



## Fossil Fuel Resources of the Inland Basins *Region 2*

The Inland Basins region, and in particular the Appalachian Basin, is hydrocarbon heaven: its evolution and paleoenvironments are ideal for the formation and preservation of widespread deposits of coal, oil, and natural gas. Appalachian Basin coal, along with oil and natural gas, fueled the industrial growth of the Eastern Seaboard and westward expansion. The coal-bearing region of the Appalachian Basin extends 800 miles from northern Pennsylvania to Alabama, and covers an area of 72,000 mi<sup>2</sup> in parts of 9 states.

### Coal

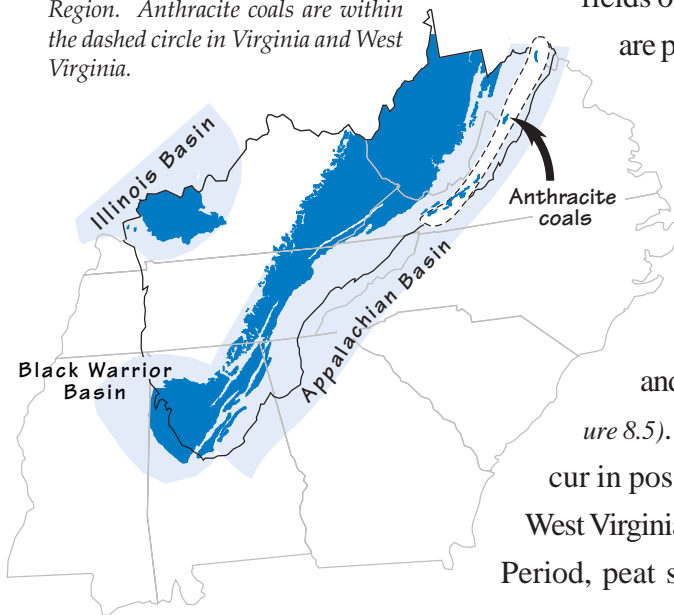
Coal is the most abundant, valuable, and historically significant natural resource in the Southeastern United States. More than 325 million years ago, during the *Mississippian Period*, the Southeast region was situated near the equator. Changes in sea level through time caused the shoreline to shift back and forth across the Inland Basins region. Peat accumulated in swamps and marshes along the shoreline when climatic and sedimentation conditions were favorable. Anthracite coals from

see *Geologic History*, p. 7, for more on the *Mississippian Period*



some of these Mississippian-age peat swamps are preserved in the Valley fields of Virginia (Figure 8.5). None are presently mined.

Figure 8.5: Bituminous and anthracite coal deposits of the Inland Basins Region. Anthracite coals are within the dashed circle in Virginia and West Virginia.



Vast coal deposits of Pennsylvanian age are present from West Virginia and western Virginia, across eastern Kentucky and Tennessee, and into northern Alabama (Figure 8.5). Lesser amounts of coal occur in possible Permian age strata in West Virginia. During the Pennsylvanian Period, peat swamps became thick and





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During the Pennsylvanian, a **tropical climate** prevailed because the Southeast was at the equator.

Coals deposited in part of the Pennsylvanian period occur in repeated successions of sedimentary rock layers. These cycles are sometimes referred to as 'cyclothem,' and resulted from the repetitive **sea level** changes caused by the formation and melting of continental glaciers in Gondwana. Extensive glaciation draws down global sea level. Melting glaciers causes a rise in sea level. More than 100 individual glacial cycles are recorded during the Mississippian and Pennsylvanian periods. Glacial and interglacial changes of 100 meters (300 feet) in sea level equated to lateral shoreline changes commonly in excess of 160 km (100 miles).



see *Geologic History*, p.7 for more on **Pangea**.



widespread. **Tropical climate**, fluctuating sea levels, and basin subsidence, resulted in the cyclic growth and burial of vast peat swamps. In fact, some of these swamps may have been among the largest tropical peat swamps of all time. Hundreds of times the seas advanced and retreated, leaving hundreds of coal beds preserved when and where conditions were right for burial of the peat. Continued subsidence in the Earth's crust in the basins of the Inland Basins region kept the basins as depressions; they did not fill entirely with sediment. This allowed the **peat** to be buried and preserved in the basins as coal. Coal beds were preserved on the eastern margin of the elongate Appalachian Basin (including the Black Warrior Basin of Alabama), and in the Illinois Basin, which extends southward into western Kentucky. **Sea level** fluctuated repeatedly during the late Mississippian and Pennsylvanian due to extensive glaciation of a combination of continents (called Gondwana) near the south pole, from about 330 to 260 million years ago.

