Kentucky Geological Survey
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Kentucky Landscapes Through Geologic Time

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UNIVERSITY OF KENTUCKY
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Introduction

We now understand that the earth's crust is broken up into a number of plates, some of continental size, and that these plates have been moving—centimeters a year—throughout geologic history, driven by the internal heat of the earth. This movement creates our mountain chains, earthquakes, geologic faults, and volcanoes. The theory of plate tectonics (from the Greek, *tektonikos:* pertaining to building) attempts to describe the process and helps explain the geology of Kentucky.

The geologic story of the rocks that form Kentucky's landscape began a half 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 (lithified) into the sedimentary rocks that we see today. Clay became mudstone and shale, loose sands and silt became sandstone and siltstone, shell fragments and lime oozes became limestone and dolomite, gravels became conglomerates, and peat swamps became coal. The ages of rocks in each region, together with a synopsis of the development of life during each period, are shown in Figure 1.

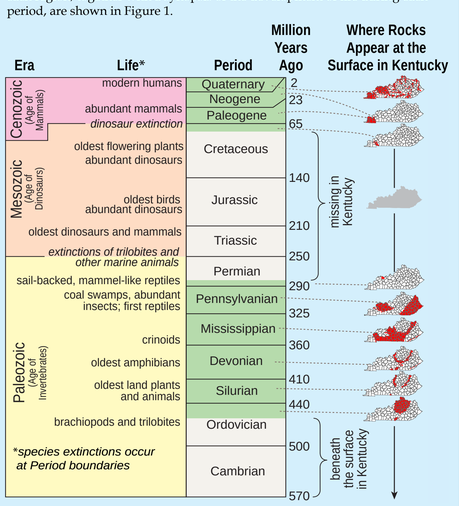

Figure 1. The geologic ages of Kentucky

With the exception of a few instances (in Crittenden and Elliott Counties) where deep-seated igneous (solidified volcanic magma) rocks have been pushed to the surface, the bedrock of Kentucky consists entirely of sedimentary rocks. Tectonic forces and erosion have bent, folded, and carved those sedimentary rocks into distinctive regions (Figs. 2–3).

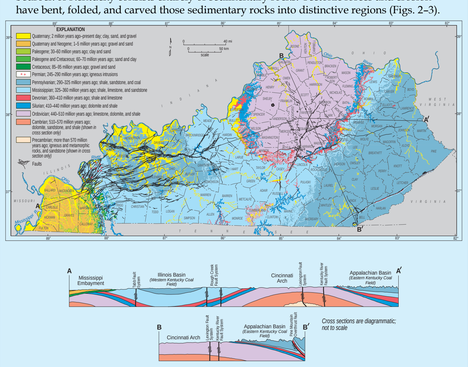

Figure 2. General geology of Kentucky.

The Landscape of Kentucky

Kentucky's natural regions, scenic geologic features, and fossil-fuel, mineral, and groundwater resources are directly related to the underlying rocks. Most of the areas underlain by sandstone, primarily the Eastern and Western Kentucky Coal Fields, are either hilly or mountainous, because sandstones resist weathering and erosion more than other rock types. Caves, sinkholes, sinking creeks, large springs, and other features associated with underground drainage are found in the limestone terrains typical of the Pennyroyal (Mississippian Plateaus) and the Bluegrass Regions. The Jackson Purchase Region (Mississippi Embayment), which is part of a large coastal plain that extends to the Gulf of Mexico, is the youngest geologic region in Kentucky, covered by unconsolidated sand, silt, clay, and gravel.

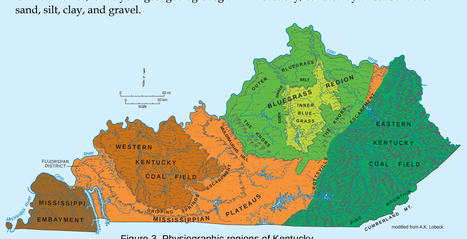

Figure 3. Physiographic regions of Kentucky.

