THE GEOLOGIC STORY OF KENTUCKY

Preston McGrain

KENTUCKY GEOLOGICAL SURVEY
UNIVERSITY OF KENTUCKY, LEXINGTON

SPECIAL PUBLICATION 8
SERIES XI, 1983

ISSN 0075-5613

ISSN 0075-5613

KENTUCKY GEOLOGICAL SURVEY
UNIVERSITY OF KENTUCKY, LEXINGTON
Donald C. Haney, Director and State Geologist
Series XI, 1983

THE GEOLOGIC STORY OF KENTUCKY

Preston McGrain

Front Cover

Natural Bridge (of Kentucky) is the focal point for Natural Bridge State Park. Deep, steep-sided stream valleys and very narrow ridges capped with resistant sandstones characterize the terrain in which most of the natural bridges in Kentucky occur. No area in the eastern United States contains more natural sandstone bridges and arches than the region along and near the Cumberland Escarpment in eastern Kentucky. Kentucky Department of the Arts photograph.

SPECIAL PUBLICATION 8

UNIVERSITY OF KENTUCKY

Otis A. Singletary, President
Art Gallaher, Jr., Chancellor, Main Campus
Wimberly C. Royster, Dean of Graduate School and Coordinator of Research
James Y. McDonald, Executive Director, University of Kentucky Research Foundation

KENTUCKY GEOLOGICAL SURVEY ADVISORY BOARD

David A. Zegeer, Chairman, Lexington
Phil M. Miles, Vice Chairman, Lexington
David E. Bayer, Lexington
John G. Donan, Sr., Madisonville
Wallace W. Hagan, Lexington
Henry L. Hinkle, Paris
J. Edward Parker, Lexington
W. J. Reynolds, Allen
Henry A. Spalding, Hazard
Henry Stratton, Pikeville
Ralph N. Thomas, Owensboro
George H. Warren, Jr., Owensboro

KENTUCKY GEOLOGICAL SURVEY

Donald C. Haney, Director and State Geologist
Preston McGrain, Assistant State Geologist
John D. Kiefer, Assistant State Geologist

