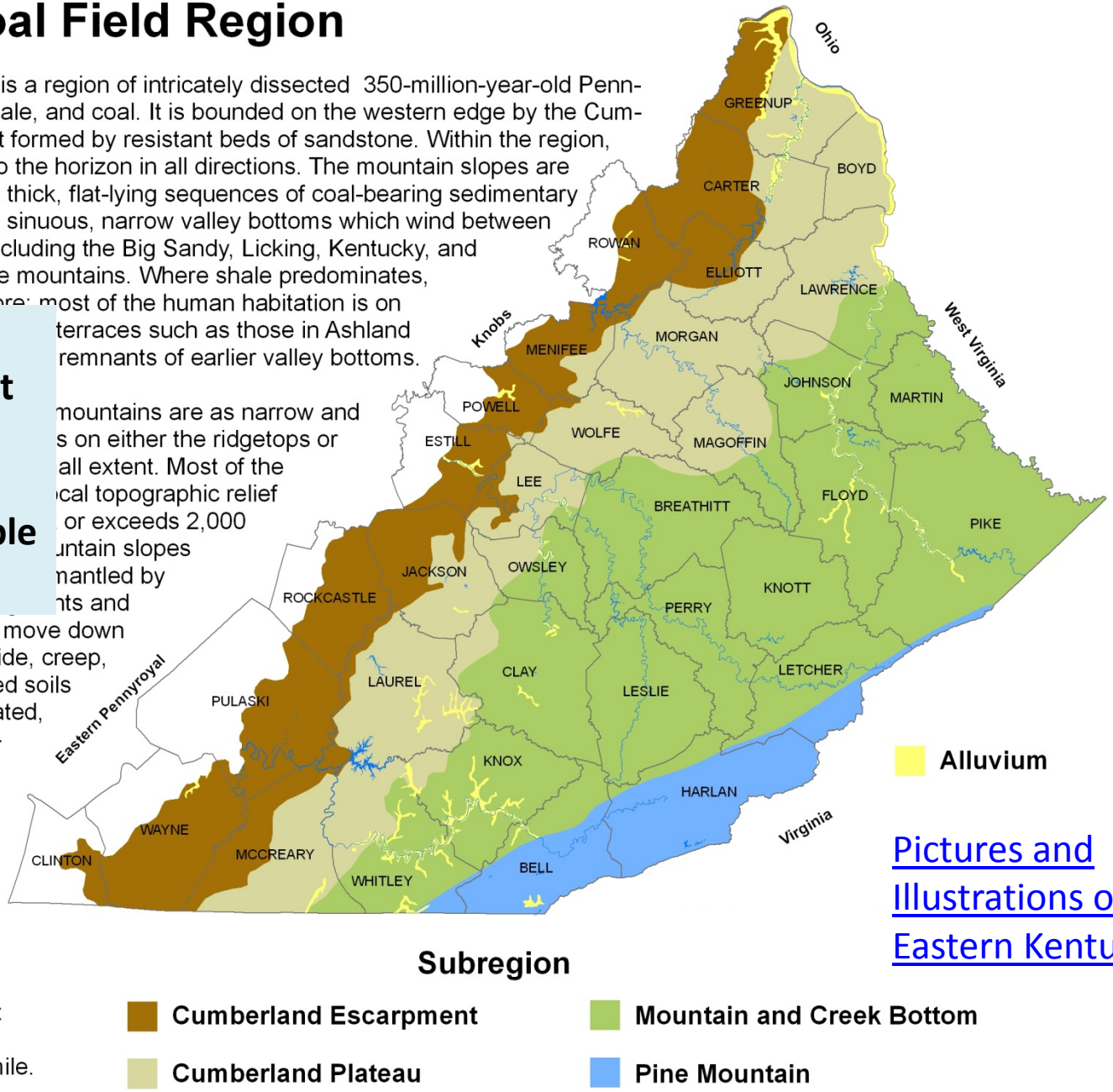
Eastern Coal Field Region

The Eastern Kentucky Coal Field is a region of intricately dissected 350-million-year-old Pennsylvanian sandstone, siltstone, shale, and coal. It is bounded on the western edge by the Cumberland (or Pottsville) Escarpment formed by resistant beds of sandstone. Within the region, wooded mountain crests extend to the horizon in all directions. The mountain slopes are carved by ravines eroded through thick, flat-lying sequences of coal-bearing sedimentary rocks. The ravines are tributary to sinuous, narrow valley bottoms which wind between steep valley walls. Major rivers, including the Big Sandy, Licking, Kentucky, and Cumberland, meander through the mountains. Where shale predominates, their valleys widen to a mile or more; most of the human habitation is on the f terraces such as those in Ashland and remnants of earlier valley bottoms.

Pictures and illustrations about land, people, and resources of each region are available from KGS

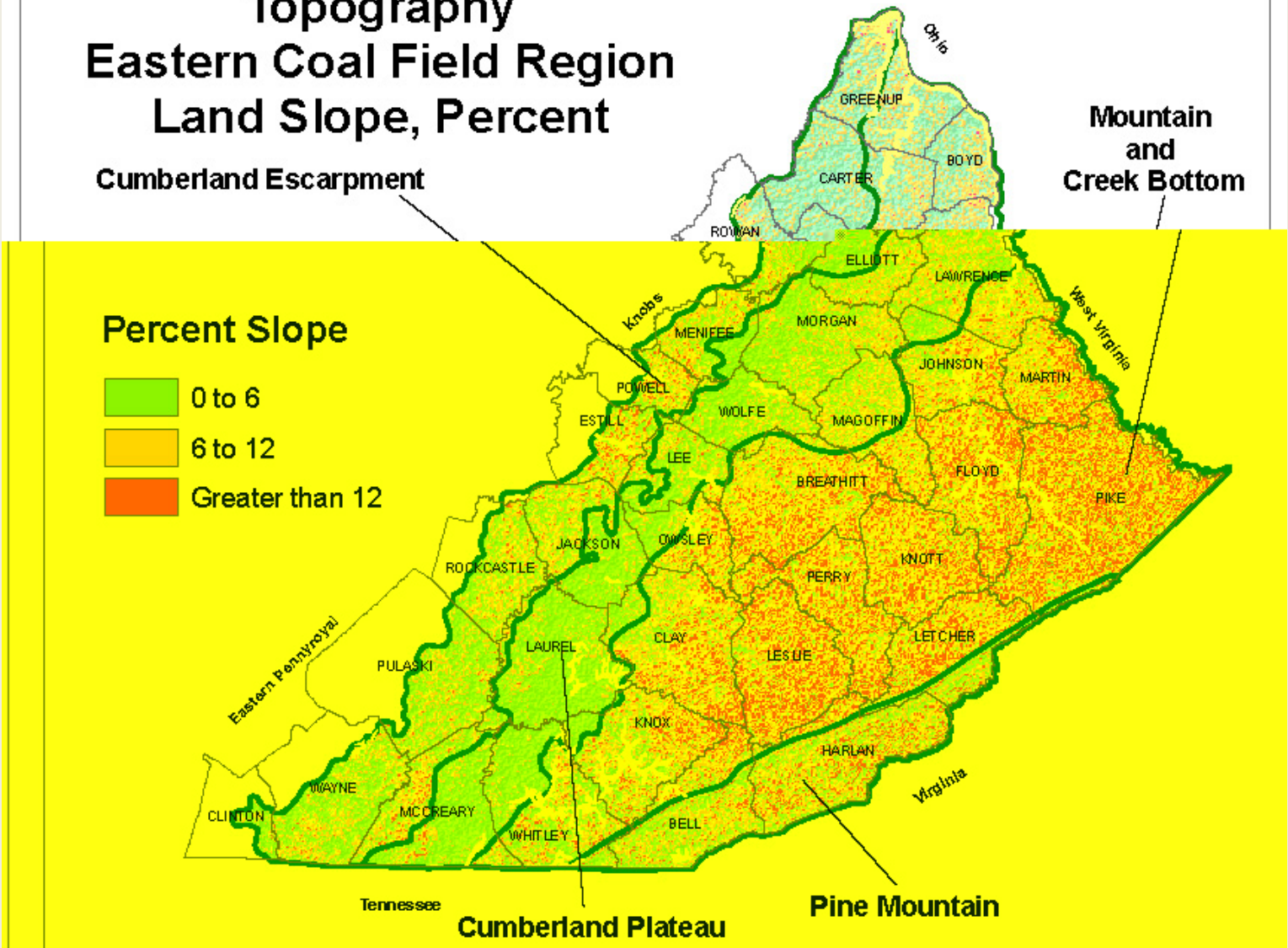
Gen mountains are as narrow and sinu s on either the ridgetops or the v all extent. Most of the terra cal topographic relief of th or exceeds 2,000 feet, untain slopes unde mantled by com nts and weathered debris (colluvium) that move down slope by debris avalanche, landslide, creep, and sheet wash. Deeply weathered soils are uncommon and occur on isolated, nearly level ridge crests and high-level terrace deposits. Cliffs of resistant sandstone cap many ridges and spurs. Scenic erosion remnants include pinnacles or "chimneys," shallow eaves known as "rock houses," and arches or natural bridges.

About 20 percent of the state's population lives on the 28 percent of the state encompassed by this region, or 67 people per square mile.



[Pictures and Illustrations of Eastern Kentucky]

Topography
Eastern Coal Field Region
Land Slope, Percent



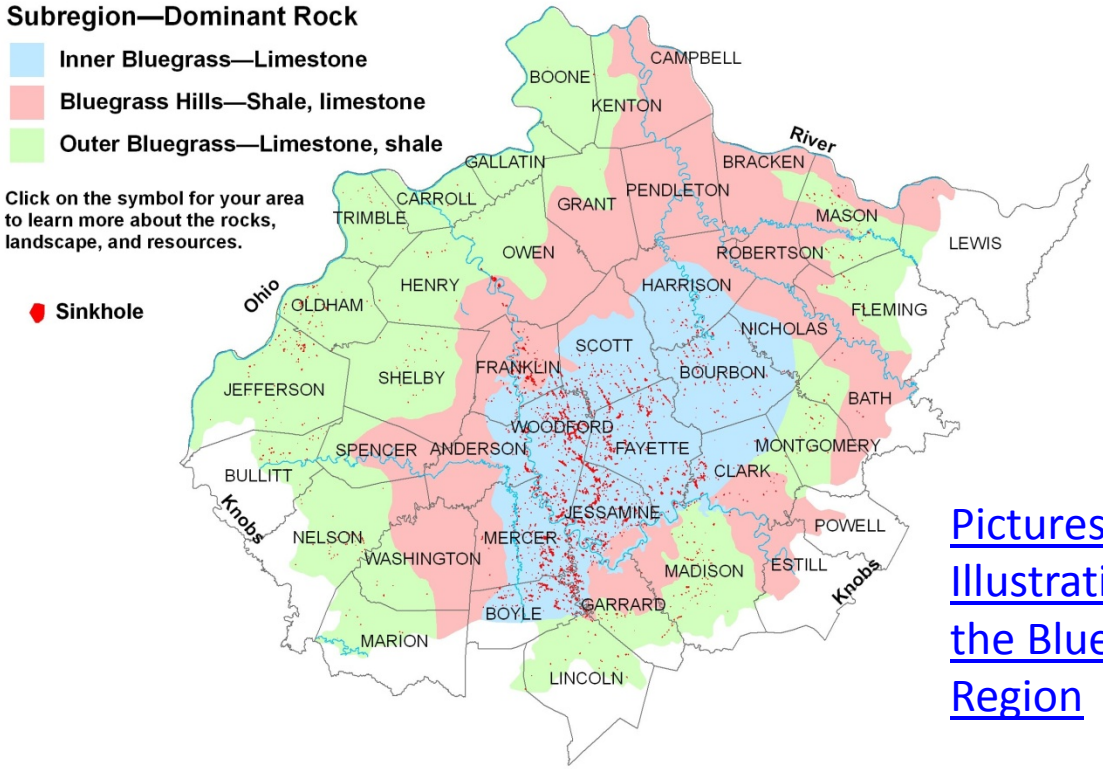
Where sandstone dominates, slopes are steep. Where shale is prevalent, the topography is less rugged.

Rolling Terrain—Cumberland Plateau Region

Shale is more dominant in the bedrock of the Cumberland Plateau Sub-Region and the landscape is less rugged and amenable to agriculture, as typified in Morgan County.

Bluegrass Region

Subregions are defined by geology. The Inner Bluegrass prime farm land is underlain by limestone. Shale predominates in the Bluegrass Hills, and the Outer Blue Grass is underlain by limestone and shale.



[Pictures and Illustrations of the Bluegrass Region]

The **Bluegrass Region** is bounded by the Knobs on the west, south, and east, and by the Ohio River in the north. Bedrock in most of the region is composed of Ordovician limestones and shales 450 million years old. Younger Devonian, Silurian, and Mississippian shales and limestones lie beneath the perimeter of the region. Much of the Ordovician strata lie buried beneath the surface. The oldest rocks at the surface in Kentucky are exposed along the Palisades of the Kentucky River. Limestones are quarried or mined throughout the region for use in construction. Water from limestone springs is bottled and sold.

The Bluegrass, the first region settled by Europeans, includes about 25 percent of Kentucky. Over 50 percent of all Kentuckians live there– an average 190 people per square mile, ranging from 1,750 people per square mile in Jefferson County to 23 people per square mile in Robertson County.

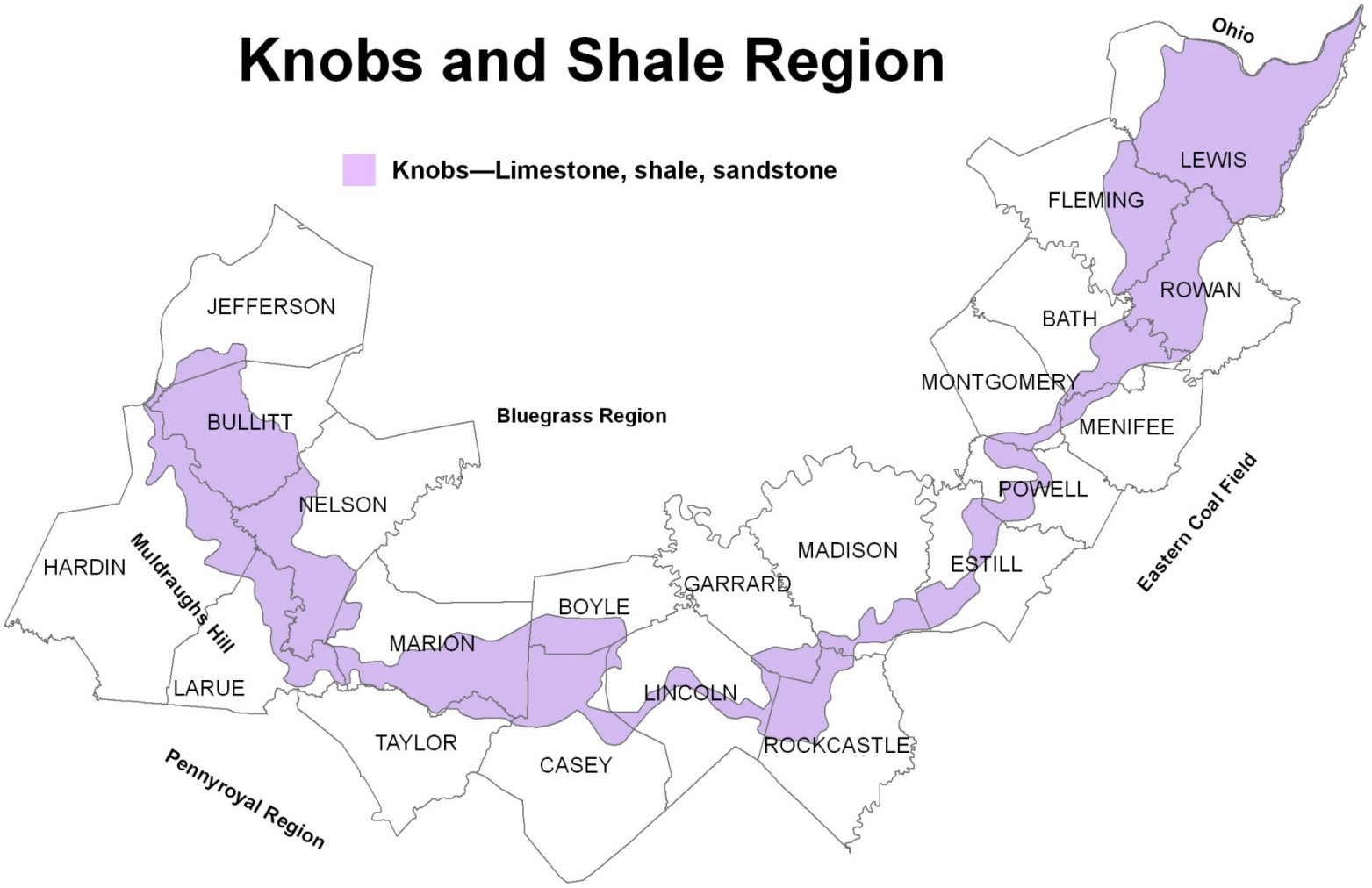
The **Inner Blue Grass** is characterized by rich, fertile phosphatic soils, which are perfect for raising thoroughbred horses. The gently rolling topography is caused by the weathering of limestone that is typical of the Ordovician strata of central Kentucky, pushed up along the Cincinnati Arch. Weathering of the limestone also produces sinkholes, sinking streams, springs, caves, and soils.