Stream erosion has been the predominant geologic force sculpting and modifying the Kentucky landscape since the close of the Paleozoic Era 250 million years ago. Younger rocks were eroded from the crest of the Cincinnati Arch (a major upwarp, or arching of the rock strata, extending from the Cincinnati, Ohio, area through the central Bluegrass Region toward Nashville, Tenn.), leaving older Ordovician rocks exposed at the surface of the Bluegrass Region. Away from the Bluegrass, the rocks are progressively younger. The softer or weaker rocks eroded faster than harder, more resistant ones. Thus, we see escarpments such as Muldraughs Hill (Knobs area), the Dripping Springs Escarpment at the outer edge of the Mississippian Plateaus, and the escarpments at the edges of the Eastern and Western Kentucky Coal Fields. For more about the landscape of Kentucky, see Carey and Hounshell (2008).

Learn More

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Acknowledgments

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The Ordovician Period

During most of the **Ordovician,** Kentucky was covered by shallow, tropical seas (Fig. 4). Limestones, dolomites, and shales were formed at this time. The oldest rocks exposed at the surface in Kentucky are the hard limestones of the Camp Nelson Limestone (Middle Ordovician age) (Fig. 5), 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 acquired from oil and gas drilling and mineral exploration. Later in Ordovician time, the seas became relatively shallow, indicated by mud and shale in the sediments. When the waters were clear and warm, a profusion of animal life flourished, particularly brachiopods and bryozoa. These became the rich fossil beds that have attracted amateur and professional paleontologists to the stream beds, rocky hillsides, and roadcuts of the Bluegrass Region.

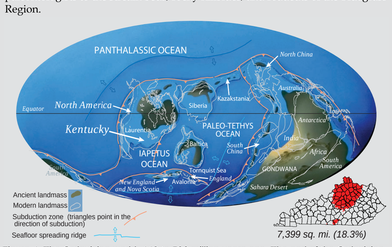

Figure 4. The Ordovician world, 440 to 500 million years ago. The end of the Ordovician was one of the coldest times in earth history. Modified from Scotese (2003); used with permission.

Figure 5. The 450-million-year-old Camp Nelson Limestone along the Kentucky River Palisades in Fayette County was formed from fine lime mud deposits in clear, shallow seas similar to those of the present-day Bahamas.

Since Kentucky was covered by shallow tropical seas during most of the Ordovician Period (Figs. 6–7), the fossils found in Kentucky's Ordovician rocks are marine (sea-dwelling) invertebrates. Common Ordovician fossils found in Kentucky include sponges (of the phylum Porifera), corals (phylum Cnidaria), bryozoans, brachiopods (Fig. 8), trilobites, snails (phylum Gastropoda), clams (phylum Pelecypoda), squid-like animals (phylum Cephalopoda), crinoids (of the class Echinodermata), and ostracodes and conodonts. Straight-shelled nautiloids (squid-like cephalopods), shown in Figure 9(a), are common fossils in the Bluegrass Region. Some have been found that are nearly 4 feet long. A fully preserved 450-million-year-old crinoid is shown in Figure 9(b).

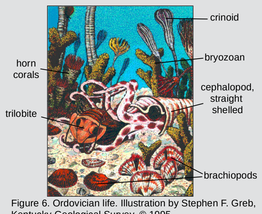

Figure 6. Ordovician life. Illustration by Stephen F. Greb, Kentucky Geological Survey, © 1995.

Figure 9. (a) Nautiloids and (b) Crinoid. Photos by Rick Schrantz, Kentucky Paleontological Society; used with permission. (c) Colonies of cyanobacteria formed stromatolites like this one from the Ordovician. Cyanobacteria, still living today, photosynthesized for billions of years to give us the oxygen-rich atmosphere in which life flourishes. Photo by Brandon Nuttall, Kentucky Geological Survey.

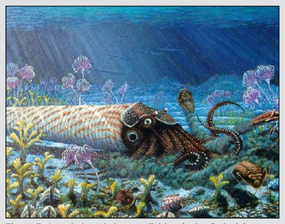

Figure 7. A cephalopod chases trilobites in the Ordovician sea. Illustration by Stephen F. Greb, Kentucky Geological Survey, ©1995.

Figure 8. A 440-million-year-old brachiopod fossil found in Bath County. The brachiopod is the Kentucky state fossil. Photo by Rick Schrantz, Kentucky Paleontological Society; used with permission.