ADMINISTRATIVE DIVISION

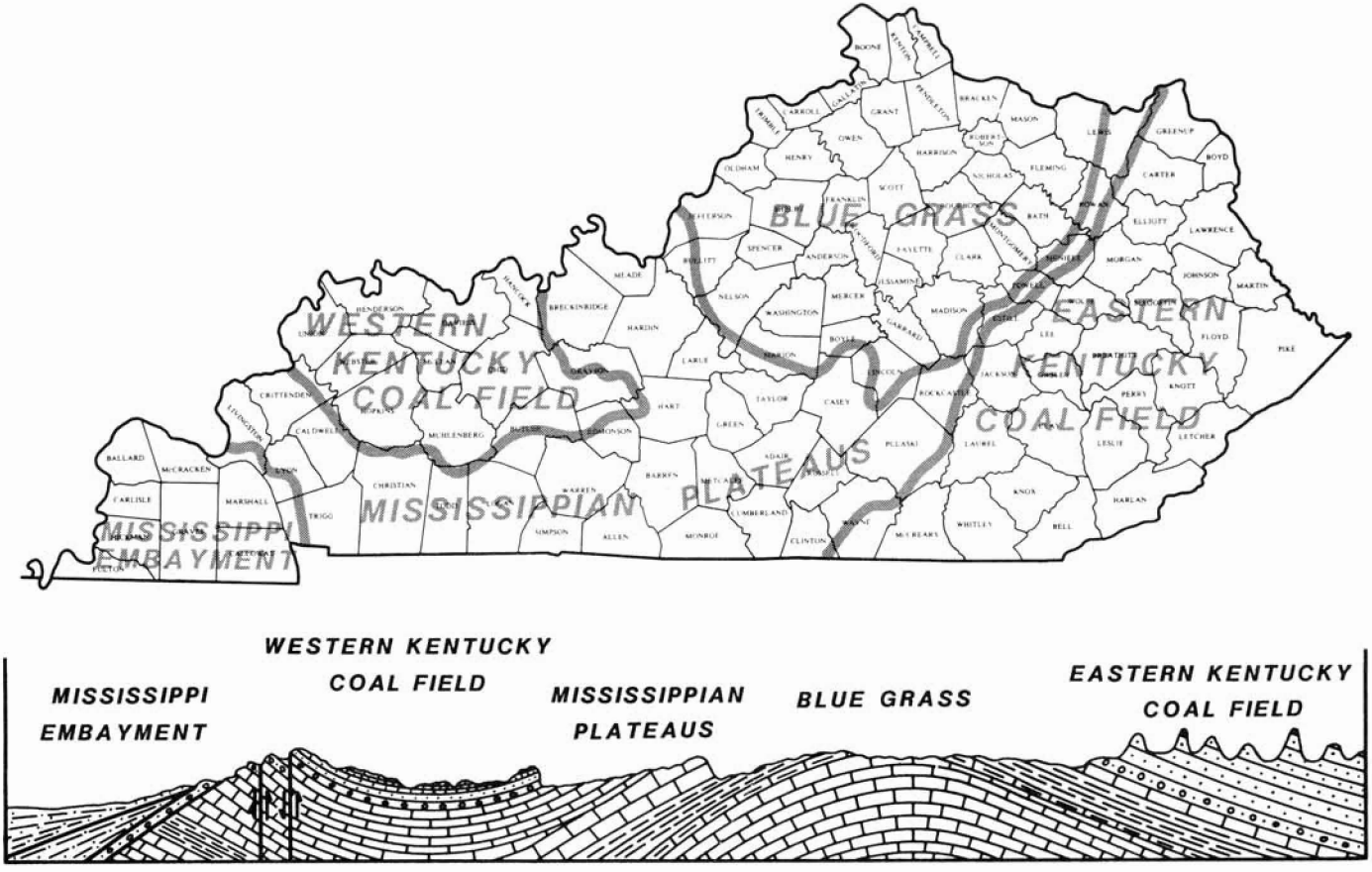
Personnel and Finance Section:
James Hamilton, Administrative Staff Officer II
Margaret Fernandez, Account Clerk V
Clerical Section:
Brenda L. Hayden, Staff Assistant VI
Anna L. Hopkins, Staff Assistant V
Donna C. Ramseur, Staff Assistant VI
Norma J. Reynolds, Staff Assistant V
Jean Kelly, Staff Assistant V
Juanita G. Smith, Staff Assistant V, Henderson Office
Publications Section:
Donald W. Hutcheson, Head
Margaret K. Luther, Assistant Editor
Roger B Potts, Chief Cartographic Illustrator
Lynn D. Guindon, Principal Drafting Technician
Robert C. Holladay, Drafting Technician
William A. Briscoe, III, Sales Supervisor
Lemuel W. Waite, Account Clerk II
John Cox, Stores Worker
Patrick H. McHaffie, Geologist Geographer II

GEOLOGICAL DIVISION

Coal Section:
Lexington Office
James C. Cobb, Head
Russell A. Brant, Geologist V
Donald R. Chesnut, Jr., Geologist III
James C. Currens, Geologist III
Richard E. Sergeant, Geologist III
Elisabeth R. Portig, Geologist II
Wayne T. Frankie, Geologist I
Ernie R. Slucher, Geologist I
Richard A. Smath, Geologist I
Ralph Palumbo, Drafting Technician
Henderson Office
Allen D. Williamson, Geologist IV
David A. Williams, Geologist III
Roxanne Bingemer, Geologist I
Industrial and Metallic Minerals Section:
Preston McGrain, Head and Assistant State Geologist
Garland R. Dever, Jr., Geologist V
Warren H. Anderson, Geologist II
Jack R. Moody, Geologist II
Stratigraphy and Petroleum Geology Section:
John D. Kiefer, Acting Head and Assistant State Geologist
Martin C. Noger, Geologist V
Louis R. Ponsetto, Geologist V
Frank H. Walker, Geologist IV
John G. Beard, Geologist IV, Henderson Office
Patrick J. Gooding, Geologist II
Brandon C. Nuttall, Geologist II
Frances Benson, Library Technician III
Richard W. Taulbee, Senior Laboratory Assistant
Robert R. Daniel, Laboratory Assistant
Water Section:
James S. Dinger, Head
Steven Cordiviola, Geologist III
James Kipp, Geologist II
Margaret A. Townsend, Geologist II
Lee E. Crawfort, Senior Scientific Analyst Programmer

CONTENTS

ILLUSTRATIONS



Generalized physiographic map of Kentucky with cross section.