Time, deep burial and metamorphism transformed the peat layers into high-grade anthracite and bituminous coal beds. Although geologic and climatic conditions were similar, extensive coal deposits are not associated with coastal deposits and deltas that formed during the earlier Taconic and Acadian mountain-building events. Significant coal deposits did not form prior to the Mississippian and Pennsylvanian because the plants that make up the coastal-swamp forests (which produced sufficient biomass for accumulation of large peat deposits) had not yet evolved. Plants had only just begun to spread on to land and evolve roots and vascular tissue during the Silurian period. Diversification and evolution of plants during the Devonian was rapid, leading to a proliferation of swamp loving land plants during the Pennsylvanian, when the coals from the Inland Basins formed.

Erosion of sediment from the Appalachian Mountains, which were formed by the assembly of **Pangea** in the late Paleozoic, created vast coastlines and deltas in adjacent basins of the Inland Basins region. Widespread deposits of coal are associated with these areas. Similar coal deposits occur in Germany, France, Britain, and northern Spain. In Europe, the main period of coal formation is known as the "Carboniferous" because of the abundant "carbon" (coal) found in rocks of this age. In the United States, the interval of time represented by the Carboniferous is divided into the Mississippian (with major limestone and minor coal) and Pennsylvanian (major coal deposits) Periods. Globally, Carboniferous-Pennsylvanian-age rocks contain a substantial amount of the world's coal resources.



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Coal was first reported in the Inland Basins region, along a tributary of the Kanawha River, West Virginia in 1742. Initially, only small amounts of coal were used for heating by local blacksmiths or by settlers living near coal outcrops. In 1810, people in Wheeling, West Virginia, began using locally mined coal to heat their cabins. The first steamboat on the Ohio River in 1811 burned coal from West Virginia, and coal began to replace charcoal as a fuel for the Kanawha River salt furnaces by 1817. In 1820, the first commercial mine opened in Kentucky. The total coal production in 1840 for West Virginia was about 300,000 tons, of which 200,000 tons was used in the Kanawha salt furnaces. Factories and homes in Wheeling consumed most of the remainder. Production continued to expand until the outbreak of the Civil War, when coal production became a matter of military strategy. After the war, the Appalachian Basin coal industry began a rapid and sustained growth that paralleled the industrialization of the United States, and its evolution into a major world industrial and economic power. West Virginia reached 50 million tons of annual production in 1909, and 100 million tons in 1924. Kentucky reached 50 million tons in 1926, and 100 million tons in 1968. Peak production for both states was more than 170 million tons.

The mining of Pennsylvanian coal is a major industry in Kentucky, Tennessee, Virginia, and West Virginia. More than 60 coal beds and coal zones have been or are currently being mined in the Southeast Region part of the Appalachian Basin and southern part of the Illinois Basin in western Kentucky, although 56% of the total is produced from just 10 coal beds or zones. In 2001, coal mined from the Appalachian Basin in West Virginia and Kentucky accounted for 26% of the total national coal production of 1.118 billion tons. West Virginia and Kentucky are among the top three coal producers in the Nation. A total of approximately 60 billion tons of coal have been produced in the United States over the past 180 years, and about two-thirds of that total (40 billion tons) have been produced from the Appalachian Basin deposits.

*About 15 % of total U.S. coal production comes from West Virginia, which leads the nation in underground coal production. In addition, West Virginia leads the nation in coal exports with over 50 million tons shipped to 23 countries, representing 47% of US coal exports. Kentucky is the largest producer of bituminous coal in the United States, with mines in the Pennsylvanian coals of the Appalachian Basin in eastern Kentucky and the Illinois Basin in western Kentucky.*

(DEF: salt furnaces).