The Silurian Period

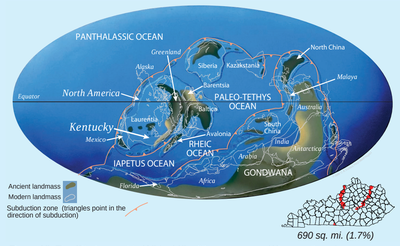

Figure 10. The Silurian world, 410 to 440 million years ago. When sediments that formed the Silurian rocks were deposited 425 million years ago, the seabed that was Kentucky contained algae, eurypterids (sea scorpions), worms, shrimp, and early fish. Coral reefs expanded and land plants began to colonize the barren continents. Modified from Scotese (2003); used with permission.

Silurian rocks are exposed at the surface in the Knobs Region, which rings the Bluegrass Region. Silurian rocks are absent in the Bluegrass, but occur below the surface in other parts of Kentucky. During most of the Silurian, Kentucky was covered by shallow tropical seas (Fig. 10). Silurian seas were commonly warm and clear (Fig. 11), although the presence of some shale beds suggests that muddy conditions prevailed at times (Fig. 12). Fluctuations in the supply of eroded material probably account for the shale units between the carbonate units; the source of sediments for that shale was from the east.

Silurian dolomite and limestone are composed largely of whole and fragmented skeletons of animals that lived in the sea. These remains were deposited near where they lived. Numerous corals and brachiopods can be found in the Silurian limestones and dolomites.

All Silurian fossils are marine invertebrates (Fig. 13). Common Silurian fossils in Kentucky include corals (Fig. 14(a)), bryozoans, brachiopods, trilobites (Fig. 14(b)), snails, clams, cephalopods, crinoids, and ostracodes and conodonts.

During the Silurian Period, gentle folding began, creating the Cincinnati Arch. This upwarping raised part of the land above sea level and temporarily separated two major geologic basins.

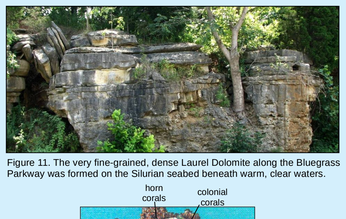

Figure 11. The very fine-grained, dense Laurel Dolomite along the Bluegrass Parkway was formed on the Silurian seabed beneath warm, clear waters.

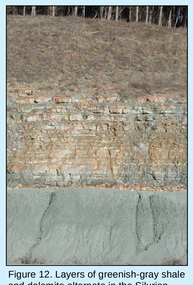

Figure 12. Layers of greenish-gray shale and dolomite alternate in the Silurian rocks along Interstate 64 in Bath County. Shales were deposited in shallow, muddy seas, and dolomites formed when seas were clearer and deeper.

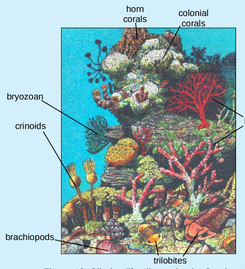

Figure 13. Silurian life. Illustration by Stephen F. Greb, Kentucky Geological Survey, ©1995.

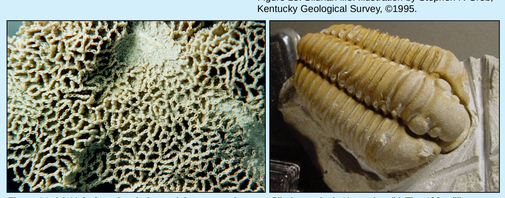

Figure 14. (a) *Halysites*, the chain coral, is common in some Silurian rocks in Kentucky. (b) The 420-million-year-old remains of a Silurian *Calymene* trilobite, found near Bardstown, are beautifully preserved by crystalline dolomite. Photos by Rick Schrantz, Kentucky Paleontological Society; used with permission.

The Devonian Period

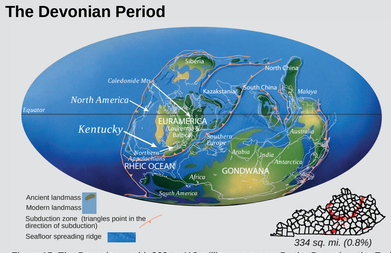

Figure 15. The Devonian world, 360 to 410 million years ago. By the Devonian, the Early Paleozoic oceans were closing, forming a precursor to a supercontinent called Pangea. Pangea contained most of the continental crust, from which the present continents are derived. Freshwater fish were able to migrate from the southern hemisphere continents to North America and Europe. Forests grew for the first time in the equatorial regions of Arctic Canada. Modified from Scotese (2003); used with permission.