THE GEOLOGIC STORY OF KENTUCKY

Preston McGrain

INTRODUCTION

From the Breaks of the Sandy to the bluffs of the Mississippi, Kentucky has a diverse geology, strikingly beautiful landscapes, an array of surface and underground natural scenic features, abundant water resources, and rich mineral wealth. Although better known for its thoroughbred race horses and tobacco and distilling industries, Kentucky has much to offer both the nature lover and student of natural science. Interesting pages of the Earth's history are revealed in the majestic mountains, rocky gorges, cascading waterfalls, picturesque caverns, broad valleys, fertile plains, and quiet glens.

Natural Bridge State Resort Park and Red River Gorge Geological Area are in a region unrivaled in the eastern United States for the number of natural sandstone arches and bridges. Cumberland Falls is one of the largest waterfalls in the Southeast. Mammoth Cave National Park contains the longest mapped cave system in the United States. And the Jackson Purchase region was once part of a much larger Gulf of Mexico.

A knowledge of geology guides the geologist in his search for needed fuels and minerals, assists the engineer in his design and construction of structures to improve our environment, helps the agriculturist interpret soil conditions, and aids the tourist in understanding the State's natural features. One cannot cross Kentucky, either east to west or north to south, without noticing changes in rock types in roadcuts and hillsides. From Lexington to Paducah one would traverse four major geologic regions and could observe rocks of eight major geologic periods. For a person who understands the geologic features, an excursion across Kentucky can be more than a sightseeing tour. The spectacle of changing landscapes becomes an adventure into the geologic mystery of the past

and the scenic beauty of the present.

The geologic story of the rocks now exposed in Kentucky began approximately half a billion years ago when the area was covered by a great body of water. Most of the surface rock formations are sedimentary, and they are generally layered like a cake. Granites and metamorphic rocks are deeply buried. There is no evidence of volcanoes. There are only a few instances where deep-seated igneous rocks have been pushed to the surface. There have been frequent changes in sea levels over Kentucky, which are reflected in types of rock and nature of animal and plant life associated with them. Various muds, sands, shell fragments, and lime oozes accumulated on ocean bottoms much as they are today. Mud became clay and shale. Loose sand and silt became sandstone and siltstone. Gravels became conglom-