The **Outer Bluegrass** is mostly composed of interbedded Ordovician limestones and shales that are more easily eroded than the limestones of the Inner Bluegrass. It is less karstic, with fewer sinkholes and rolling hills. The shales impede the flow of groundwater, and there are fewer springs and wells..

Shale is more dominant in the **Bluegrass Hills**. The land is hilly, with limited agriculture. Slope stability may be a problem in development, particularly in the Greater Cincinnati area.

The Kentucky River Palisades are cliffs in the gorge or canyon along the Kentucky River where it cuts through resistant massive limestones and dolostones (High Bridge Group). These are the oldest rocks exposed at the surface in Kentucky.

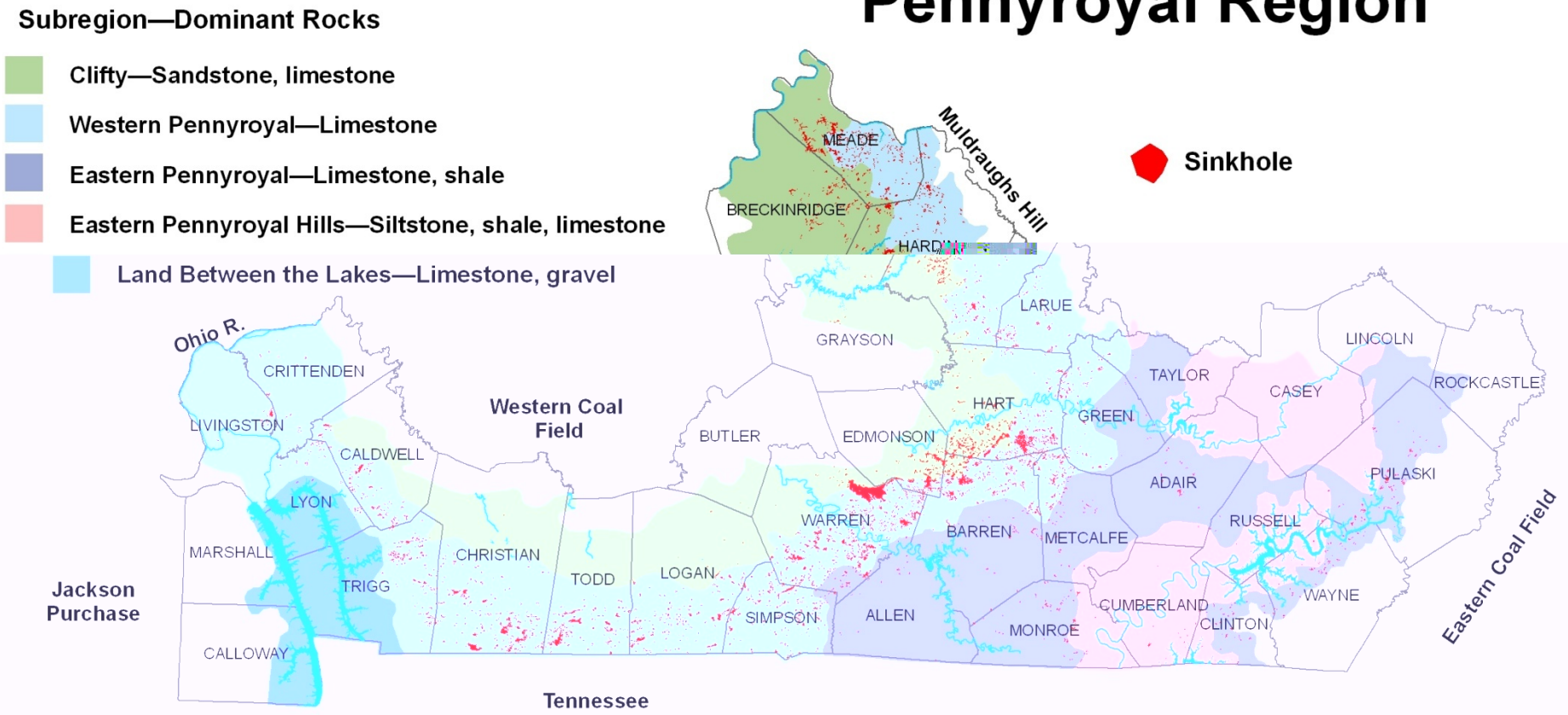
Knobs and Shale Region



The Knobs consists of hundreds of isolated, steep sloping, often cone-shaped hills lying at the outer edge of the Bluegrass Region. The hills are monadnocks or erosional remnants that were originally part of the Mississippian Plateau (Pennyroyal Region), but were separated from the plateau by stream erosion. Many of the knobs are still capped by erosion-resistant limestones or sandstones. The sloping sides of the Knobs are mostly composed of shales of the 350-million-year-old Mississippian Borden Formation, which are more easily eroded than the overlying limestones and sandstones. The Knobs are associated with the outcrop belt of Silurian and Devonian black and clay shales. Bernheim Forest (south of Louisville) and Berea, Kentucky are located in the Knobs Region.

Streams that flow through the Knobs and Shale Belt, such as the Rolling Fork River and Red River in the east, carve wide valleys with fertile alluvium deposits.

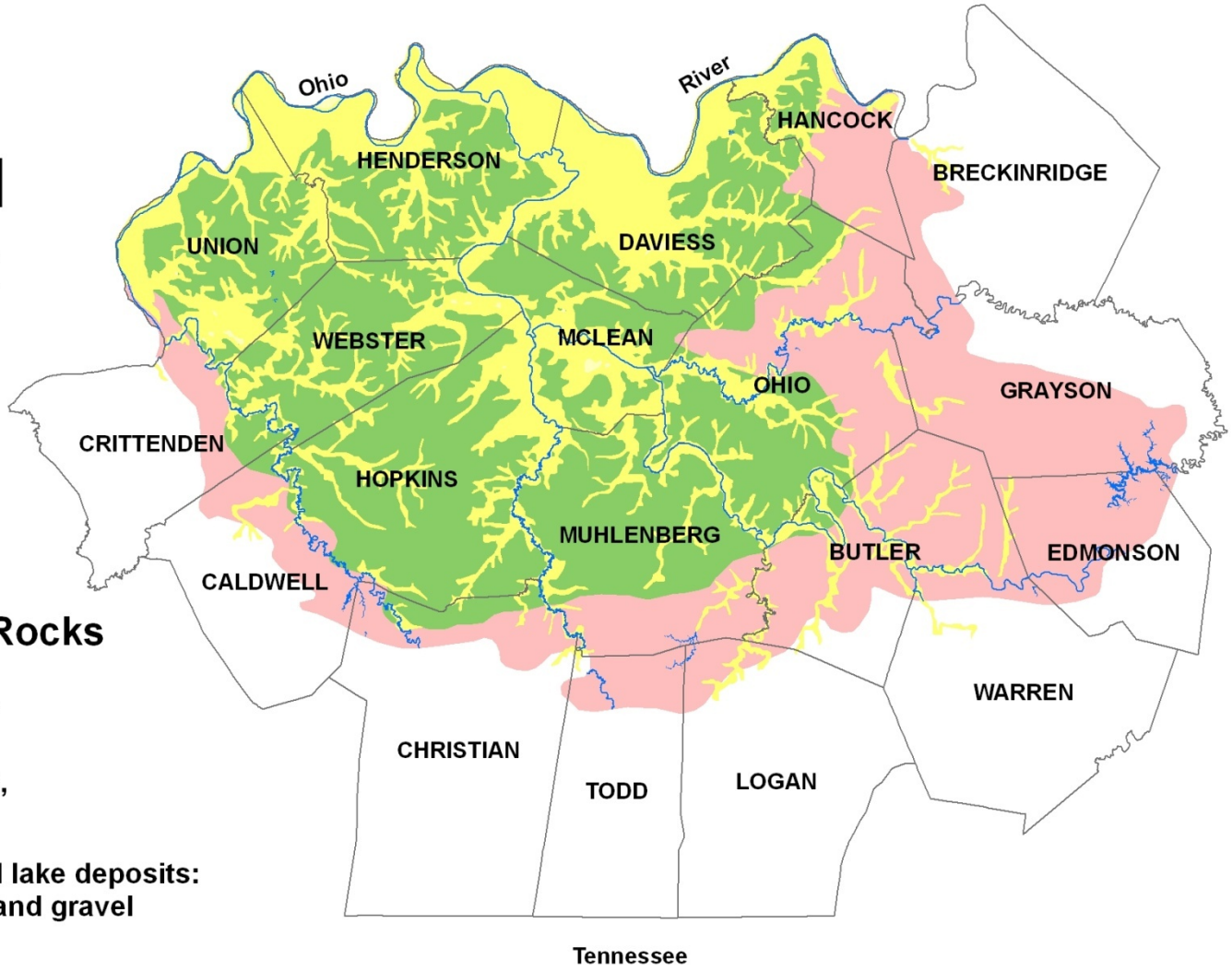
Pennyroyal Region



The Pennyroyal Region (Mississippian Plateau), stretches from the Eastern Coal Field and the Bluegrass to the Jackson Purchase, surrounding the Western Coal Field. It is primarily characterized as a limestone plain containing tens of thousands of sinkholes, sinking streams, streamless valleys, springs, and caverns. Sinkholes are depressions on the land surface into which water drains underground. Usually circular and often funnel-shaped, they range in size from a few feet to hundreds of feet in diameter. Springs occur when water emerges from underground to become surface water. Caves are solution-enlarged fractures or conduits large enough for a person to enter. This terrain, called karst, occurs because the bedrock in the eastern and southern parts of the region is dominated by thick deposits of Mississippian limestones. These limestones are soluble, which means they can easily be dissolved by waters moving through the ground. These groundwaters can form miles of passages beneath the surface, from tiny conduits only inches wide, to large caverns and rooms more than 100 feet wide. The Mammoth Cave—Flint Ridge cave system is the longest cave in the world (by far), with 365 miles explored to date.

The Pennyroyal includes 26 percent of Kentucky and 1 in 6 Kentuckians live there.

Western Coal Field Region



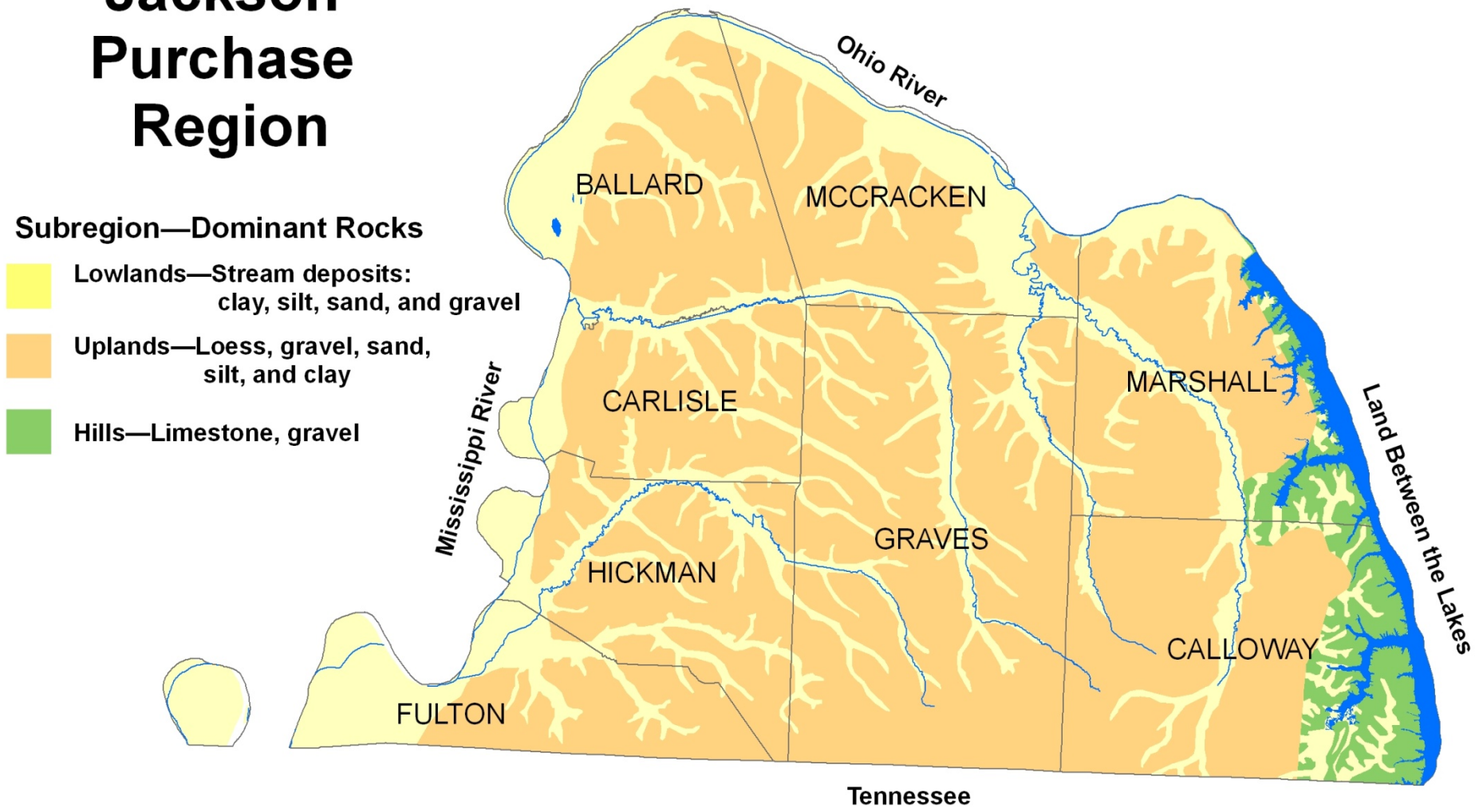
Subregion—Dominant Rocks

- **Hills—Sandstone, siltstone, shale, some coal**
- **Uplands—Shale, sandstone, siltstone, coal**
- **Lowlands—Loess, river and lake deposits: clay, silt, sand, and gravel**

The topography of the Western Coal Field Region ranges from nearly level bottomlands to rolling uplands to forested hills. The poorly-drained floodplains and terraces along the Ohio River and the wide valleys of the interior streams are underlain by loess, sand, silt, clay, and gravel. Outside the valleys, low hills predominate, underlain by 300-million-year-old Pennsylvanian shale, sand-stone, siltstone, limestone, coal, and underclay. Around the boundary of the region the valleys are narrower and the terrain more rugged, with hills capped by erosion-resistant sandstone.