*As early as the 1850s, immigrants from Wales, England, and Scotland came to work in the coal mines of North America. Cheap immigrant labor increased profitability, but the miners were often subjected to long working hours, poor medical care, and generally inferior living conditions. Poor mine conditions brought about the first West Virginia coal mining legislation in 1883, and a state mine inspector was appointed to inspect all mines for adequate safety conditions. The United Mine Workers of America was organized in Wheeling, West Virginia to push for better mine conditions in 1890, and the West Virginia Department of Mines was established in 1905 to enforce inspections laws.*

*More than 56 % of electricity consumed in the United States is generated from coal, and coal provides the majority of electric power in 32 states. More than eighty percent of the mined coal in the Southeast region is used for combustion in electrical power plants to generate electricity. Kentucky has the lowest electricity costs in the nation because of its readily available coal supplies.*





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## Coalbed Methane

Since about 1980, large reserves of natural gas have been exploited in tandem with coal seams. This natural resource, known as “coalbed methane,” forms at the same time as the coal it is associated with. In some parts of the Appalachian Basin it occurs in economic quantities. In Alabama, the gas is sometimes produced in advance of underground coal mining. Since this gas can be a safety hazard in underground mines, coalbed methane gas production in mining areas, helps to eliminate a potential hazard as well as provide an energy resource. As of the year 2000, 7% of the country’s yearly natural gas production came from coalbed methane. Since nearly half of United States coal comes from the Southeast, it follows that natural gas has correspondingly become increasingly important in the coalfields of the Appalachian Basin. The Black Warrior Basin in northern Alabama and Mississippi, and the Southwest Virginia Coalfield have hundreds of coal-bed methane wells currently in operation.

Petroleum had previously been discovered in wells drilled in the Appalachian Basin for brine (salt water). Martin Beatty of Abingdon, Virginia encountered oil while drilling a well in search of salt on the South Fork of the Cumberland River in Kentucky near the Tennessee state line in 1819. A salt prospect well near Burkesville, Kentucky struck oil under pressure in March 1829. Called the “Great American Well,” the gusher flowed into the nearby Cumberland River and the oil was carried downstream. A fisherman 40 miles downstream ignited the floating oil and flames roared upstream along the top of the river, climbed the bank, and engulfed the well.



Thomas Jefferson visited springs venting natural gas on a stream called **Burning Springs**, a tributary of the Little Kanawha River, West Virginia as early as 1781. He wrote an article describing the brilliant flame that could be produced by thrusting a lighted candle into the escaping gas. George Washington had visited the site in 1775.

## Oil & Gas

### Appalachian Basin:

The Appalachian Basin was the site of much early oil exploration. In the early and mid-1800’s drillers searching for salt in the Appalachians sometimes struck oil by accident. One such incidence, was a well drilled by the Rathbone brothers in 1859, along **Burning Springs**, in West Virginia. The following year, they drilled a well in search of more oil. Their oil well produced 1,200 barrels a day. This was just one year after the famous Drake well of Titusville, Pennsylvania, which is recognized as the first well purposefully drilled for oil (Figure 8.6).

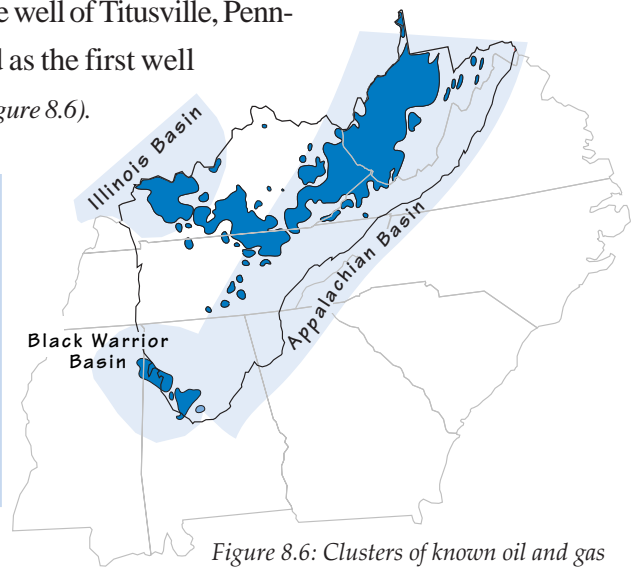


Figure 8.6: Clusters of known oil and gas fields in the Inland Basins Region.



# Fossil Fuel Resources



Petroleum production spread rapidly throughout the Appalachian Basin after the success of the Drake Well, and probably reached a peak of around 40 million barrels per year in the 1890s. The Inland Basin region peaked around 1900 as a culmination of the first major oil boom in America. The second oil boom began with the discovery of the Spindletop oil field in 1901 along the Gulf Coastal Plain of Texas. The Gulf Coast in the Southeast has not been nearly as productive as the Gulf Coast of Louisiana and Texas to the west, but shows some similar characteristics as a petroleum producer. From 1859 through 1993, the Appalachian Basin produced about **3 billion barrels of oil** (BBO) and 42 trillion cubic feet of natural gas (TCFG).