Upwarping of the Cincinnati Arch continued during the first part of the **Devonian Period,** 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 patterns and regional topography in the state.

Devonian rocks are exposed at the surface in the Knobs Region, which rings the Bluegrass Region. Devonian rocks are absent in the Bluegrass, but occur below the surface in other areas of Kentucky. During most of the Devonian, Kentucky was covered by shallow tropical seas (Fig. 15), although some lands may have been dry at times in what became central Kentucky. During the latter part of the Devonian, deep seas covered Kentucky, and the water was poorly oxygenated at depth. Dark, organic-rich muds were deposited during the Late Devonian, producing the Devonian black shales in Kentucky (Fig. 16), which contain oil 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; consequently, all the fossils are marine invertebrates and vertebrates (Fig. 17). Common Devonian fossils found in Kentucky include sponges, corals, bryozoans, brachiopods, trilobites, snails, clams, cephalopods, crinoids, and ostracodes and conodonts.

Probably the most common sponge fossils found in Kentucky are the stromatoporoids. They are calcareous sponges that form mounds 2 to 3 feet across on the seafloor. They still exist today in moderately deep water. Devonian stromatoporoids can be seen at the Falls of the Ohio near Louisville.

Fossil bones of giant arthrodires (Fig. 18), sharks, and other fish have been found in the Devonian rocks in the Knobs Region. 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 Devonian shales.

One of the most famous fossil coral outcrops in the world is at 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.

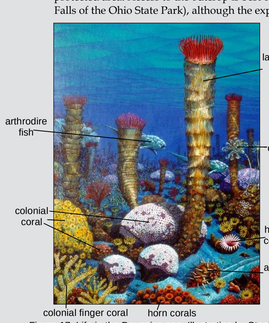

Figure 17. Life in the Devonian sea. Illustration by Stephen F. Greb, Kentucky Geological Survey, ©1995.

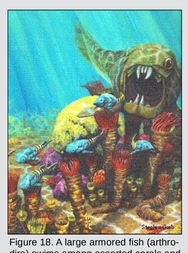

Figure 18. A large armored fish (arthrodire) swims among assorted corals and smaller fish in the Devonian sea. Illustration by Stephen F. Greb, Kentucky Geological Survey, ©1995.

Figure 16. Devonian Ohio Shale along Ky. 559 in eastern Fleming County. The shale was formed in low-oxygen (anaerobic) seas that preserved the organic matter in the sediments. The shale is dark gray to black, weathers medium gray to light brown, and is highly carbonaceous, containing enough organic matter to burn.

The Mississippian Period

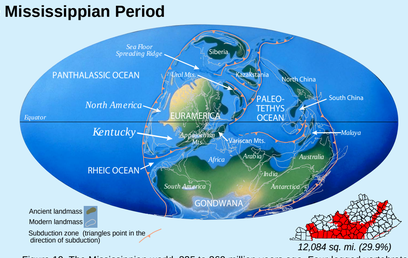

Figure 19. The Mississippian world, 325 to 360 million years ago. Four-legged vertebrates evolved in swamps near the equator. Modified from Scotese (2003); used with permission.

Mississippian rocks are exposed at the surface in the Mississippian Plateaus (Pennyroyal or Pennyrile) Region and occur below the surface in both of the coal fields. Mississippian rocks are absent in the Bluegrass Region.

During most of the Mississippian, Kentucky was covered by shallow tropical seas (Fig. 19). Changing depositional environments led to different types of rocks being deposited throughout the Mississippian (Fig. 20). Black shale continued to be deposited briefly during the Early 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 that were deposited as a great delta. Peculiar markings on some slabs of siltstone are indications of water currents and sea-bottom life.

When seas cleared during the middle part of the Mississippian, great thicknesses of limestone were deposited in the warm, shallow waters. Many caves have developed in these limestones during the past 5 million years. This area is now known as one of the world's most famous karst (cave-bearing) regions and is home to the world's longest cave system, Mammoth Cave.