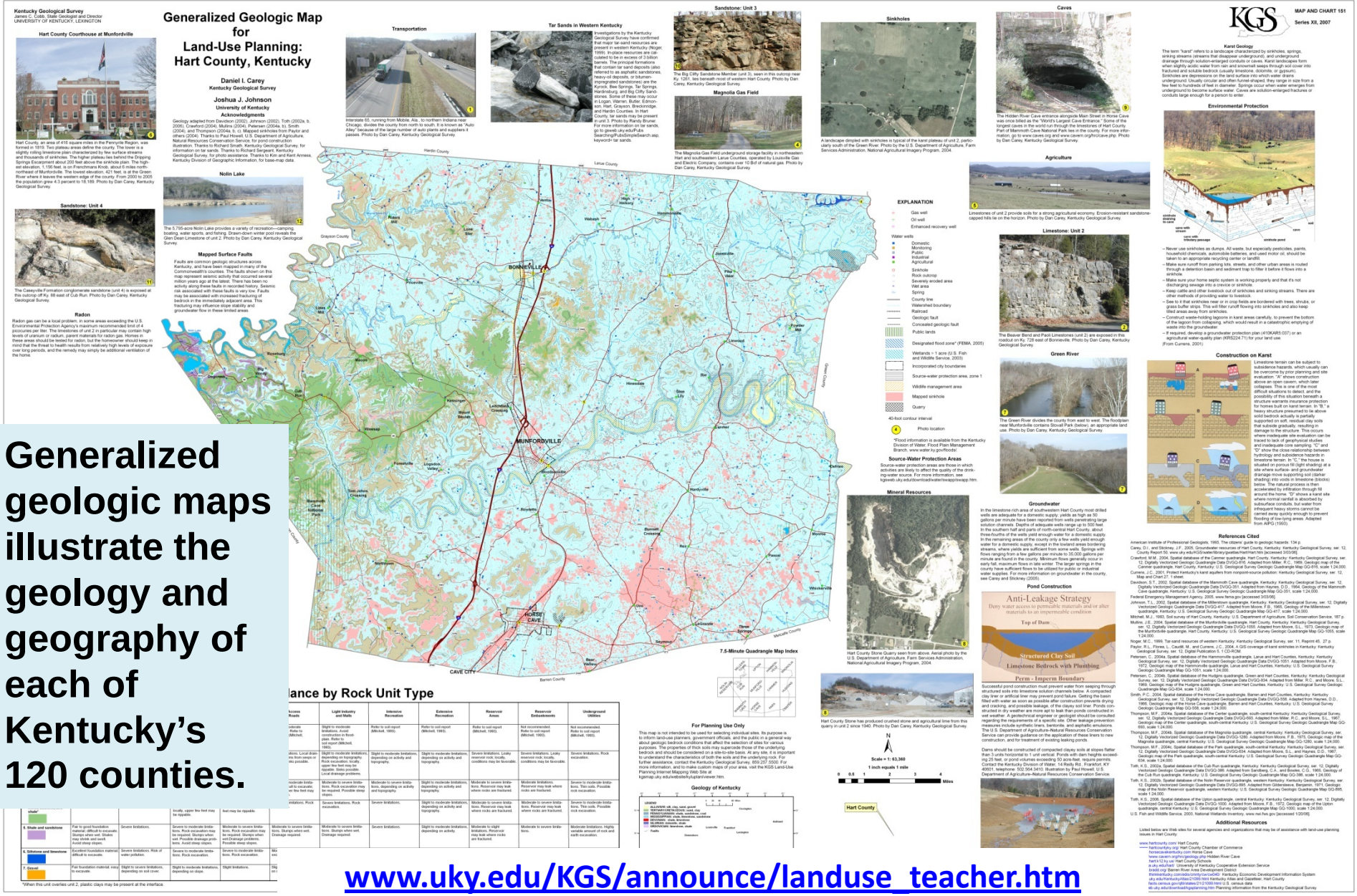
Eight percent of Kentuckians live on the region's 12 percent of the land—about 60 people per square mile.

Jackson Purchase Region



In recent geologic time, the Jackson Purchase was covered by a northern extension of the Gulf of Mexico. Most of the deposits are unconsolidated sediment instead of rock, therefore they are easily eroded, and, consequently, this part of Kentucky is relatively flat lying, with numerous lakes, ponds, sloughs, and swamps. Local relief is generally less than 100 feet. The loess plains—windblown deposits of silt from the Great Plains—provide a productive agricultural area of gently rolling uplands, broad bottomlands, and terraces. Grasslands and forested wetlands were once widespread, but have been replaced in many areas by cropland.

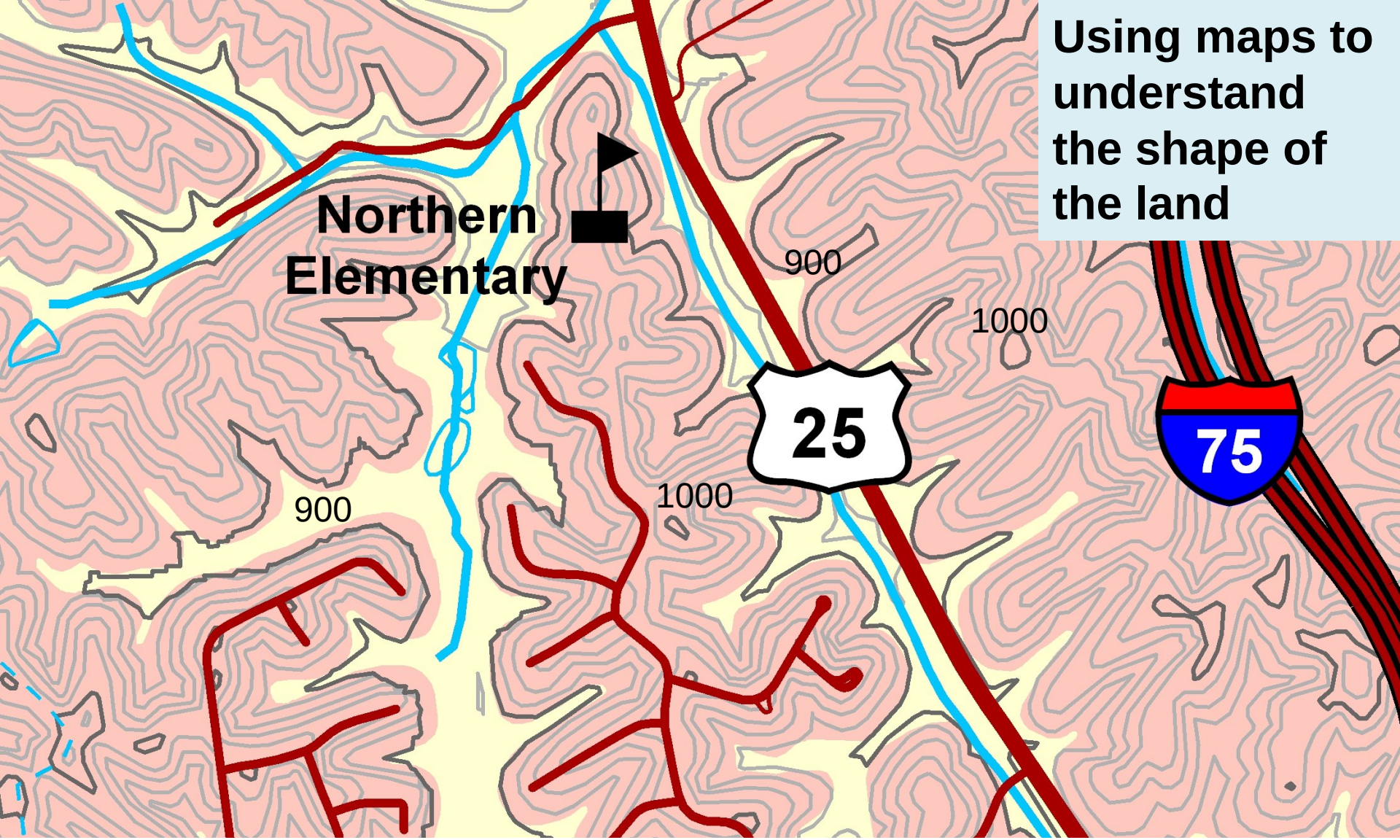
The area of the region is about 6 percent of the state, with 4.8 percent of the state's population—about 75 people per square mile.



Generalized geologic maps illustrate the geology and geography of each of Kentucky's 120 counties.

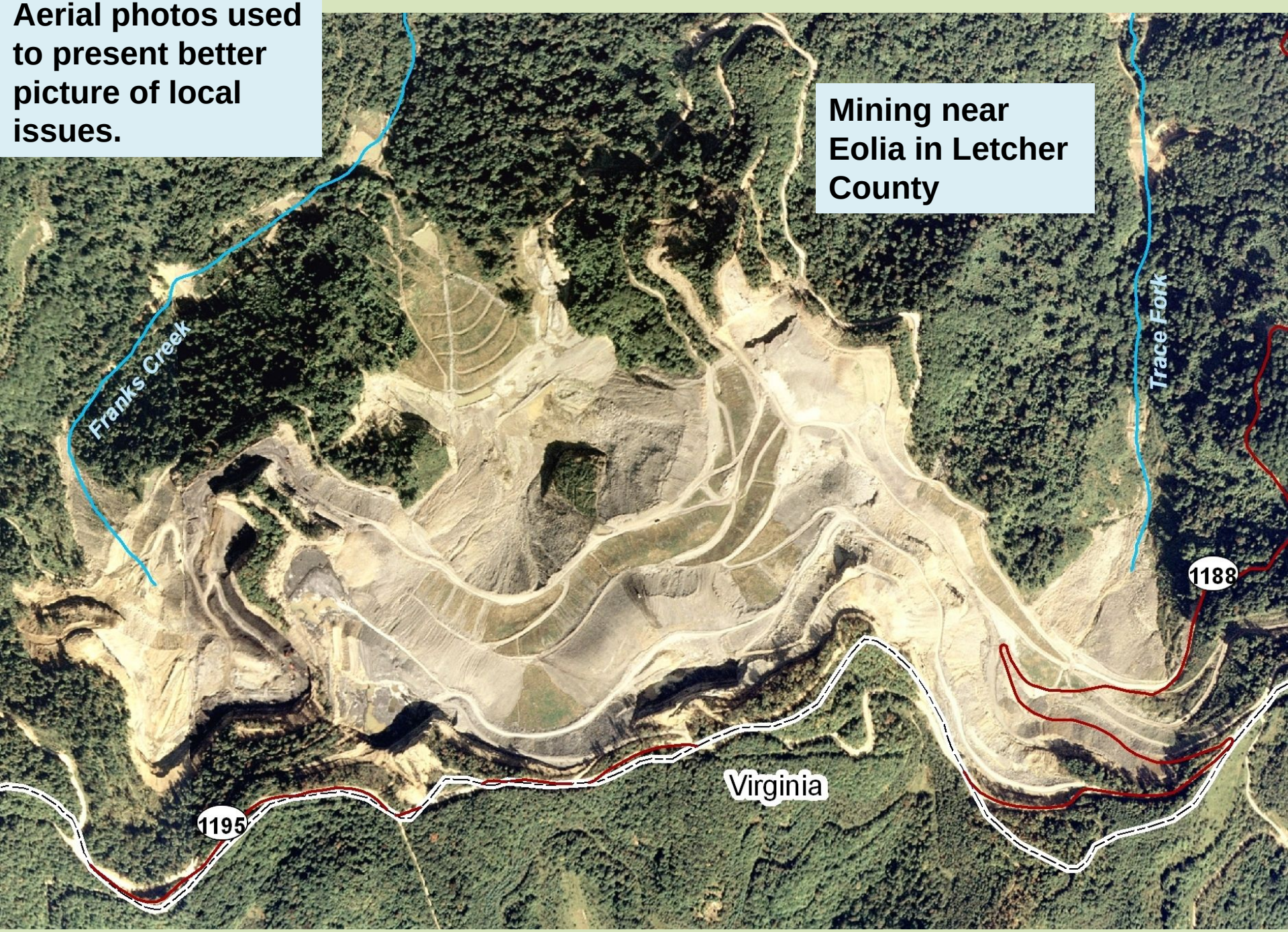
There are many things to consider when you are looking for a place to live. Maps can help you decide. What is the biggest town or city in your county? Why do you think they built it where they did? Where is your house? What kind of rock is your house built on?

Using maps to understand the shape of the land



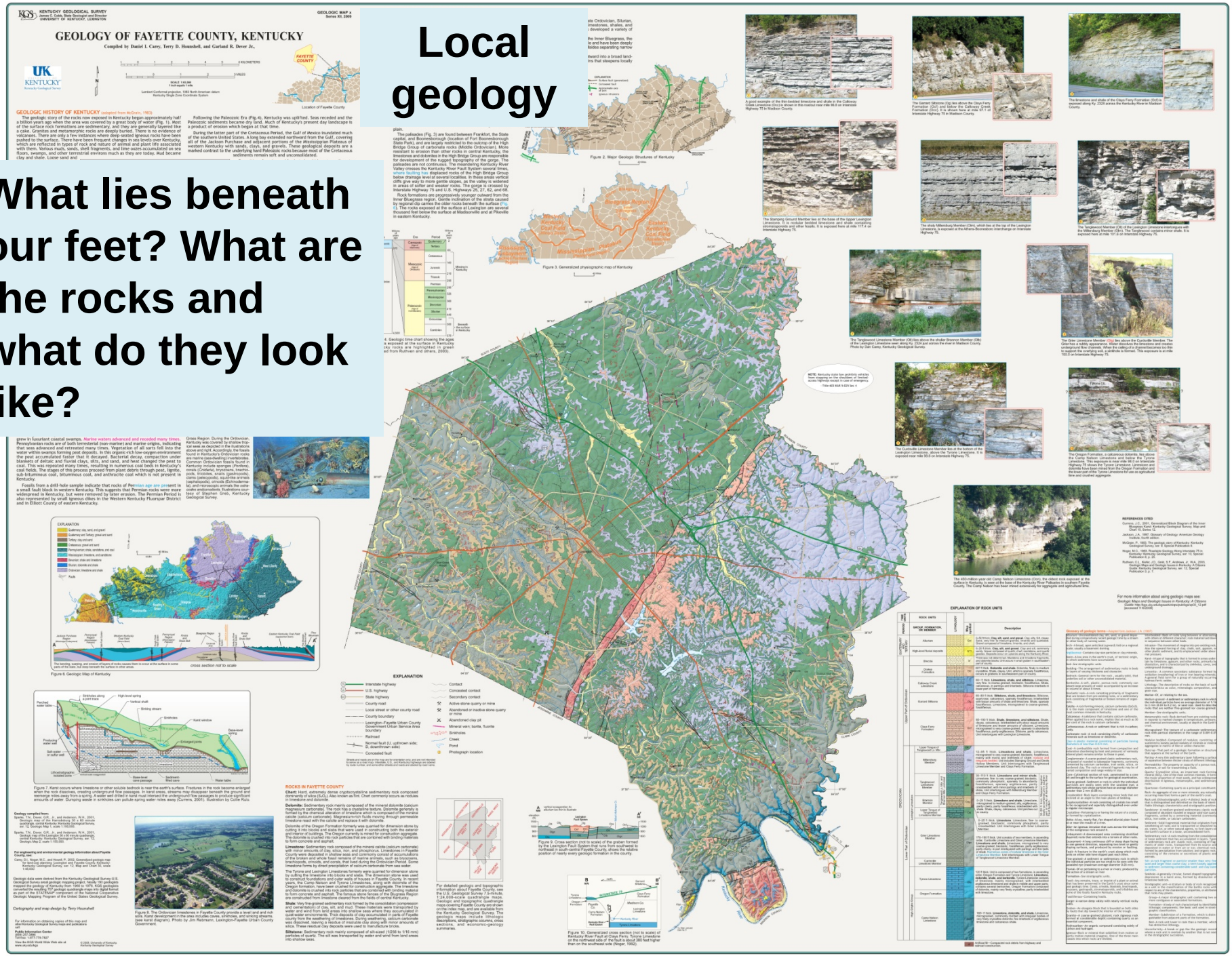
Contour lines illustrate the shape of the land. Contour lines tell you the elevation of the land above sea level. Along a contour line the elevation remains the same. Highway U.S. 25 above follows the creek at an elevation of about 900 feet and avoids the hills. Northern Elementary and the residential streets are at the top of the hill at about 1,000 feet. When contour lines are close together, on hillsides, the land is steeper. In stream valleys, the land is flatter. Different maps have different contour intervals, 20-feet for this map. Find your school on your county map. What is the elevation? Is the land steep or level?

Aerial photos used to present better picture of local issues.