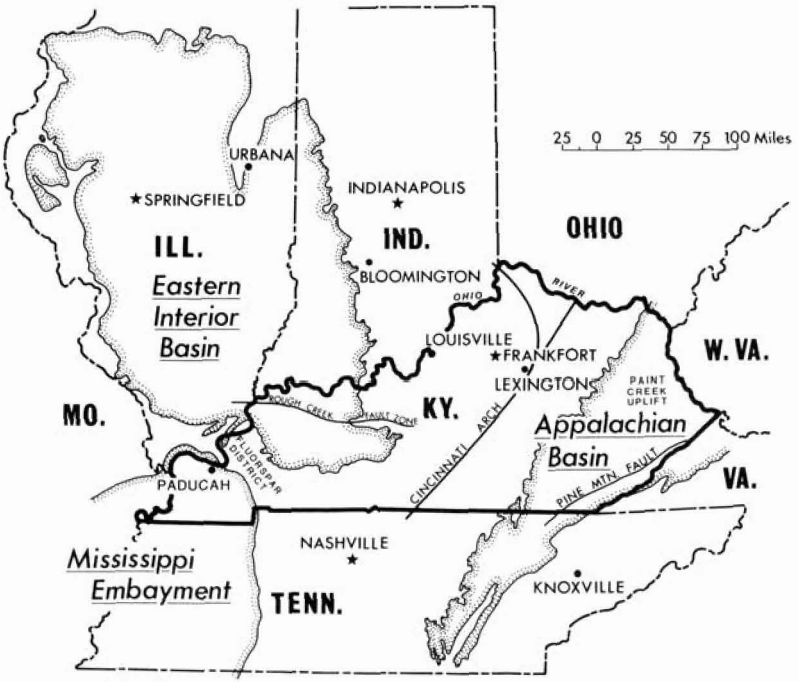


Figure 1. Regional geologic setting of Kentucky showing principal features affecting the distribution of geologic formations and mineral resources of Kentucky.

erates. Shells, shell fragments, lime oozes, and chemical precipitates became limestone.

Geologic factors affecting the distribution of rock formations and natural landscape features in Kentucky include the Cincinnati Arch, regional dip of rock layers into the Appalachian and Eastern Interior (Illinois) Basins, the Mississippi Embayment, complex faulting in and near the Western Kentucky Fluorspar District, Pine Mountain overthrust fault, and the Rough Creek Fault System (Fig. 1).

The oldest rocks exposed at the surface of the ground in Kentucky are hard limestones of Middle Ordovician age (Fig. 2). They are found along the Kentucky River gorge in central Kentucky between Boonesboro and Frankfort. Older rocks

ERA	ROCKS EXPOSED IN KENTUCKY	PERIOD (DURATION IN MILLIONS OF YEARS)		AGE (MILLIONS OF YEARS)
CENOZOIC		QUATERNARY	1	1
		TERTIARY	69	70
MESOZOIC		CRETACEOUS	65	135
		JURASSIC	45	180
		TRIASSIC	40	220
PALEOZOIC		PERMIAN	50	270
		PENNSYLVANIAN	50	320
		MISSISSIPPIAN	30	350
		DEVONIAN	50	400
		SILURIAN	30	430
		ORDOVICIAN	60	490
		CAMBRIAN	110	600
PRECAMBRIAN		PRECAMBRIAN	4,000	4,600

Figure 2. Geologic time chart showing the ages of rocks exposed in Kentucky.

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, as indicated by the amount of mud (shale) in the sediments. When the waters were clear and warm, a profusion of animal life developed, particularly brachiopods and bryozoa. These are the rich fossil beds which have attracted amateur and professional paleontologists to the stream beds, rocky hillsides, and roadcuts of the Outer Blue Grass.

Silurian seas were commonly warm and clear, although the presence of some shale beds suggests that muddy conditions prevailed at times. Locally, numerous corals and brachiopods can be found in the Silurian limestones and dolomites (Fig. 3). 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.

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. Limestone formations of Devonian age are thin in Kentucky but may contain brachiopods, crinoids, and corals. Before the end of Devonian time, the sea floor became covered with an organic black muck. This muck is now a hard black shale (an oil shale) which is one of the most distinctive of all geological formations in Kentucky. It is easily recognized by its black color and thin, hard, brittle layers. Fossil remains of the earliest known trees have been found in this formation (Fig. 4).