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

Most of the Mississippian rocks found in Kentucky are marine, so many of the fossils in them are marine invertebrates (Fig. 21). Common Mississippian fossils found in Kentucky include corals, bryozoans, brachiopods, trilobites, snails, clams, cephalopods, crinoids and blastoids, fish teeth, and ostracodes and conodonts.

When there was dry 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. Insects and arthropods were probably numerous on land. Amphibians lived in estuaries and ox-bow lakes, but only one amphibian fossil has been found in Kentucky (in 1995). Called an embolomere (Fig. 22), it was about 5 feet long, had a long, streamlined body, and probably lived most of the time in water and ate fish and other small amphibians and reptiles. It was found in Mississippian sandstones on the margin of the Western Kentucky Coal Field.

Many types of sharks lived in Kentucky during the Mississippian; some had teeth for capturing swimming animals and others had teeth especially adapted for crushing and eating shellfish such as brachiopods, clams, crinoids, and cephalopods (Fig. 23).

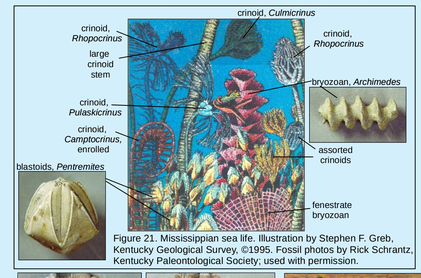

Figure 21. Mississippian sea life. Illustration by Stephen F. Greb, Kentucky Geological Survey, ©1995. Fossil photos by Rick Schrantz, Kentucky Paleontological Society; used with permission.

Figure 23. Mississippian shark teeth, 330 million years old. Photos by Rick Schrantz, Kentucky Paleontological Society; used with permission.

Figure 22. A Mississippian embolomere, an early amphibian. Illustration by Stephen F. Greb, Kentucky Geological Survey, ©1995.

Figure 20. Interbedded siltstone, limestone, and shale of the 350-million-year-old Fort Payne Formation along Ky. 61 in Cumberland County. The depositional environment changed throughout the Mississippian, producing a variety of limestones, dolomites, shales, siltstones, and sandstones.

The Pennsylvanian Period

Pennsylvanian rocks are both marine and nonmarine, the latter predominating. Although all of Kentucky was probably covered by Pennsylvanian sediments at one time, erosion has completely removed Pennsylvanian rocks from all areas but the Eastern and Western Kentucky Coal Fields.

During the Pennsylvanian, often called the Coal Age, parts of Kentucky were covered intermittently by shallow seas (Fig. 24). Marine waters advanced and receded many times. The climate was warm, and extensive forests grew in great coastal swamps (Fig. 25) at the edge of the water. Grasses, seed ferns, ferns, scale trees, calamite trees, and cordaite trees grew in these luxuriant forests (Fig. 26). 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 (Fig. 27). Clay sealed the vegetation from oxygen, preventing decay. The process was repeated many times. The weight of sediments over long geologic time compressed the buried vegetation into the numerous coal beds in Kentucky's two coal fields.

When the sea level rose, which it did periodically, 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 invertebrates and vertebrates lived in Kentucky (Fig. 28). Common Pennsylvanian marine fossils found in Kentucky include corals, brachiopods, trilobites, snails, clams, cephalopods, crinoids, fish teeth, and ostracodes and conodonts.

Figure 24. The Pennsylvanian world, 290 to 325 million years ago. Vast coal swamps formed along the equator. Modified from Scotese (2003); used with permission.

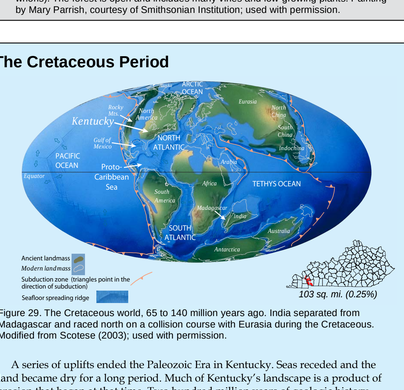

Figure 25. Peat-forming swamps, also known as mires, formed over Kentucky during the Pennsylvanian. The coal beds are the remains of these swampy landscapes. This reconstruction shows a forest dominated by a mixture of lycopsid—nonseed-bearing—trees (front right, also with juvenile tree), tree ferns (left, with mantles of prop roots extending out from the trunks), seed ferns (center, trees with crown of frond-like leaves), and calamites—extinct early horsetails (right side, rear foreground, with branches in whorls). The forest is open and includes many vines and low-growing plants. Painting by Mary Parrish, courtesy of Smithsonian Institution; used with permission.