Local geology

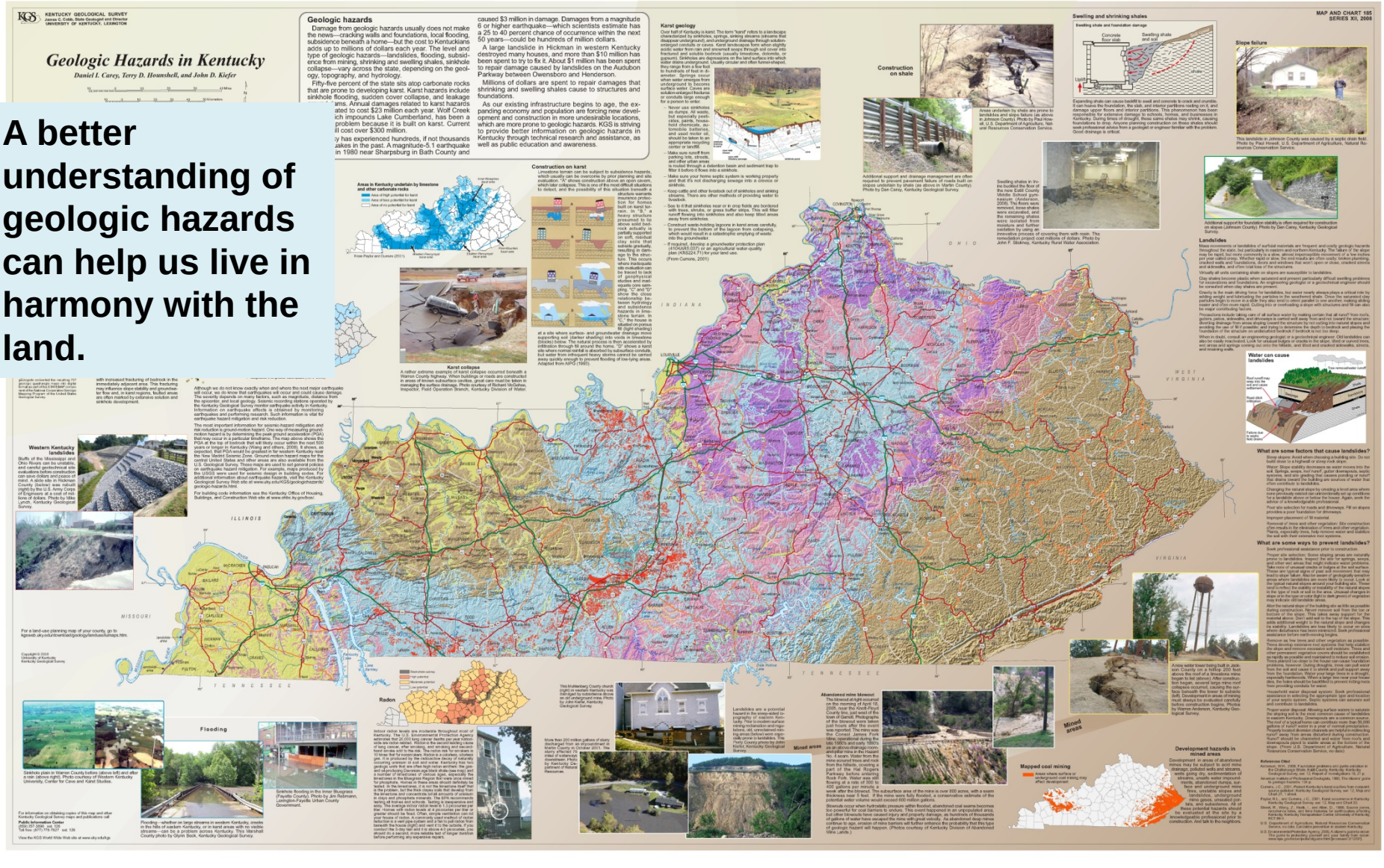
What lies beneath our feet? What are the rocks and what do they look like?



Where can the rocks be seen? Photo locations on map

The Grier Limestone Member (Olg) lies above the Curdsville Member. The Grier has a rubbly appearance. Water dissolves the limestone and creates underground flow channels. When the ceiling of the underground channel becomes too thin to support the overlying soil, a sinkhole is formed. This exposure is at mile 100.0 on Interstate 75.

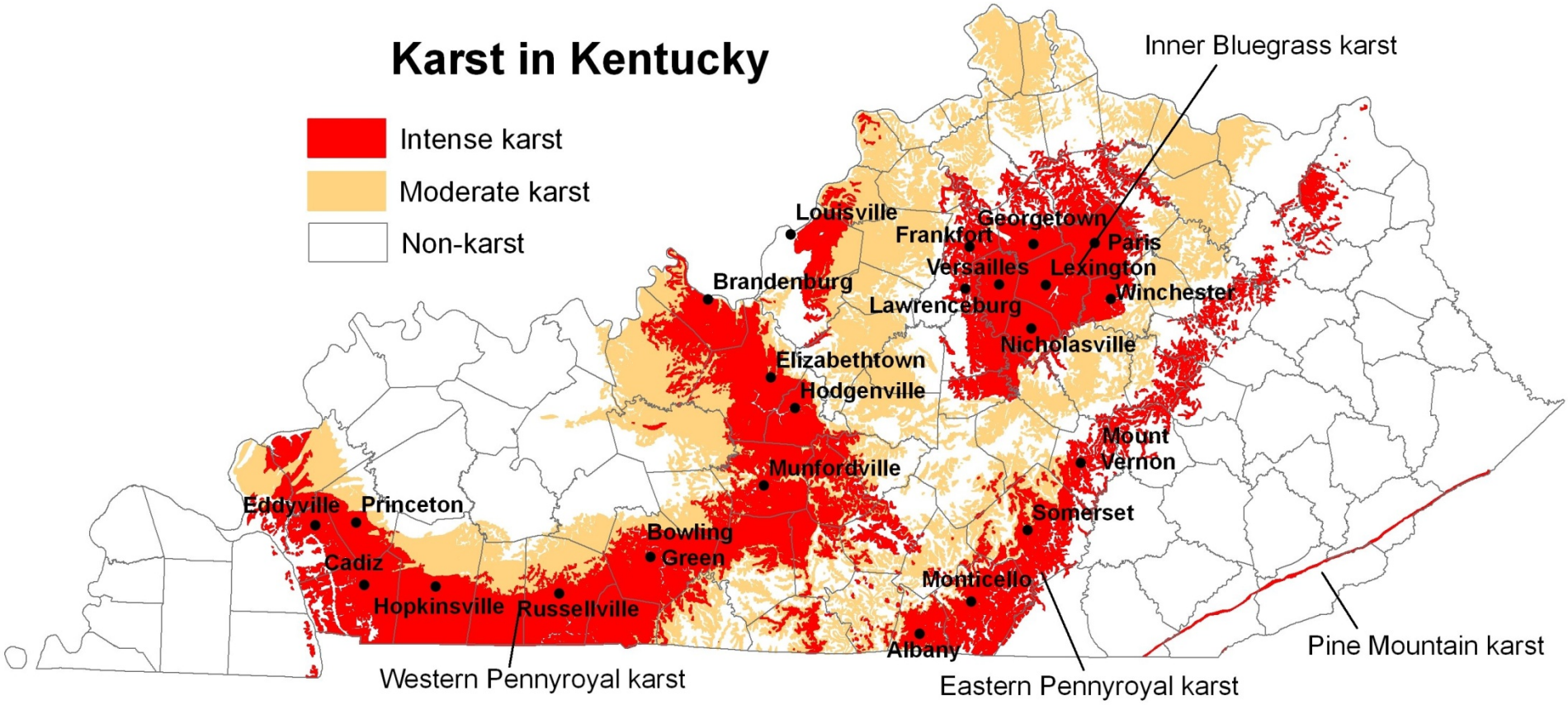
Geologic Hazards in Kentucky



A better understanding of geologic hazards can help us live in harmony with the land.

Awareness of potential geologic hazards can help avoid the $millions of annual damages in Kentucky.

If we live in a karst area, we need to understand what "karst" means in order to protect our environment and build wisely

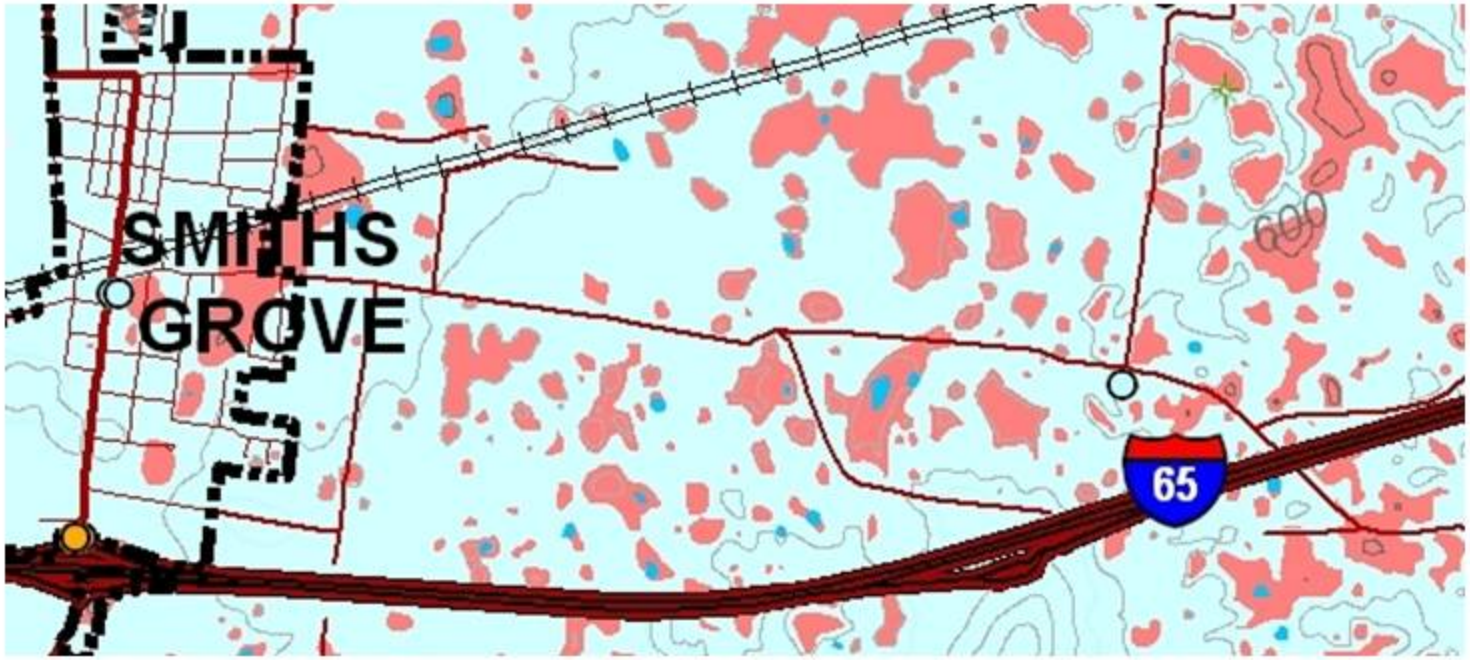


Photos, diagrams, illustration, used on maps to better express local issues.

Using sinkholes for waste disposal, even in rural areas, can threaten valuable water resources.

More about Karst

If you live in a karst area, your map will show sinkholes like those below.



Karst in Warren County

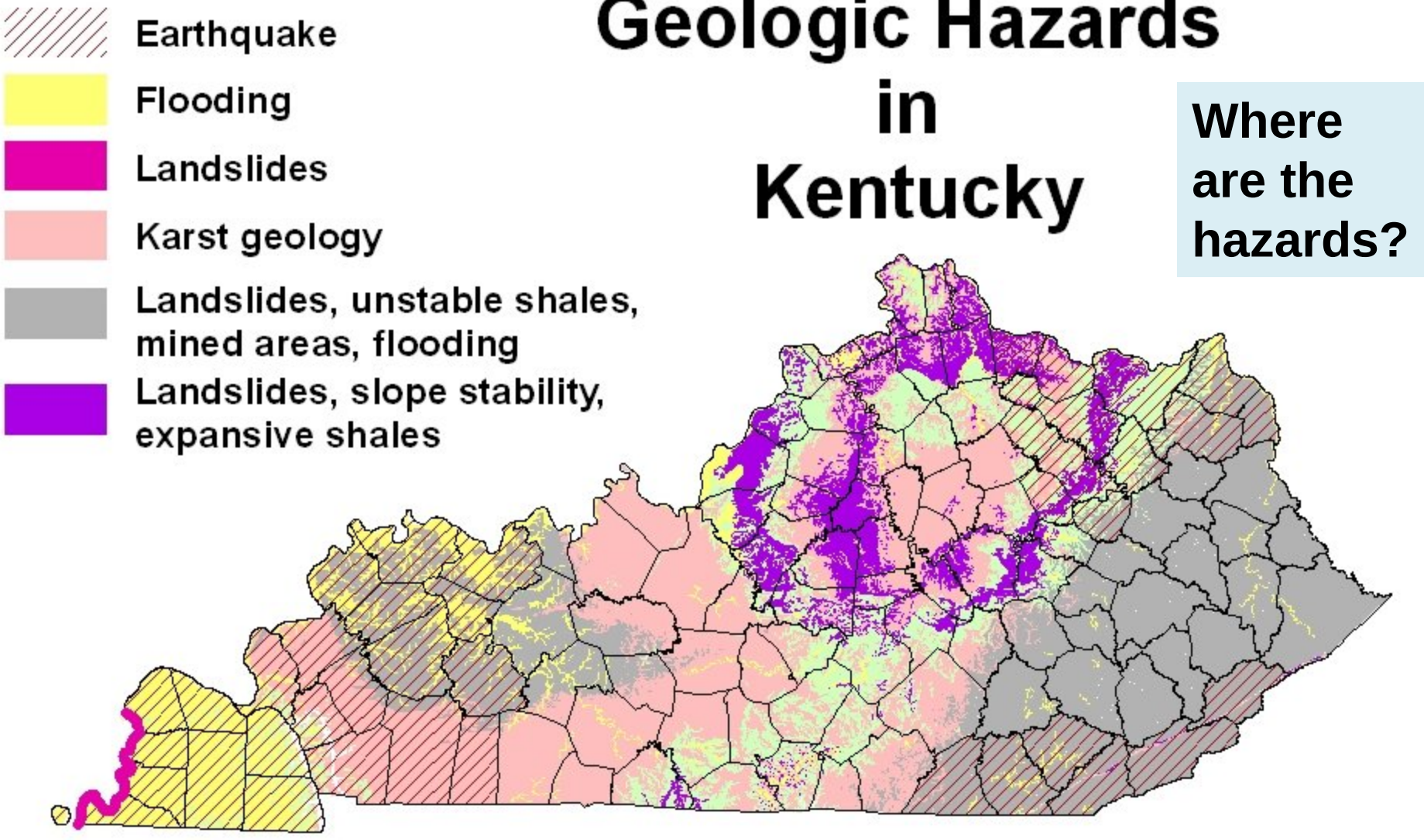
There are many sinkholes in Warren County, shown above.

Do you see any streams?

The water flows through the limestone beneath the ground.

Even though there is no stream, you can still get flooded if you build your house near a sinkhole.

Geologic Hazards in Kentucky

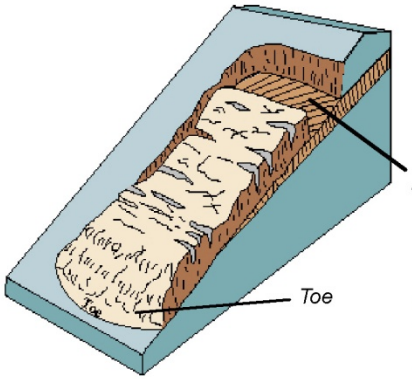


Sinkholes are not the only geologic hazard in Kentucky. You should be aware of possible hazards in order to avoid costly damages, or worse. What are the possible hazards in your county?