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 indica-

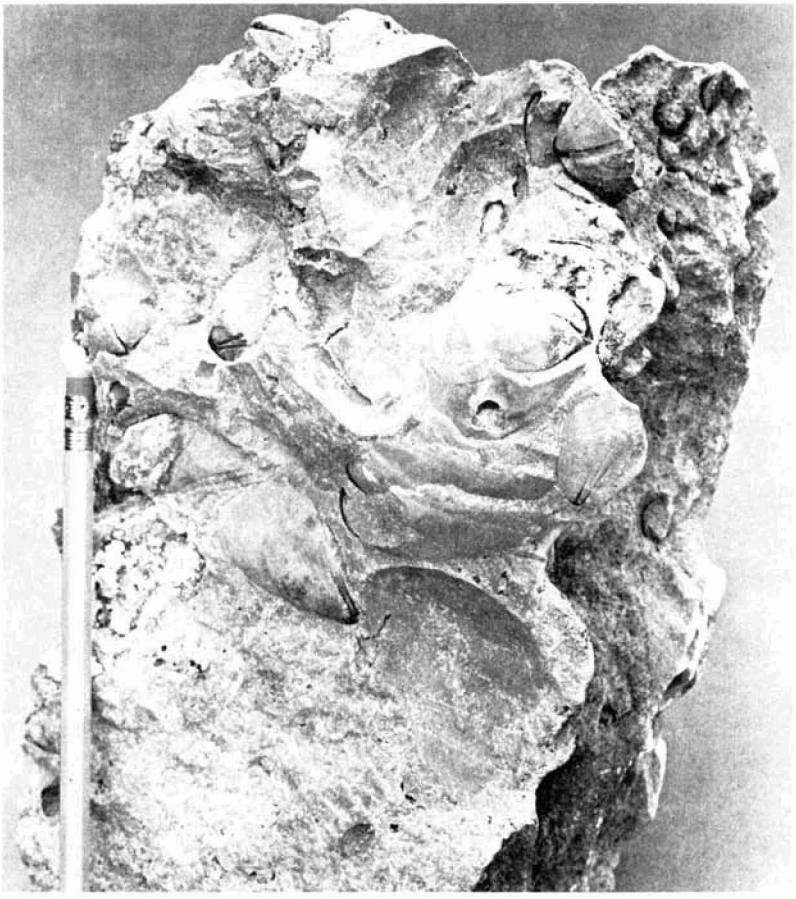


Figure 3. Block of Middle Silurian dolomite with casts and molds of the brachiopod *Pentamerus.* This is a guide, or index, fossil for these rocks. Bernheim Forest photograph.

tions of water currents and sea-bottom life (Fig. 5). When Mississippian seas cleared, great thicknesses of limestone were deposited in the warm, shallow waters. Blastoids, brachiopods, bryozoa, corals, and crinoids were common forms during that geologic time period (Fig. 6). The seas receded briefly at the end of the Mississippian Period, as indicated by the uneven, eroded surface on which subsequent Pennsylvanian sediments were deposited.

Figure 4. Portion of a fossil tree in Devonian black shale. It has been identified as *Callixylon newberryi,* a form considered as probably the oldest fossil tree known—approximately 350 million years old. Bernheim Forest photograph.

During the Pennsylvanian Period parts of Kentucky were covered intermittently by shallow seas. 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 nonmarine, with the latter predominating. Grasses, reeds, and trees grew in these luxuriant forests. Vegetation of all sorts fell into the water and was buried under blankets of deltaic clays, silts, and sands (Figs. 7 and 8). 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.