Figure 26. Plant fossils from the Eastern Kentucky Coal Field (350 million years old). Left, horsetail plant, *Annularia*. Right, seed fern. Photos by Rick Schrantz, Kentucky Paleontological Society; used with permission.

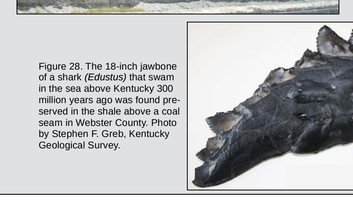

Figure 27. The Four Corners Formation along Ky. 7 in Morgan County has alternating bands of sandstones and siltstones (light) and shales and coals (dark), revealing the changing depositional environment—shallow seas, deltas, river deposits, swamps—during the Pennsylvanian.

Figure 28. The 18-inch jawbone of a shark *(Edustus)* that swam in the sea above Kentucky 300 million years ago was found preserved in the shale above a coal seam in Webster County. Photo by Stephen F. Greb, Kentucky Geological Survey.

The Cretaceous Period

Figure 29. The Cretaceous world, 65 to 140 million years ago. India separated from Madagascar and raced north on a collision course with Eurasia during the Cretaceous. Modified from Scotese (2003); used with permission.

A series of uplifts ended the Paleozoic Era in Kentucky. Seas receded and the land became dry for a long period. Much of Kentucky's landscape is a product of erosion that began at that time. Two hundred million years of geologic history are missing in Kentucky, including the Middle and Late Permian, Triassic, Jurassic, and most of the Cretaceous Periods.

During the latter part of the **Cretaceous,** the Gulf of Mexico inundated much of the southern United States (Fig. 29). A long bay extended north from the Gulf, covering all of the Jackson Purchase Region and adjacent parts of the Mississippian Plateaus with sands, clays, and gravels (Fig. 30). These geologic deposits are a marked contrast to the underlying hard Paleozoic rocks because to this day most of the Cretaceous sediments remain unconsolidated and soft.

Figure 30. Contrasting colors of reddish-brown Neogene gravel stored in a pit of whitish-gray Cretaceous gravel in Livingston County. Photo by Paul Potter, University of Cincinnati; used with permission.

The Paleogene/Neogene Periods

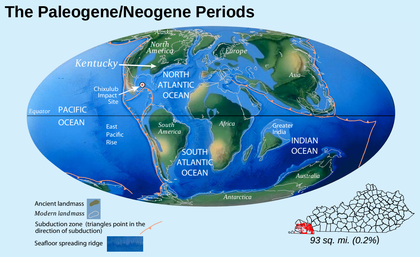

Figure 31. The Paleogene/Neogene world, 2 to 65 million years ago. The 10-mile-wide comet impact at Chicxulub 65 million years ago caused climate changes thought to have killed the dinosaurs and many other forms of life. Modified from Scotese (2003); used with permission.

Deposition of marine and fresh- to brackish-water sediments continued in the Jackson Purchase Region during **Paleogene/Neogene** time (Fig. 31). Distribution of deposits indicates that the area was near the northern limit of the Mississippi Embayment. Parts 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 Region.

The Quaternary Period

Glaciations during the **Quaternary** (1.8 million to 10,000 years ago) (Fig. 32) played only an indirect role in the geologic history of Kentucky, compared to the extensively glaciated states of Illinois, Ohio, and Indiana. The southern margin of the continental ice sheet reached Kentucky only in the vicinity of Covington. It did, however, affect the course of the Ohio River upstream from Cincinnati and at Louisville, and glacial meltwaters from the north filled its valley with deposits of sand and gravel. The ice sheet or floodwaters from the melting glacier temporarily obstructed the flow of some north-flowing streams such as the Licking, Kentucky, Salt, and Green Rivers, causing local drainage modifications and leaving remnants of slackwater or lake-bottom sediments various distances upstream.

Figure 32. The world during the last ice age, 18,000 years ago. Modified from Scotese (2003); used with permission.