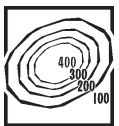
Oil and gas have been produced from Ordovician through Pennsylvanian-age strata in the Appalachian Basin. The basin was created as a result of the formation of the ancestral Appalachian Mountains. The crust was buckled and downwarped repeatedly during the Paleozoic mountain-building events to form the basin, which is deepest beneath the Appalachian Plateau. Sedimentary rocks of the **Appalachian Plateau** are not tightly folded like the adjoining **Valley and Ridge** province, but have broad, gentle folds as well as faults, which provide the opportunity to trap oil and gas. If there is source rock present, the possibility generally exists for oil and gas to be trapped at the crests of folds. This is especially the case in a 50-mile (80 km) wide zone running through western West Virginia. The reservoirs in this zone are Paleozoic in age, with the most important production coming from the Devonian Oriskany Sandstone and Mississippian Greenbrier Limestone (also known as “Big Lime”). Structural traps (mostly folds) dominate this zone, although some stratigraphic traps are produced as a result of lens-shaped sand bodies or great thicknesses of widespread rock layers. The Oriskany Sandstone, for example, extends from New York into Virginia, but is only an oil producer in some areas. The Greenbrier Limestone and its equivalents extend throughout West Virginia, eastern Kentucky and Tennessee, and parts of Alabama, Georgia, and Virginia. In some places this limestone is more than 260 feet (80 meters) thick, so drillers call it the “Big Lime”. This great thickness also allows the trapping of large quantities of oil and gas, but only in areas where there are structural traps, stratigraphic traps, or where naturally occurring fractures in the limestone allow oil and gas to accumulate. Not all reservoirs are extensive. An example of production from more isolated reservoirs is the petroleum production from the Mississippian-age Fort Payne Forma-

West Virginia actually lead the nation in oil production for one year, in 1899.

Note: the numbers cited are **totals** for the Appalachian basin, including New York, Ohio, and Pennsylvania, which are not part of the Southeast Region.

The Appalachian Basin has two distinct sections: the **Valley and Ridge**, and the **Appalachian Plateau**. Though the rocks are basically the same in the two parts of the basin, the Valley and Ridge section was squeezed into tight folds because it was closest to the plate-collision center during the Paleozoic mountain building events.

see *Topography*, p. 7, for more on the **Appalachian Plateau** and **Valley and Ridge** provinces.





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Rocks as old as the Cambrian-age Rome sand (Middle Cambrian age) have produced gas in the basin. A well in West Virginia produced gas at a depth of 14,358 feet for about six months before mechanical problems forced the well to be plugged. To date, the deepest exploration test has been in Calhoun County, West Virginia to a depth of 20,222 feet, bottoming in Precambrian-age rocks.

The **Trenton-Black River** is a carbonate rock unit that is both an oil and gas producer in states north of the Southeast Region even into Ontario, Canada.



see *Geologic History*, p. 7 for more on the **Mississippian** and **Pennsylvanian** Periods.



tion in eastern Tennessee. These reservoirs occur in carbonate mounds (called bioherms) that were formed in shallow seas. The mounds were buried by mud. The carbonate mounds are very permeable. If oil migrates into a mound, the shale cap forms a stratigraphic trap.

Large amounts of gas are also produced from thick Devonian-age black shales. These shales were deposited in inland seas that were oxygen poor (at least near the sea bed). Because there was little oxygen in the substrate when they were deposited, organic material was preserved. With time, pressure, and heat, the organic material in the shales was changed into petroleum and gas. The Devonian-age shales are the major source rock for most of the younger petroleum reservoirs. They are also a major gas reservoir. Because the shales are not permeable, like the sandstone and shale reservoirs discussed previously, gas production occurs where the shales are naturally fractured, or is induced by man-made fracturing.

Petroleum and natural gas production continue to be important in the Appalachian part of the Southeast Region, though production has generally declined in recent years in Kentucky, Tennessee, Virginia, and West Virginia. The future of exploration in the Appalachian Basin appears to be in deeper units, such as the Ordovician **Trenton-Black River Formation**. In 1999, a highly successful discovery well struck natural gas in Roane County, West Virginia to a depth greater than 10,000 feet (3,050 meters), proving the Trenton-Black River formation to be productive southward in the Appalachian Basin.