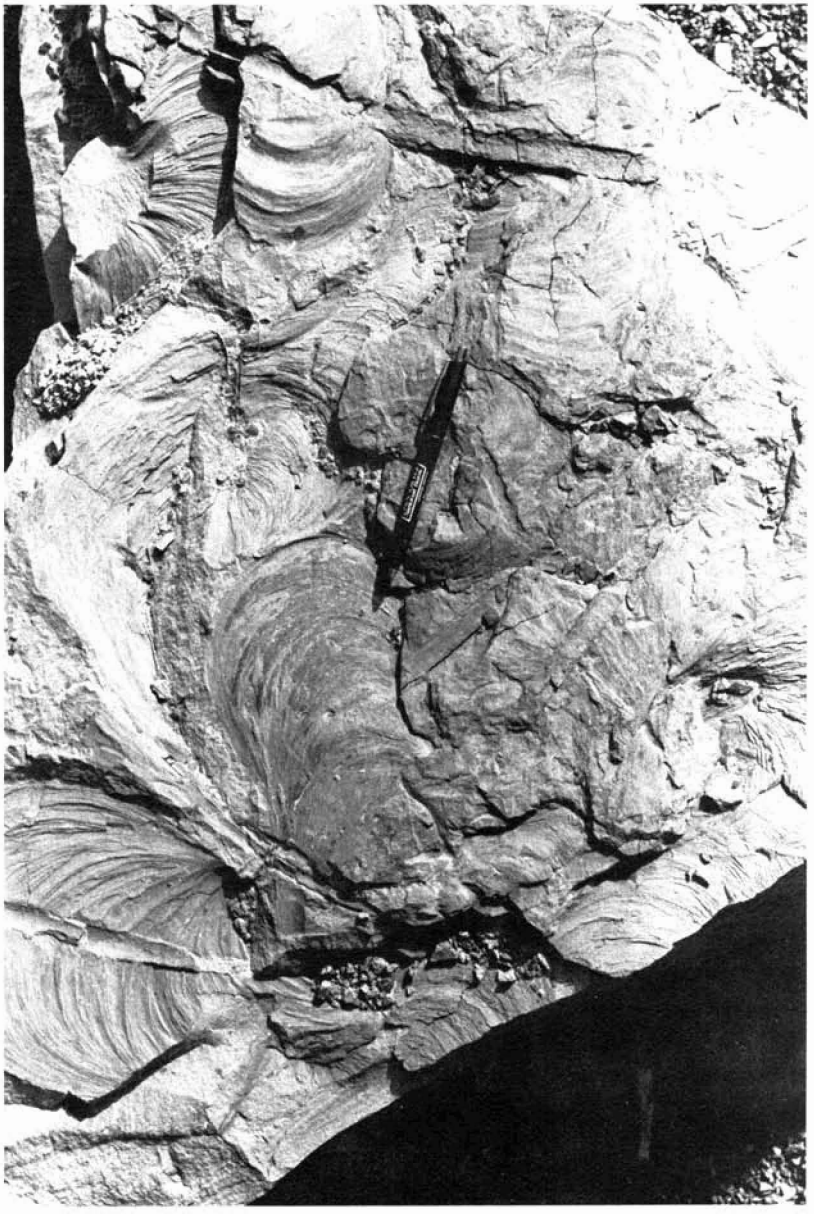


Figure 5. Tube-like and fan-shaped markings on slabs of siltstone record activities of sea-bottom life in Early Mississippian time.

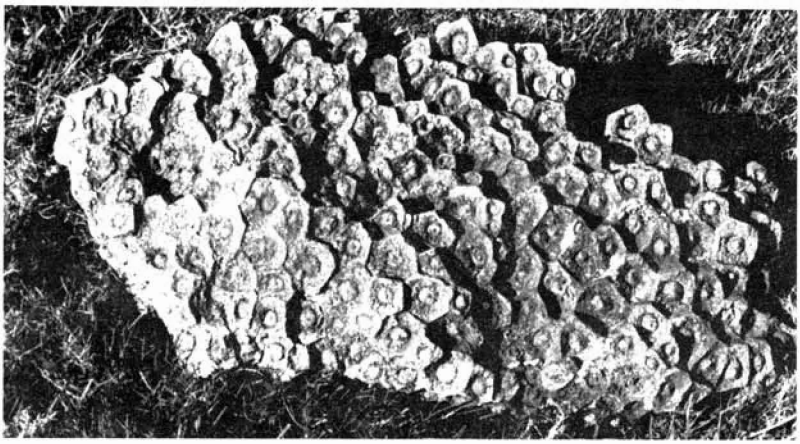


Figure 6. Petrified coral *Lithostrotionella* from the St. Louis Limestone of Mississippian age. This is a guide, or index, fossil for these rocks and is commonly found in limestones of Middle Mississippian age in many parts of the eastern United States.