General Landslide and Geologic Map

Population increase, rapid urbanization, and development will cause an increasing trend in landslide activity. Direct costs of landslides include repair and maintenance of roads and property. Indirect costs such as loss of tax revenue on property devalued because of landslides, loss of real estate value in landslide prone areas, and environmental

Poster illustrates the landslide problem in many areas of Kentucky



An idealized translational landslide, moving along a planar surface. Many of these landslides occur at the contact between rock and soil. Source: USGS Landslide Fact Sheet FS2004-3072.

especially on steep slopes, are more susceptible to landslides. Note the areas of concentrated landslides and which geologic formations and type of rocks they occur.

- Locations from current field work
- Locations from Kentucky Transportation Cabinet reports
- Locations from existing geologic maps

Geology

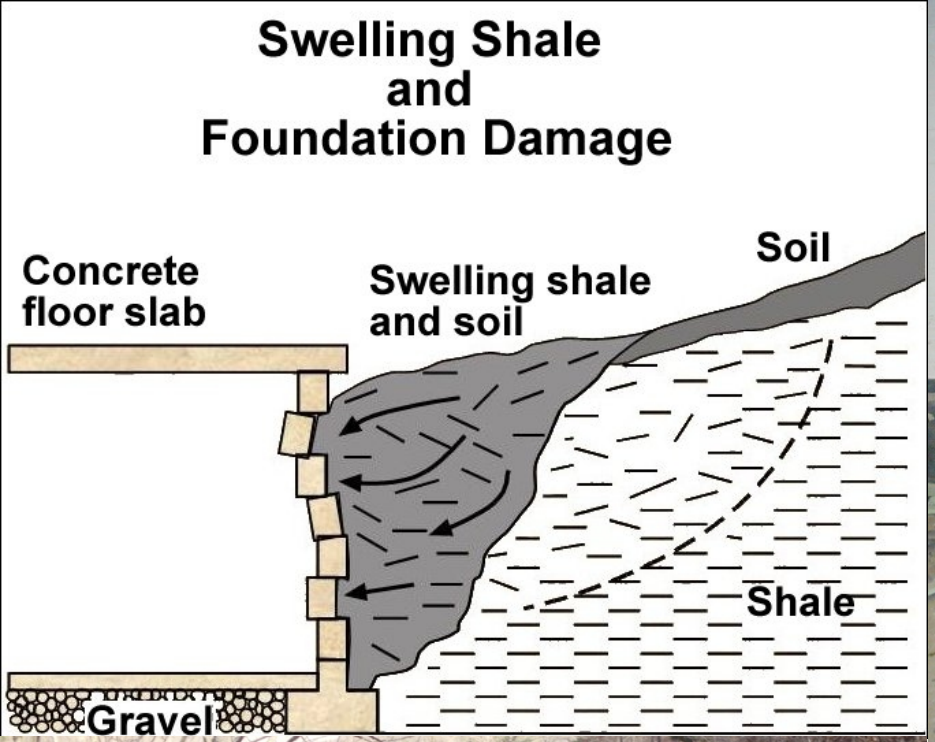
- Alluvium
- Continental deposits & loess
- Continental deposits
- Jackson & Claiborne Formations
- Wilcox Formation
- Porters Creek Clay
- Clayton & McNairy Formations
- Tuscaloosa Formation
- Mauzy Formation
- Sturgis Formation
- Carbondale Formation
- Tradewater Formation
- Caseyville Formation
- Chesterian age rocks, upper part
- Chesterian age rocks, lower part
- Mooretown Formation (Sandstone Member)
- Ste. Genevieve & St. Louis Limestones
- Salem, Warsaw, & Harrodsburg Limestones
- Warsaw Limestone
- Fort Payne Formation
- Fort Payne Fm & Muldraugh/Renfro Mbrs, Borden Fm
- Fort Payne Formation (Knifley Sandstone Mbr)
- Glacial deposits
- Sellersburg & Jeffersonville Limestones
- Louisville Limestone & Waldron Shale
- Bisher Dolomite
- Laurel Dolomite, Osgood Formation, & Brassfield Dolomite
- Bull Fork Formation
- Ashlock Fm, Grant Lake Ls, Calloway Creek Ls, and Fairview Fm
- Garrard Siltstone & Clays Ferry Formation
- Garrard Siltstone, Kope & Clays Ferry Formations
- Kope Formation
- Lexington Limestone
- High Bridge Group
- Pennington Formation & Newman Limestone (Upper Mbr)
- Pennington (Paragon) Formation, Bangor Ls, Hartselle Fm, & Monteagle Limestone (Kidder Mbr)
- Pennington Formation thru Bedford Shale, incl. Newman Limestone & Grainger Formation
- Newman Limestone
- Borden Formation, Sunbury Shale, Berea Sandstone, & Bedford Shale
- Chattanooga & Ohio Shales
- New Albany, Chattanooga, & Ohio Shales, Boyle Dolomite & Sellersburg Limestone
- Crab Orchard Formation & Brassfield Dolomite
- Cumberland Fm, Leipers & Catheys (?) Limestone
- Drakes Formation
- Drakes Fm (Preachersville Member) & Bull Fork Formation
- Drakes Fm, Grant Lake & Calloway Creek Ls
- peridotite, intrusive
- Monongahela & Conemaugh Formations
- Breathitt Formation, upper part
- Breathitt Formation, middle part
- Breathitt Formation, lower part (incl Livingston Cgl)
- Lee & Breathitt Formations (Corbin Sandstone)
- Lee Formation
- Lee Formation (Rockcastle Conglomerate)

KGS

Finding a place to live

If you build your house on the side of a hill, the rocks may not be strong enough to hold it, or there may be a landslide. You need to know what kind of rocks will be below your house.

What kind of rock is beneath your house? What kind of rock is your school built on?



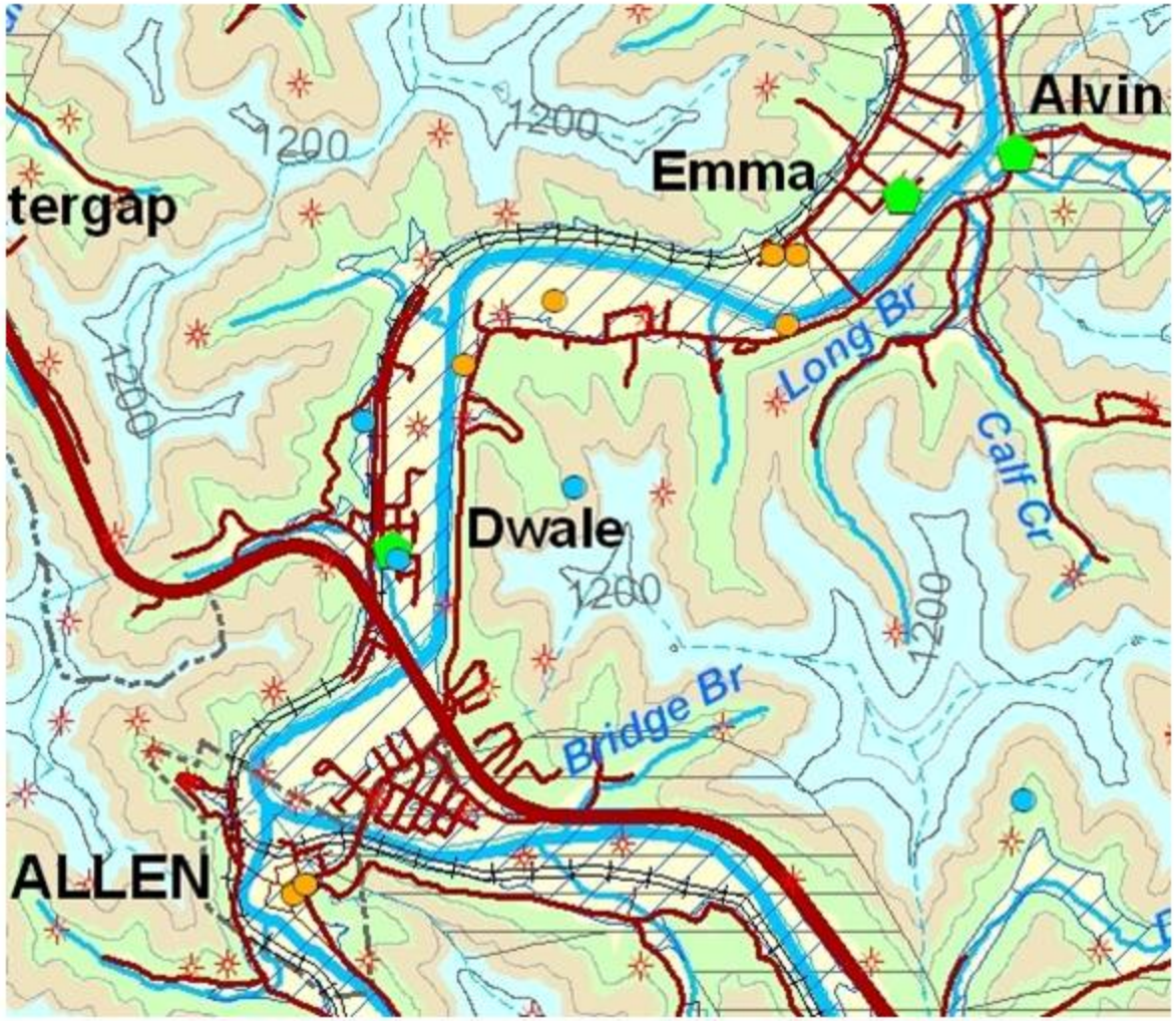
Swelling shales in Irvine buckled the floor of the new Estill County Middle School gymnasium. The floors were removed, loose shales were excavated, and the remaining shales were isolated from moisture and further oxidation by using an innovative process of covering them with resin. The remediation project cost millions of dollars.

Road Failures on Shale

Is there shale or swelling shale where you live?

Flooding

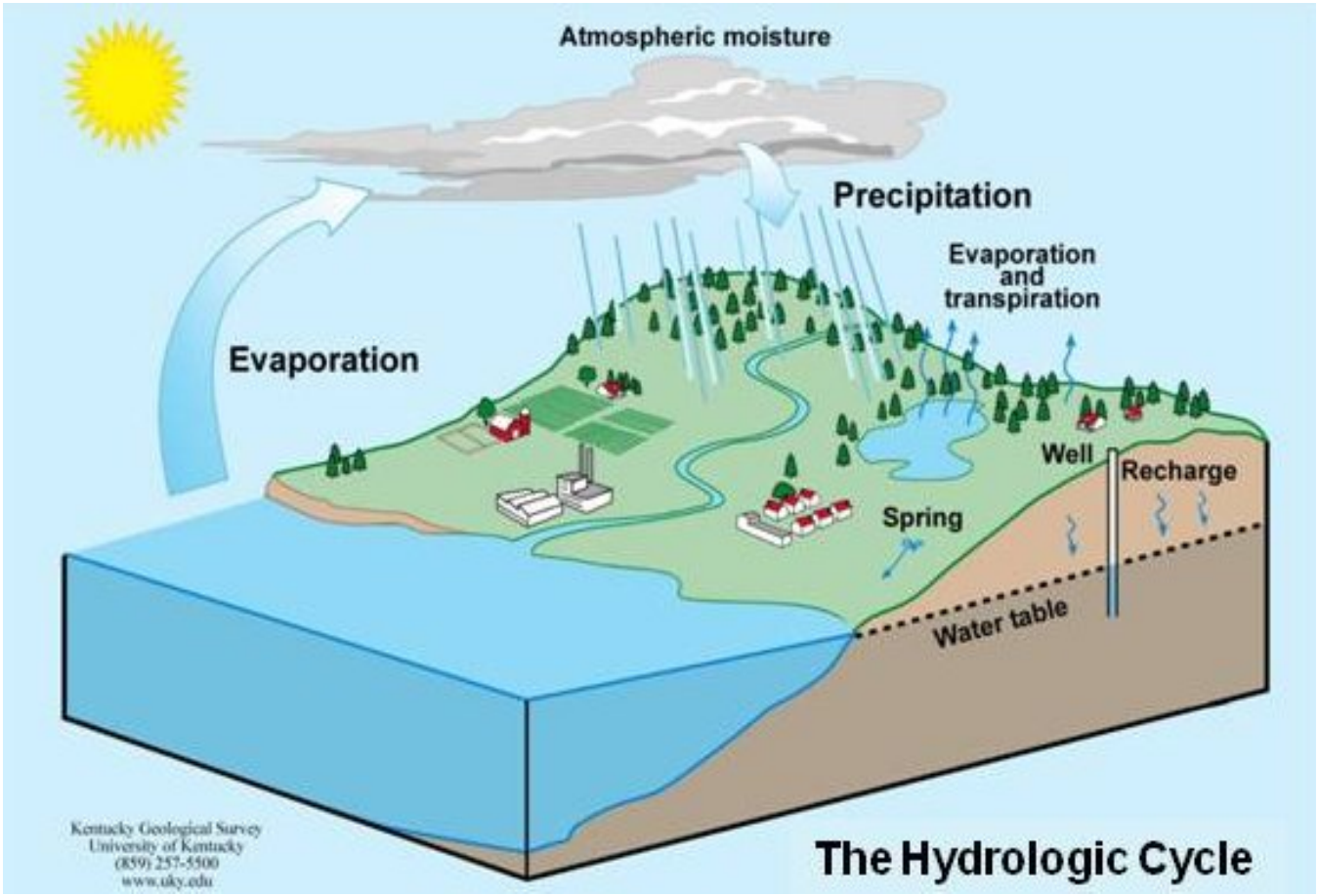
If you build your house too close to a stream, it might get flooded. Alluvium—yellow on the map— lies along streams and indicates possible areas of flooding, like those shown below in Floyd County. Also, some of the flood zones have been mapped. Can you find any flood zones on your map? Parks and athletic fields are a good use for floodplains.



Water in Kentucky **provides an overview of the hydrologic cycle, watersheds, surface and ground water, water use, water quality, and flooding in the state**

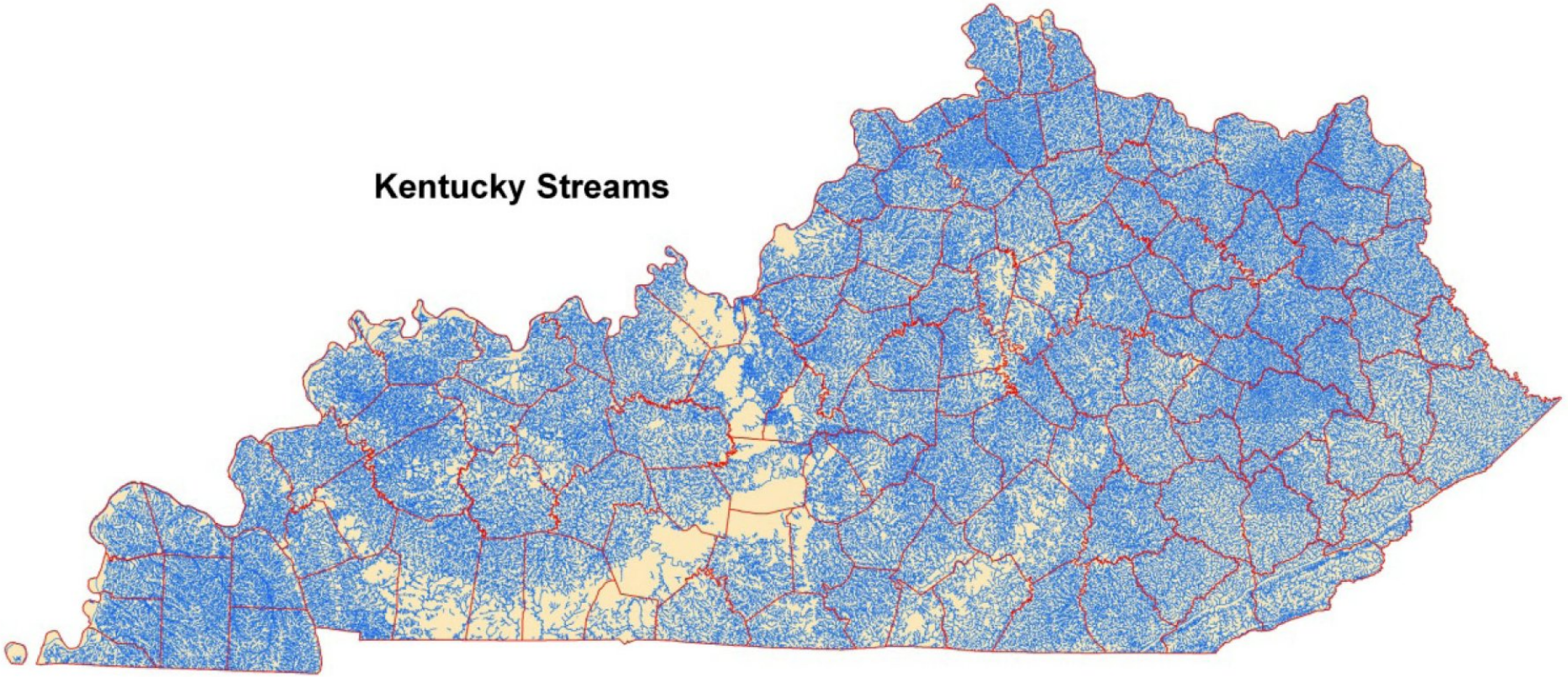
Water in Kentucky

More than 32 trillion (32 million million) gallons of water normally falls from the skies over Kentucky each year. Where does our precipitation come from? Most of Kentucky's water has been lifted from the western Gulf of Mexico by the sun (evaporation) and carried to us by southerly winds. The evaporation process leaves the sea salts behind and gives us fresh water. As the air cools, the water vapor condenses into droplets and falls as precipitation



The Hydrologic Cycle
Lifted by the Sun
Carried by the Wind
The Sea moves over the land
Washing and feeding
Her lost children.