## Illinois Basin:

The productive Illinois Basin, deepest in south central Illinois, continues into western Kentucky and extreme north-central Tennessee. Oil and gas have been produced from Ordovician through Pennsylvanian-age strata in the Appalachian Basin. The main production is from structural and stratigraphic traps in **Pennsylvanian** and **Mississippian** sandstones and porous Mississippian limestones. The Pennsylvanian reservoirs are mainly sandstones that formed in rivers and estuaries that occupied deep valleys cut into underlying units. Late Mississippian sandstones formed in a wide range of fluvial, coastal, and shallow marine environments. Some of these shallow-sea sandstones are very porous, which make them great reservoir rocks. Mississippian limestone reservoirs were deposited in shallow, tropical seas. Some of the most productive Mississippian reservoirs were deposited as shoals.



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The tidal action on these shoals produced spherical grains called oolites. Oolitic shoals can be very permeable. The limestones in which these shoals occur are extensive and similar in age to the “Big Lime” of the Appalachian Basin, Limestones as old as the Ordovician Trenton-Black River have produced oil in the Southeast part of the Illinois Basin. As in the Appalachian Basin, *deeper* units are also being investigated for their reservoir potential.

## Illinois Basin:

The Black Warrior basin occupies northwestern Alabama and northeastern Mississippi. The first petroleum discovery in the region was made in 1909, when natural gas was struck in rocks of Pennsylvanian age in northwestern Alabama. Most traps are structural in nature (folds and faults), and contain both oil and natural gas. Less oil is produced in this basin than in parts of the Appalachian basin to the north, or the Illinois Basin.

## Asphalt or Bitumen

Natural asphalt or bitumen impregnating rocks occurs throughout the Inland Basins region. These deposits represent “fossil” oil reservoirs or seeps that have lost most of the lighter hydrocarbons, so they have become viscous, like tar. The most extensive deposits are found in Kentucky and Alabama. Native asphalt was first “discovered” in Lawrence County, Alabama in 1840, although previously known to Native Americans. Alabama reserves are at least 700 million tons of material containing around 100 million tons of petroleum, with limited production from 1927 to the present. Kentucky reserves are at least 500 million tons.

## Oil Shale

Oil shales are extensive formations of organic-rich (at least 10%) sediments that may grade into impure coal deposits in places. Depending on the amount and type of organic matter present, oil shales may yield up to 100 gallons of oil per ton when mined and processed to extract petroleum products. Crude oil, coal oil (kerosene), lubricating oils, and waxes were obtained from oil shales and coal in the Eastern United States before the birth of the petroleum industry in 1860. Although

The **deepest** well in the southeastern part of the basin was drilled to a depth of 15, 200 feet into the Cambrian-age Eau Claire Formation, but was plugged and abandoned.

### Between the Basins?

Oil and gas are also produced in the “Cumberland Saddle,” a sag along the **Cincinnati Arch** between the Kentucky Jessamine Dome and the Tennessee Nashville Dome. The Cincinnati Arch separates the Illinois and Appalachian Basins. In the saddle, Cambrian and Ordovician rock units, which are tens of thousands of feet deep within the basins, come to the surface. Limestones and dolomites of the Cambrian-Ordovician **Knox Group** are very productive in Tennessee and south-central Kentucky. Much of the petroleum from the Knox reservoirs was trapped in ancient sinkholes and caves along an unconformity surface; a type of stratigraphic trap. The unconformity marks a surface of erosion and weathering when the carbonates were exposed during a drop in sea level, before being buried by the next rise in sea level.

see *Rocks*, p.35  
for more on the  
**Cincinnati Arch**  
and the **Knox**  
**Group**.





# Fossil Fuel Resources

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present recovery is small scale and largely experimental, Appalachian Basin oil shale may be a major energy resource in the future. When oil shale occurs at depth, it is a source rock for much of the oil and natural gas produced in the Inland Basins region. However, it is not now economic to use it as a direct source of oil where exposed at the surface.

Two important reserves of potential oil shales have been identified in the Appalachian Basin. One is an extensive sequence of Devonian and Mississippian black shales that extends from New York to Alabama, and known as the Chattanooga, New Albany, or Ohio Shale . This extensive sequence was deposited under anoxic conditions in the inland sea that formed in the basin west of the rising Acadian Mountains. The second group of potential oil shales is Pennsylvanian black shales associated with coal beds, and widespread in the subsurface throughout portions of Kentucky, Tennessee, Virginia, and West Virginia.