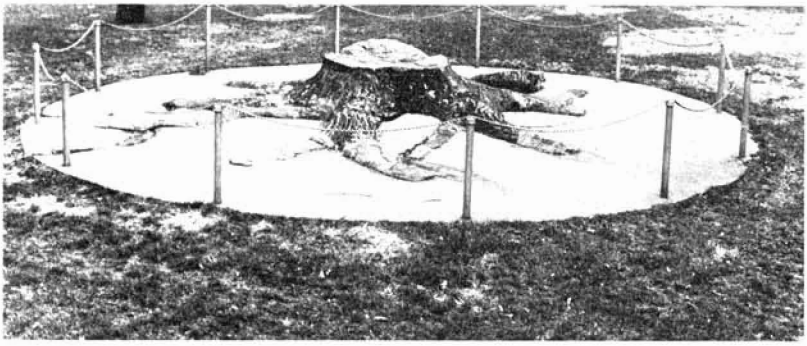


Figure 7. A fossil tree stump from the Eastern Kentucky Coal Field records evidence of plant life during the Pennsylvanian Period. The Pennsylvanian Period is characterized as having a relatively warm, moist climate which supported abundant vegetation such as trees, reeds, and ferns in a swampy terrain. This relic of a coal-age forest is now displayed on the University of Kentucky campus. University of Kentucky photograph.

Figure 8. Carbonized ferns of Pennsylvanian age in coal field rocks of eastern Kentucky. Photograph by J. R. Jennings.

Fossils from a drill-hole sample suggest that rocks of Permian age might be present in a small fault block in western Kentucky. This may indicate that Permian rocks, too, were widespread in Kentucky, but have been removed by later erosion. The Permian Period is further represented by the small igneous dikes in the Western Kentucky Fluorspar District and the small igneous plugs and dikes in Elliott County in eastern Kentucky.

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.

During the latter part of the Cretaceous Period, the Gulf of Mexico inundated much of the southern United States. 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 sedi-

ments remain unconsolidated and soft.

Deposition of marine and fresh- to brackish-water sediments continued in the Jackson Purchase area during Tertiary time. 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.

Glaciation played only a minor role in the geologic history of Kentucky as compared to our sister states to the north because the southern margin of the continental ice sheet rarely crossed the Ohio River. 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.

Kentucky's natural regions, scenic geologic features, and fossil-fuel, mineral, and ground-water resources are directly related to the underlying rock strata (Figs. 9 and 10). The land-surface features largely reflect the kinds of rock which lie beneath them and the effects of weathering and erosion upon these rocks. After layers of sediment were deposited, the area we know as Kentucky began to be modified by geological processes. Weathering and erosion of surface rocks and deformation by folding and faulting of many strata altered the landscape. Most of the areas underlain by sandstones are either hilly or mountainous because sandstones tend to resist weathering and erosion more than other Kentucky rocks. Caves, sinkholes, sinking creeks, large springs, and other features associated with underground drainage are found in the limestone terranes.

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.

Kentucky is characterized by many miles of streams and a lack of many natural lakes. The Ohio River forms 664 miles of Kentucky's northern boundary. Other major rivers which border or cross Kentucky include Big Sandy, Cumberland, Green, Kentucky, Licking, Mississippi, and Tennessee. Segments of some of the streams, such as portions of Cumberland and Rockcastle Rivers, are exceedingly scenic and picturesque, and have been designated "wild rivers" for the purpose of maintaining their beauty and primitive character (Fig. 11). Despite the lack of natural lakes, Kentucky has many man-made impoundments, several of which have been the focal points for development of major parks and recreation areas. Each of the reservoirs is distinctive because of the role of local rock strata and topography.

Springs are a conspicuous part of the Kentucky landscape and have been a contributor to the early development of the State. They provided focal points for watering places, camping grounds, rural homesteads, villages, and industrial development. When mineral waters were popular in the late 1800's and early 1900's for medicinal purposes, health resorts and hotels were established at many locations.

Elevations in Kentucky range from a low of 260 feet on the Mississippi River where it leaves Fulton County in the western extremity of the State to 4,145 feet at a peak on Black Mountain in Harlan County near the Kentucky-Virginia border.

Higher elevations occur in the southern part of the Eastern Kentucky Coal Field. Bell, Harlan, Letcher, and Pike Counties have elevations greater than 3,000 feet. Only Harlan County contains elevations greater than 4,000 feet. Eight counties—Clay, Floyd, Knott, Leslie, McCreary, Perry, and Whitley—have elevations of more than 2,000 feet.