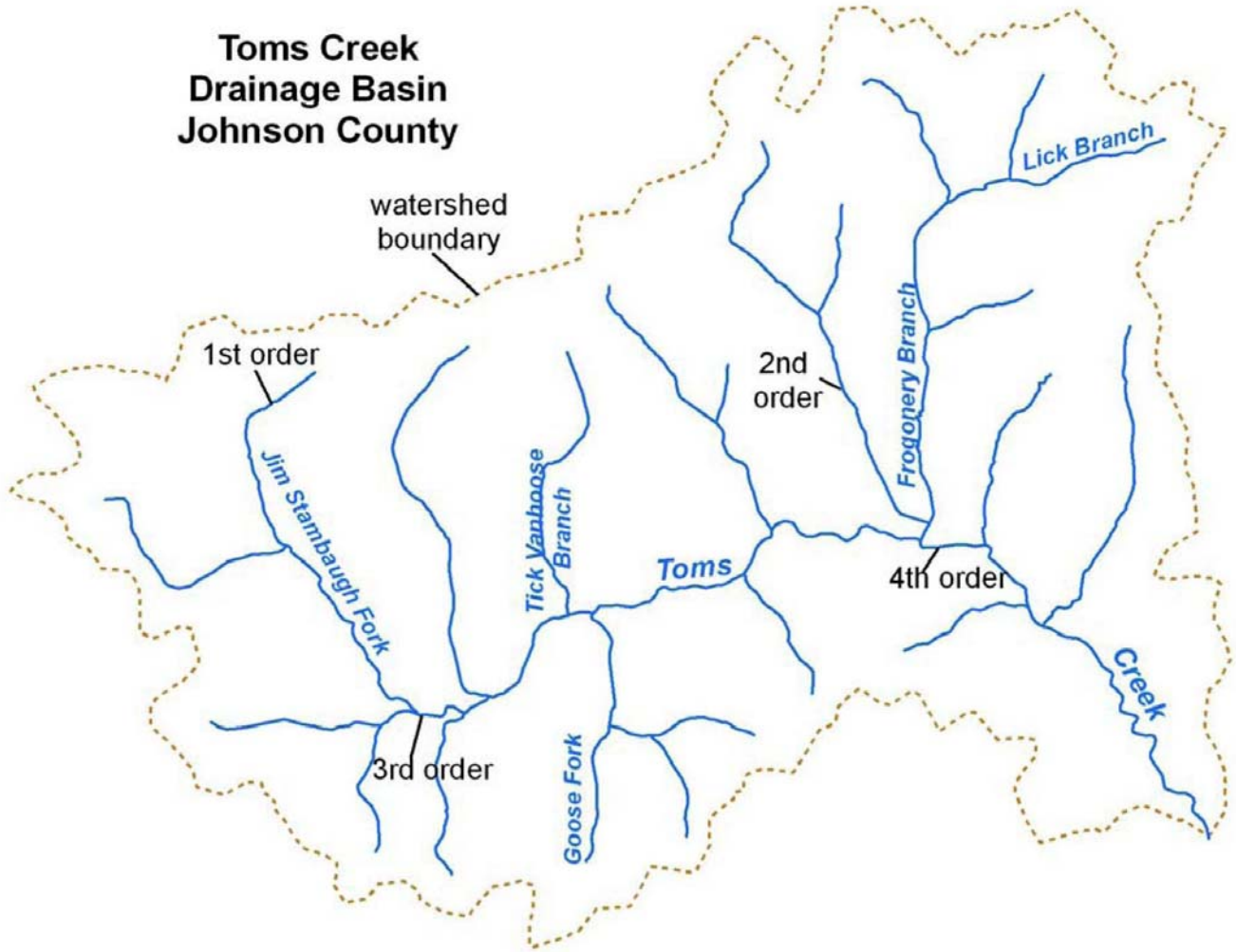
Kentucky has 90,000 miles of streams



Stream densities, the length of streams per square mile, vary by region. In the Sinkhole Plain of the Pennyroyal Region, where many streams flow into sinkholes to underground conduits (flow channels), the surface stream density is half that of the rest of the state. On the impermeable (resistant to water infiltration) shale of hilly areas of the Bluegrass Region, there are nearly 3 miles of surface streams per square mile.

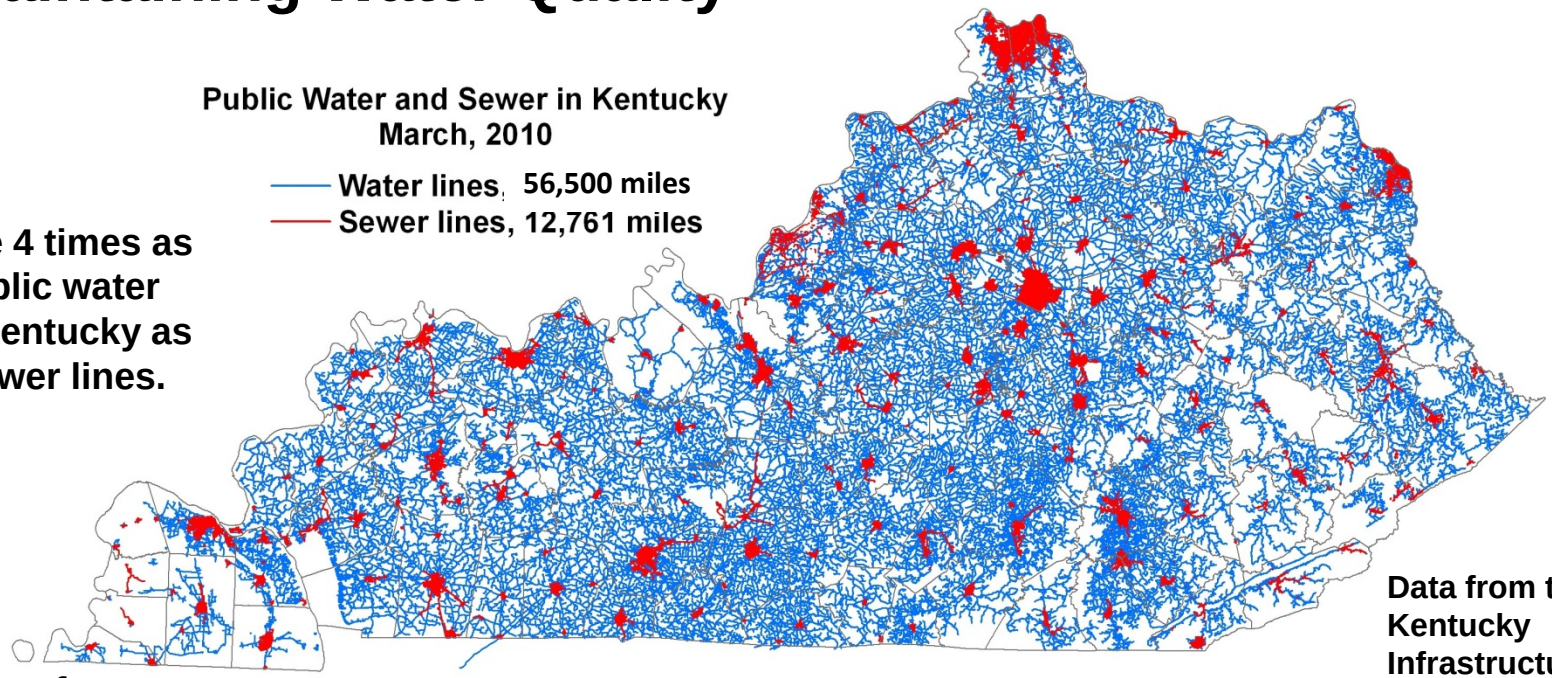
Watersheds

On your map, trace the boundaries of the watershed containing your school.



One way streams are characterized by hydrologists (those who study the movement, distribution, and quality of water throughout the Earth) is by the term "order." Initial perennial streams segments in a watershed are designated as 1st order. Two 1st order streams combine to form a 2nd order stream, and so forth.

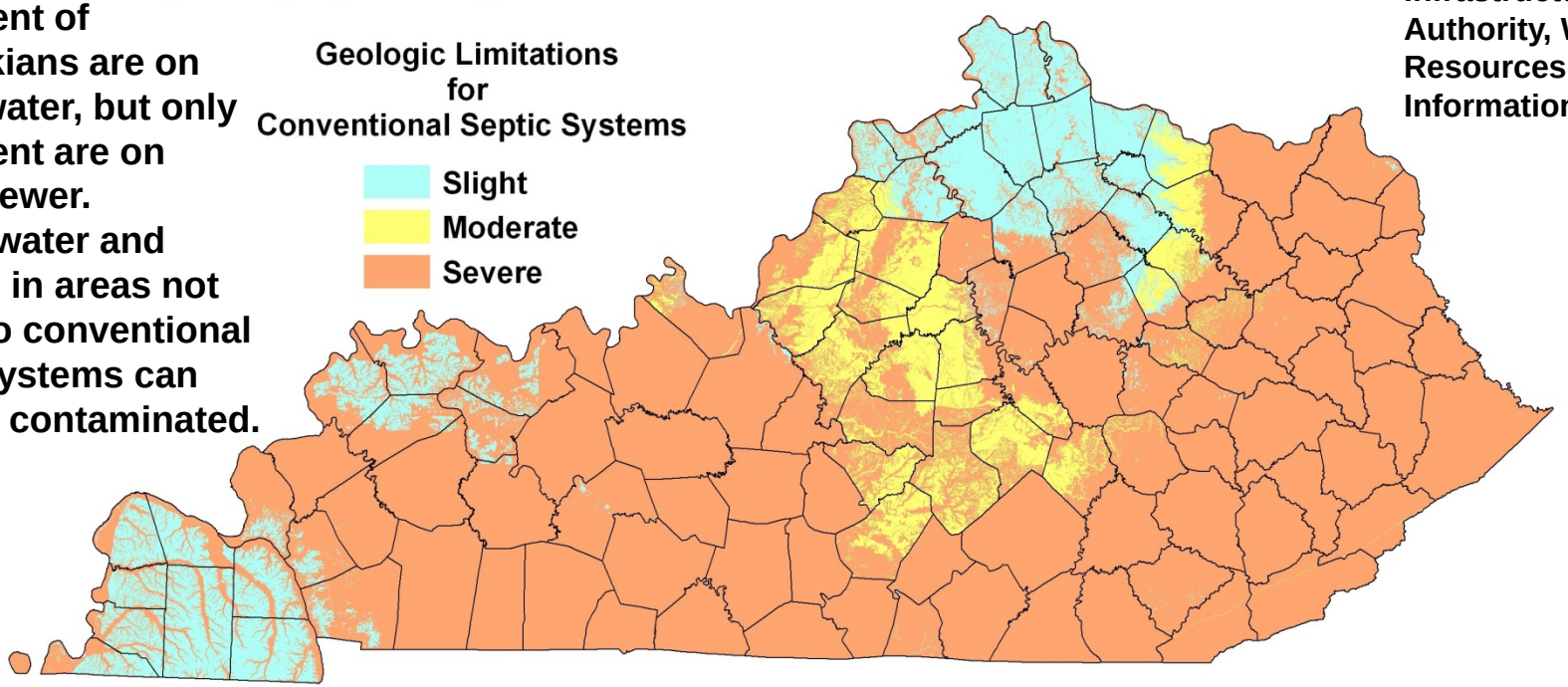
Maintaining Water Quality



There are 4 times as many public water lines in Kentucky as public sewer lines.

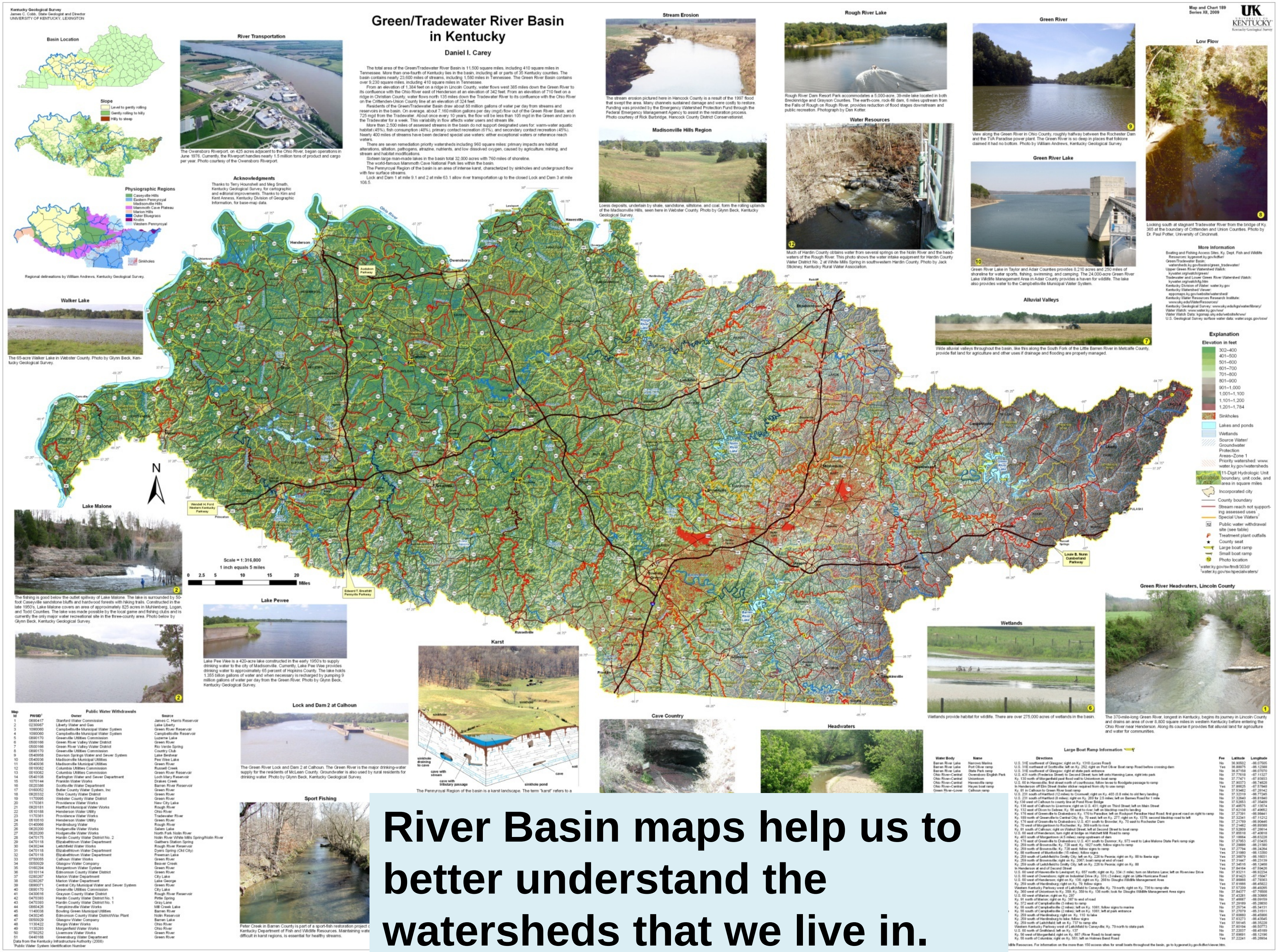
Data from the Kentucky Infrastructure Authority, Water Resources Information System

97 percent of Kentuckians are on public water, but only 52 percent are on public sewer. Groundwater and streams in areas not suited to conventional septic systems can become contaminated.



River Basins of Kentucky

Kentucky streams follow the topography and flow primarily to the north and west. Nearly all the water (97%) that runs off flows to the Ohio River before entering the Mississippi River for the trip back to the Gulf.



River Basin maps help us to better understand the watersheds that we live in.

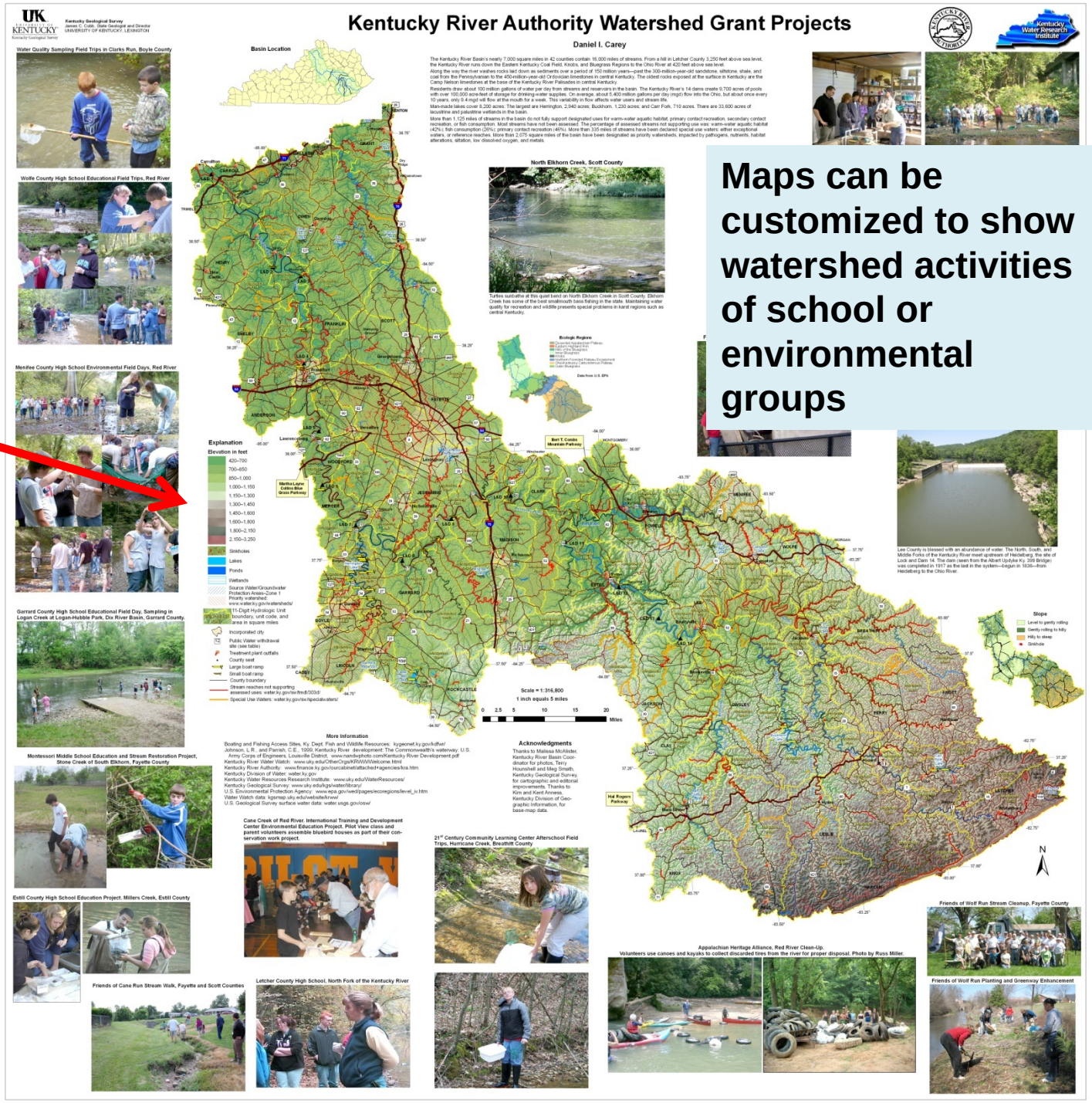
Explanation

Elevation in feet

- 302–400
- 401–500
- 501–600
- 601–700
- 701–800
- 801–900
- 901–1,000
- 1,001–1,100
- 1,101–1,200
- 1,201–1,784

- Sinkholes
- Lakes and ponds
- Wetlands
- Source Water/ Groundwater Protection Areas–Zone 1
- Priority watershed: www.water.ky.gov/watersheds
- 11-Digit Hydrologic Unit boundary, unit code, and area in square miles (05140103060 / 50.07)
- Incorporated city
- County boundary
- Stream reach not supporting assessed uses[1]
- Special Use Waters[2]
- 12 — Public water withdrawal site (see table)
- Treatment plant outfalls
- ★ County seat
- Large boat ramp
- Small boat ramp
- 12 — Photo location

[1] water.ky.gov/sw/tmdl/303d/
[2] water.ky.gov/sw/specialwaters/

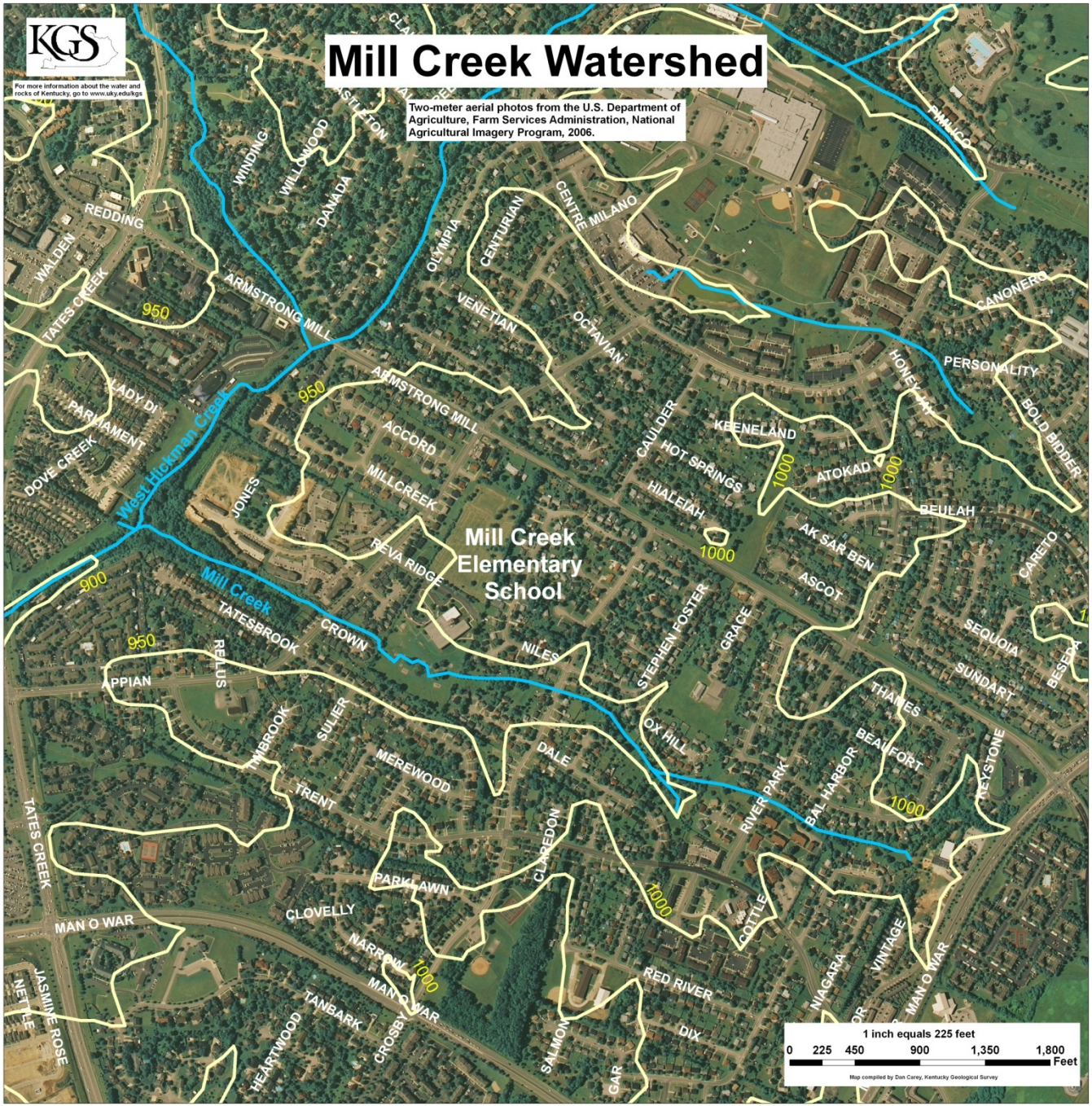


Maps can be customized to show watershed activities of school or environmental groups

Menifee County High School Environmental Field Days, Red River

Wolfe County High School Educational Field Trips, Red River

Estill County High School Educational Field Trips, Millers Creek



School Watershed Studies

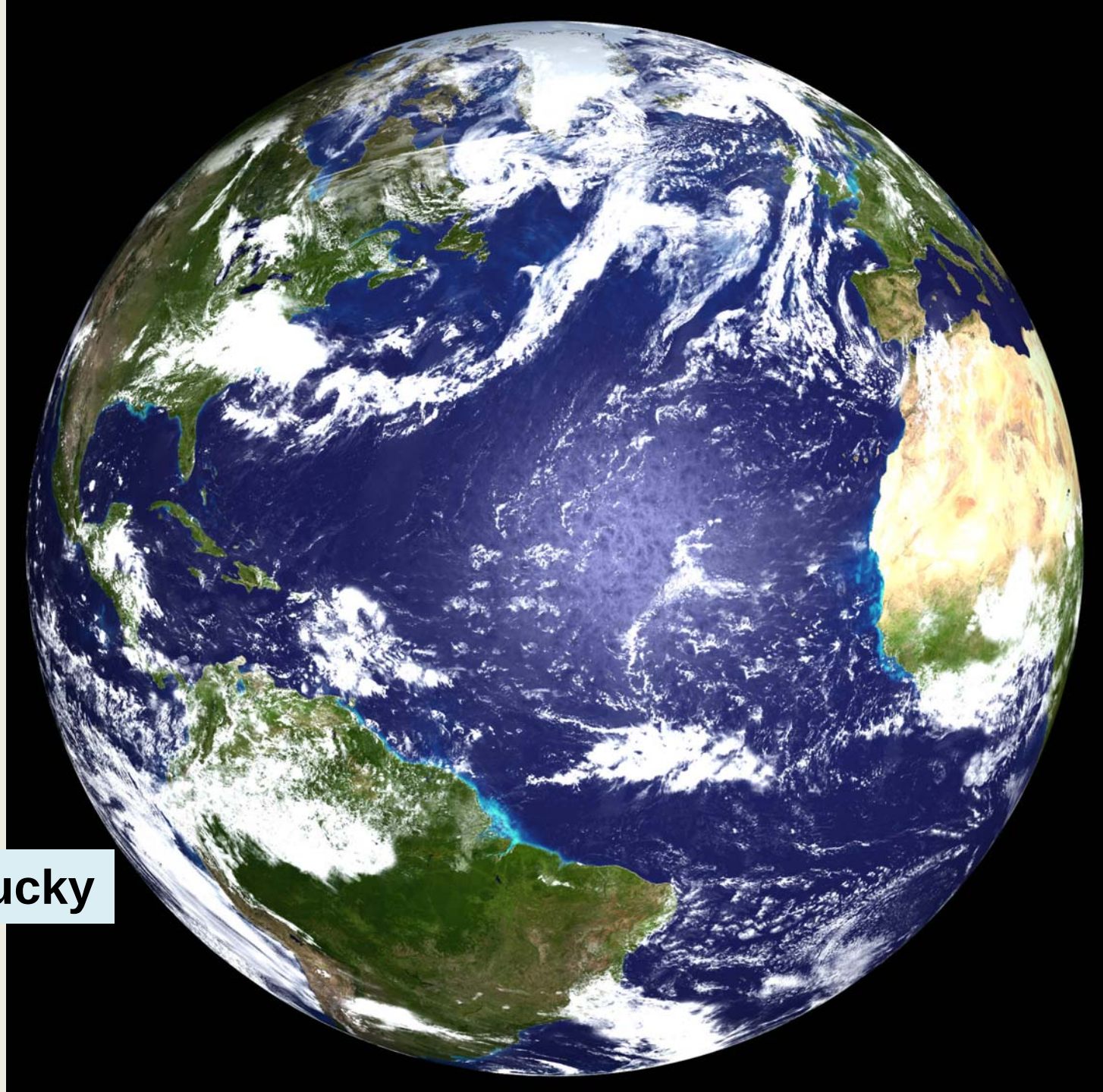
GIS + Kentucky Data = Anyone can do it!

A Brief History of Earth

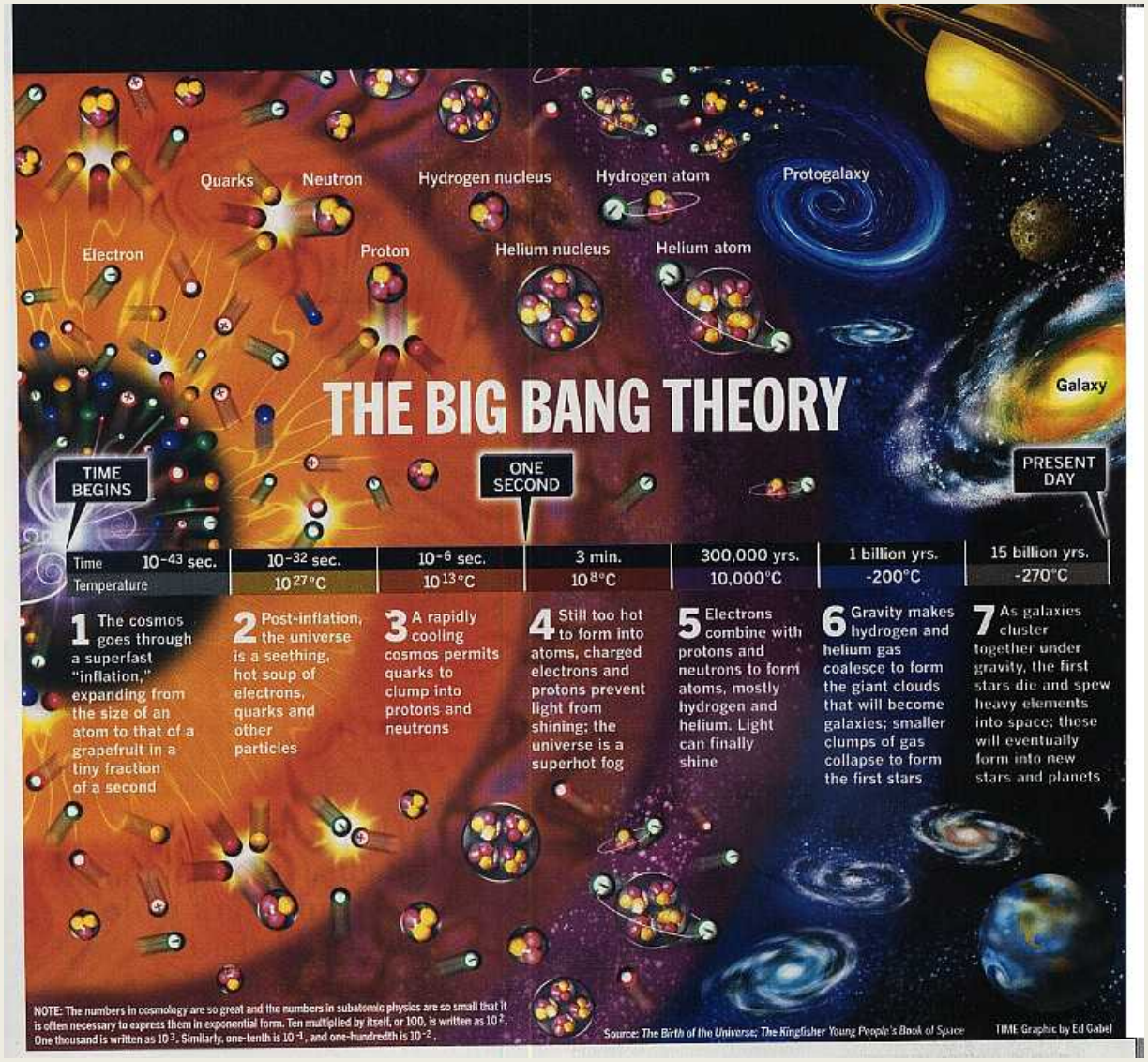
(100-slide Power Point)