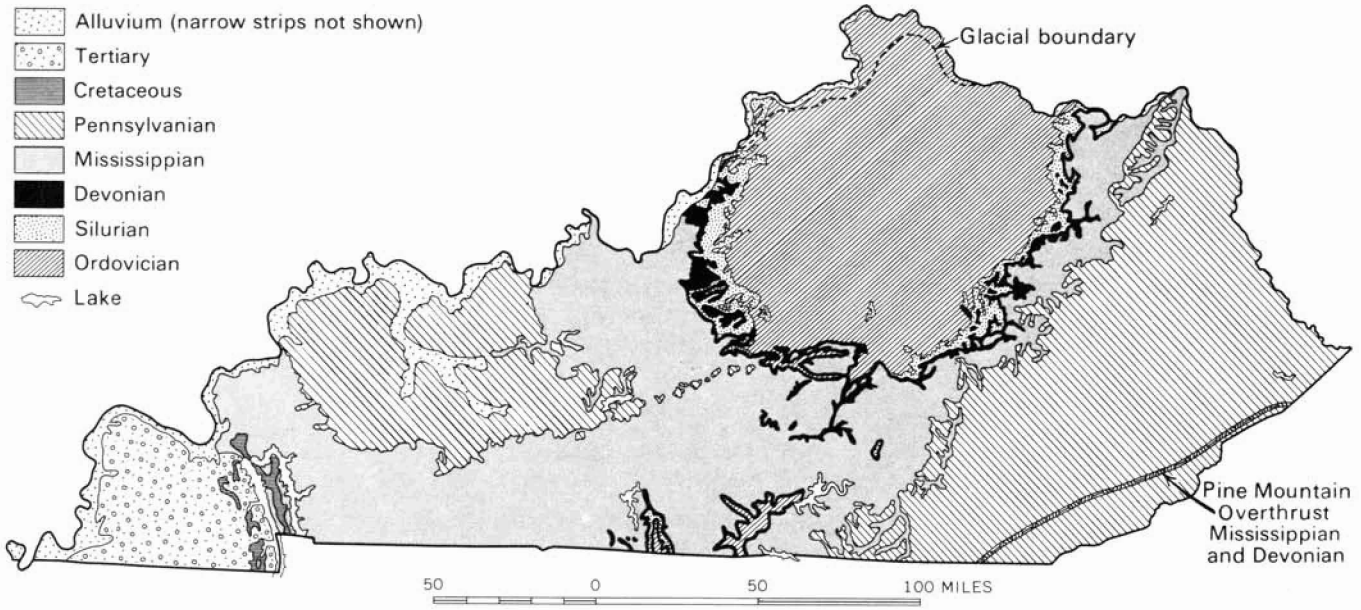


Figure 9. Generalized geologic map of Kentucky showing the distribution of rocks of various ages. The Ordovician rocks, which are exposed in the Blue Grass region, are the oldest. They dip gently to the southeast, south, and west from Lexington; successively younger rocks are encountered on the surface of the ground as one proceeds in those directions. Thus, at Madisonville or Pikeville one would have to drill a hole 5,000 to 6,000 feet to reach the same rock formations exposed in the Kentucky River gorge.

Figure 54. Kentucky Dam, on the Tennessee River in western Kentucky, impounds waters to form Kentucky Lake, the largest in the Tennessee Valley Authority system. The dam and lake are used for flood control, navigation, power generation, and recreation. Kentucky Office of Tourism Development photograph.

Lake. Three State parks have been developed in the vicinity of the two lakes. A canal, 2 miles upstream from Barkley Dam, connects Barkley Lake with Kentucky Lake for navigation and to permit operating the two flood-control reservoirs as a unit. Beginning at the canal and extending southward into Tennessee is a narrow ridge of land approximately 40 miles long that separates the two lakes. The Tennessee Valley Authority has developed this area of woodland, open fields, and irregular shoreline into an outdoor recreation and conservation area. Appropriately, it has been named "Land Between the Lakes." It is in the transition area between the Mississippian Plateaus and the Mississippi Embayment. The hills and ridges adjacent to both lakes are capped with Cretaceous and Tertiary gravels