kgs.uky.edu/kgsweb/download/geology/EARTHHISTORY.ZIP

Beyond Kentucky



The Big Bang

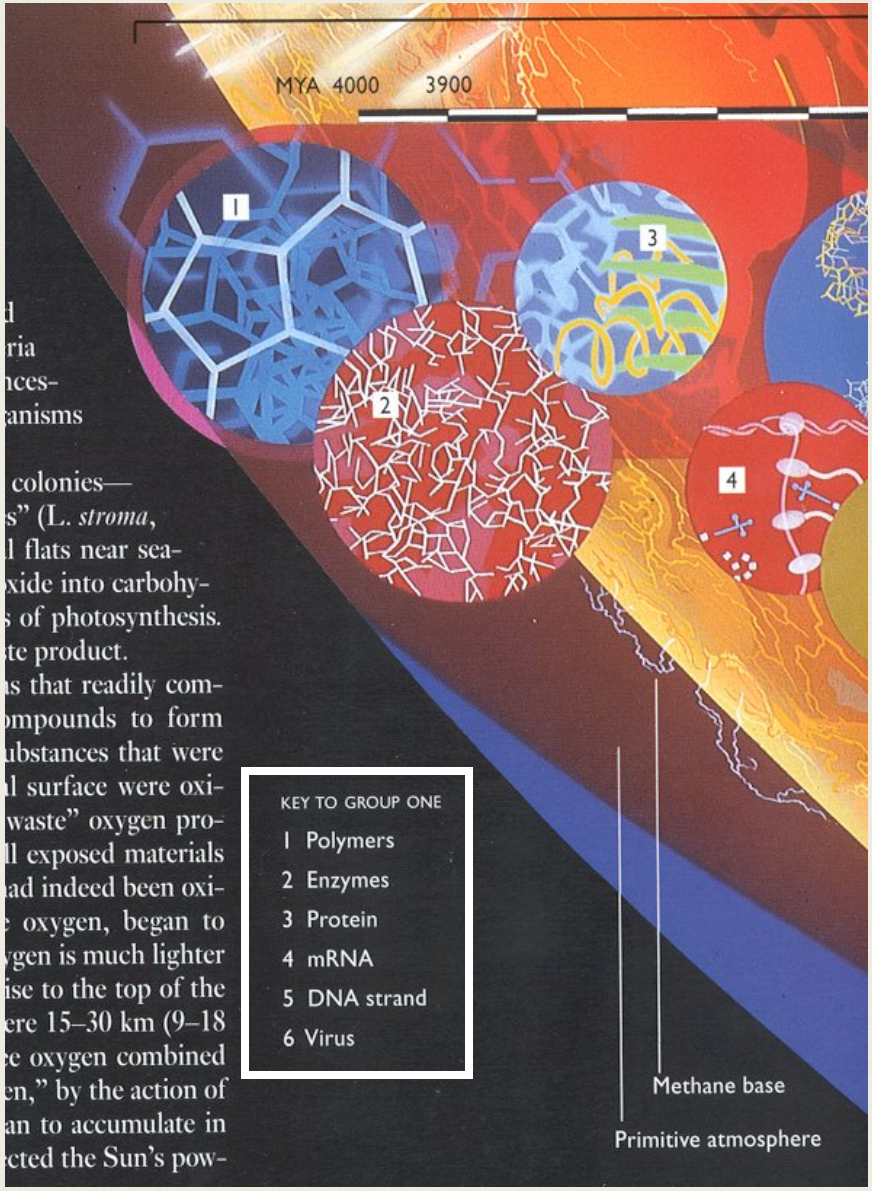


Some of the best minds of our generation have spent their lives studying the heavens and the Earth. They have concluded that the universe came into being 13.7 billion years ago with a massive, explosive expansion of pure energy, the Big Bang.

Within minutes, they tell us, the energy began to differentiate into atomic particles: quarks, electrons, protons and neutrons. Nuclear and electromagnetic forces arranged those particles into the lighter elements, hydrogen and helium.

Gravitational forces brought the newly created matter together into galaxies of stars. The stars began to burn with nuclear fire, and there was light. Heavier elements were cooked in the stellar ovens, and as the first stars burned out and died, they exploded, strewing across space the building blocks for the next generation of stars.

[The Big Bang – 13.7 BYA]



The beginnings of life on Earth

Molecular forces provided the mechanism by which many of the earliest forms– polymers, enzymes, proteins, mRNA (messenger RNA), DNA, and viruses– could reproduce.

Replication templates

The Sacred Depths of Nature, Ursula Goodenough, Oxford U. Press, 1998

Origins: The Evolution of Oceans, Continents, and Life. RonRedfern, U. Okla. Press, 2001.

The Sixth Extinction

Present	Anthropocene Extinction Human activity ??% lost
65 million years ago	Cretaceous Extinction Impact and volcanos 17% lost
208 million years ago	Triassic Extinction ?? 23 % lost
245 million years ago	Permian Extinction Climate change? Plate movements? Impact? 54% lost
354 million years ago	Devonian Extinction Climate change? 19% lost
438 million years ago	Ordovician Extinction Climate change 25% lost

"In pushing other species to extinction, humanity is busy sawing off the limb on which it is perched." – Paul Ehrlich

As the human population grows and our demand for natural resources increases, more and more habitats are devastated. Today, we may be losing 30,000 species a year—a rate much faster than at any time since the last great extinction 65 million years ago that wiped out most of the dinosaurs.

Can we stop the devastation of our planet and save our own species? We are in a biodiversity crisis — the fastest mass extinction in Earth's history, largely due to:

- human destruction of ecosystems
- overexploitation of species and natural resources
- human overpopulation
- the spread of agriculture
- pollution

http://www.actionbioscience.org/environment/

Geological maps becoming popular in Kentucky classrooms

By Jennifer Humble, Paul Laurence Dunbar High
Cathey Seaton, Ballard County Middle School
Dan Carey, Kentucky Geological Survey

Hundreds of teachers across Kentucky have responded enthusiastically to the offer of free, laminated county geology maps through the Maps-to-Teachers service from the Kentucky Geological Survey (KGS) at the University of Kentucky (UK).

A Generalized Geologic Map for Land-Use Planning has been developed – with an accompanying brochure/PowerPoint, Maps Tell Us About Where We Live – for each of

Paul Lawrence Dunbar High School

UK missions of service and dedication to applying, sharing and disseminating knowledge across Kentucky, as we work to make the state a better place to live and learn."

Jennifer Humble, a teacher at Paul Laurence Dunbar High (Fayette County), uses the Fayette County map to show her students the complexities involved in land use planning for selecting a hospital site in the county. Humble used the free *Generalized Geologic Map for Land Use Planning* with Google Earth so that students could see satellite images of Fayette County, their homes and the Geologic map at the same time.

To use the map, students located where they lived through Google Earth and discussed geological features near their homes. Finding features such as sink holes and earthquake fault lines made the Geologic Map personal to them and enhanced their interest.

The project officially began when students obtained per capita income and population density data geographical maps that also were placed into Google Earth. By combining the information from the maps, students were able to find a site to build their hospital. To share their site location, students wrote a report summarizing their findings and presented it to their peers. Humble said the project was very interesting to her students, and they gained insight regarding their county and the initial processes that can [illegible] selecting an area to build a large stru[illegible]

Ballard County Middle School

Cathey Seaton, a teacher at Ballard [illegible] Middle School, was an earth science [illegible] she was delighted to have the chance [illegible] that interest with her students. She [illegible] her 6th-grade classrooms into groups according to the part of the county in which they lived. They used geologic quadrangle maps to reproduce those areas. Each group then got six sheets of flexible foam to make a rough physical model of the landform.

"They couldn't believe that those curved lines on the map really do show what the land really looks like," Seaton said.

The students referred to the geologic map provided by UK to determine what kinds of rock types were found in the area. "The kids loved it," she said. "They thought it was pretty neat that Ballard is a 'baby,' geologically speaking, meaning the county is comparatively [illegible] youngest [illegible] to the [illegible] ting the [illegible] nce Bal- [illegible] Madrid fault line, Seaton also gets earthquake notifications from the U.S. Geological Survey in Memphis, which the class graphs according to frequency and intensity.

The lessons fulfilled part of the social studies applications standards in Kentucky's Core Content for Assessment related to using maps to interpret patterns and locations on the Earth's surface. Seaton's students now know how to read contour maps, a skill many adults haven't mastered. They also learned to recognize different soil types and have a better understanding of geologic time periods, she continued. "And they got to get up and move around, which is always a plus for middle-schoolers."

MORE INFO...
www.uky.edu/KGS/announce/landuse_teacher.htm
Dan Carey, carey@uky.edu

Photo by Amy Wallot

At Paul Laurence Dunbar High (Fayette County), juniors Ailin Shen, left, Elizabeth Osbourne, middle, and Darshali Vyas, all students in Jennifer Humble's Math, Science and Technology Center's Earth Space class, use Google Earth, a map of Fayette County plus population density and area income information to decide where a new hospital should be located.

Photo submitted by Cathey Seaton

Naoma Curtis, a 6th-grade student at Ballard County Middle, refers to geologic and topographic quadrangle maps of her home as she prepares topographic models during teacher Cathey Seaton's class.

Good publicity, warm response

"On behalf of our entire Science Department, I want to thank you for the beautiful map of Mason County. It is full of terrific learning opportunities for our kids."

"I recently received the Floyd county map and it is wonderful. In fact it is so nice that the social studies teachers in my building and the rest of the science department asked if they could each get one. That is a total of 7 teachers. Just checking if it would be possible to get some more of those? Have a great day and great job on the map."

KGS Maps in Kentucky Classrooms

Teachers across the Commonwealth are using Kentucky Geological Survey maps in their classrooms to help students of all ages to learn more about the geology and landscape of their own and surrounding counties.

Southern Oaks Elementary, Daviess County

Lee County Middle School

Western Elementary, Ohio County

North Middle School, Henderson County

Ryle High School, Boone County

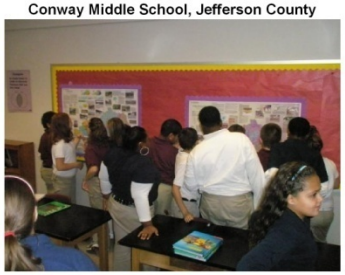
Russell-McDowell Elementary, Greenup County

Marion County Conservation District

Ballard County Middle School

Caldwell County ATC

Conway Middle School, Jefferson County



Roy G. Eversole Middle School, Perry County

Taylor Mill Elementary, Kenton County

Betsy Layne, Floyd County

Beaver Dam Elementary, Ohio County

Henderson County High School

Scott High School, Kenton County

The good news

Maps in over 1,000 classrooms in 400 schools.

Whoo hoo!!

The bad news

KGS Maps and materials currently in fewer than 25% of schools!!

Goal
5,000 more maps
to
2,500 classrooms and libraries
in
1,000 Kentucky schools.

Earth Science in the classroom: Learning about the place where we live

Next step, developing a curriculum to complement the maps

Draft ideas

Geology and Landforms

Sedimentary Rocks
Geologic History: The Building of Kentucky
Fossils
Stream Deposits
Geologic Faults
Physiographic Regions
How the Land has been Shaped
Karst

Questions for the Classroom

What are sedimentary rocks?
What are the different rock types in your county?
When and where were the sedimentary rocks in Kentucky formed?
Why are the rocks older in central Kentucky than in eastern and western Kentucky?
What is a geologic fault?
What is alluvium?
What is karst?

What Students Should Know

Younger rocks lay atop older rocks.
How the rocks in their county were formed.
Approximate ages of the rocks in their county.
Kentucky once lay beneath the sea.
The topography of Kentucky
The relationship between geology and the shape of the land.
The geology of karst.
The Physiographic Regions: Eastern Coal Field, Knobs, Bluegrass, Mississippian Plateau, Western Coal Field, Purchase
The region or subregion in which they live.

Water

The Hydrologic Cycle
Kentucky Water Facts
Rainfall
Streams
Droughts
Floods
Water and Early Development
Springs, Wells, and Streams
Water for Communities, Industry, Agriculture, and Wildlife
Water Usage
Water Sources
River Basins and Watersheds
River basin facts
Ground Water
Water in Karst Areas

Questions for the Classroom

What is a watershed?
What is ground water?
Why are there fewer streams in karst areas?
How much water falls on Kentucky in an average year?
Where does the water in your house come from?
When they flush the toilet, where does it go?

What Students Should Know

What the hydrologic cycle is
Where their water comes from.
About how much water they use in a year.
The major river basins of Kentucky
Which river basin they live in and where.
Why early settlers established towns where they did.

Living with the Land

- Understanding the Land We Live On
- Protecting the Air, Land, and Water
  - Water quality
    - Wastewater Treatment
      - Public, Domestic, Straight Pipes
  - Wetlands
  - Storm Water Management
  - Source and Ground Water Protection Areas
  - Air quality
- Geologic Hazards
  - Flooding
  - Landslides
  - Earthquakes
  - Unstable Shales
  - Radon
  - Mined Areas
  - Shrinking and Swelling Shales
  - Sinkholes

Help?

Show us the way.

carey@uky.edu

Questions for the Classroom

Where are the areas in your county that might get flooded?
Are there shales in your county?
Should you build a house on or near a sinkhole?
Why should you not throw trash in a sinkhole?
What is the risk of an earthquake where you live?
Are there mined areas in your county?
Why do we need to know about radon? Is it in your county?
If you could live anywhere in your county, where would it be and why?
If you could live anywhere in Kentucky, where would it be and why?

What Students Should Know

Why wastewater treatment is important.
Where geologic hazards may occur and what to do about them.
Best uses for floodplains.
What wetlands are and why they are important.
Why it is important to understand the geology of where they live.

Resources and Environment

- Minerals
  - Energy Resources
    - Oil and Gas
      - How it was formed, How much we have
    - Coal
      - How it was formed, How much we have
    - Electric Power
      - Coal-fired power plants
      - Usage of electricity by Kentuckians
      - Dealing with CO2
      - Hydroelectricity
  - Agriculture
    - Importance to Kentucky economy
    - Prime Farm Lands and Pasture Lands
  - Recreation
    - Public Lands
      - Wildlife Management Areas
      - State and National Parks
    - Lakes and Waterways
      - Large lakes, Ponds, Wetlands
      - Aquatic life
      - Fishing
      - Boat Ramps
      - Locks and Dams

Questions for the Classroom

Is there a farmer's market in your county?
Energy resources in the county?
Minerals used in the community?
What are the recreational areas in your county?

What Students Should Know

How electricity is generated and where it comes from.
Where their food comes from.
The resources within their county.

LEARNING ABOUT WHERE WE LIVE
KENTUCKY'S LAND AND WATER :
EARTH SCIENCE RESOURCE MATERIALS FOR TEACHERS

Ask and try to answer every question you can think of about everything below, above, and on the ground where you live. There's no better textbook, no better laboratory, no better place for teaching and learning earth science than right here.

Western Elementary School, Ohio County

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Kentucky Geological Survey
228 Mining and Mineral Resources Building
University of Kentucky, Lexington, KY 40303
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Kentucky Geological Survey