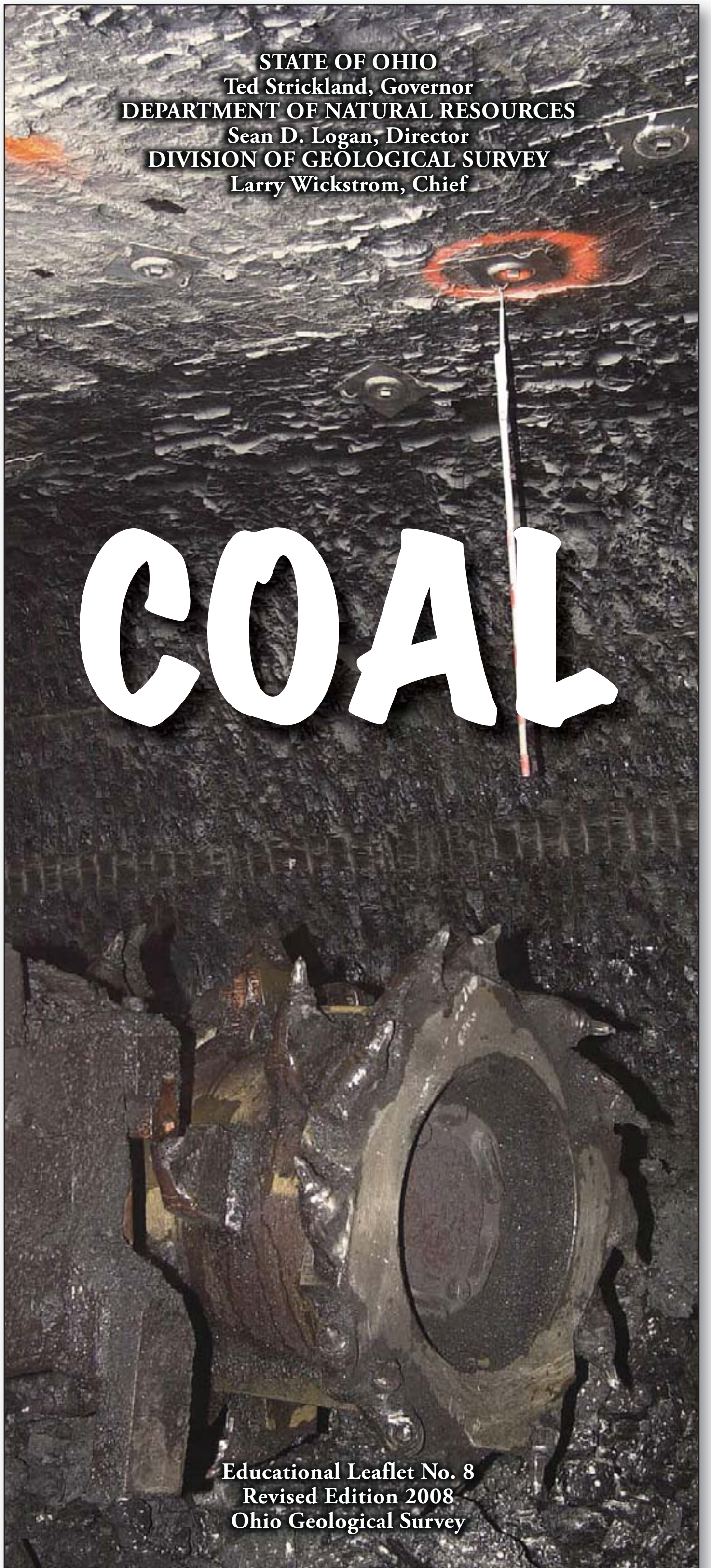


INTRODUCTION

Coal is one of Ohio's most valuable mineral resources and the nation's most abundant fossil fuel. More than 3.7 billion tons of Ohio coal has been mined since 1800, and recent figures indicate that Ohio is the 3rd largest coal-consuming state in the nation, consuming about 62 million tons per year. Ohio ranks 13th in the nation in coal production, and 7th in terms of demonstrated coal reserves with approximately 23.3 billion short tons, or 4.7% of the nation's total coal reserves. ("Demonstrated Coal Reserve" is a term used to identify the part of the total resource that is potentially mineable when considering economic, legal, and engineering constraints). At present production levels, Ohio has more than 500 years worth of potentially mineable coal remaining.

GEOLOGY OF COAL

The coal-bearing rocks of Ohio were deposited during the Pennsylvanian and Permian Periods, approximately 320 to 245 million years ago. During Pennsylvanian time, or the great Coal Age, a shallow sea covered central Ohio. A series of river deltas extended into this sea carrying sediments that eroded from the ancestral Appalachian Mountains and flowed northwest into the deltas. Extensive freshwater and brackish-water peat-forming ecosystems formed in these low-lying coastal and near-coastal deltas, which were similar to those of the current Mississippi and Amazon Rivers. These peat swamps remained undisturbed for thousands of years.

Coal forms from the accumulation and physical and chemical alteration of plant remains that settle in swampy areas and form peat, which thickens until heat and pressure transform it into the coal we use. The ancient wetland areas where Ohio's coal originated included swamps, marshes, lakes, abandoned or cut-off river channels, and back-barrier lagoons and bays associated with the development of river deltas. The Everglades of Florida, the Okefenokee Swamp of Georgia, and the Dismal Swamp of North Carolina and Virginia are modern-day examples of such wetlands.

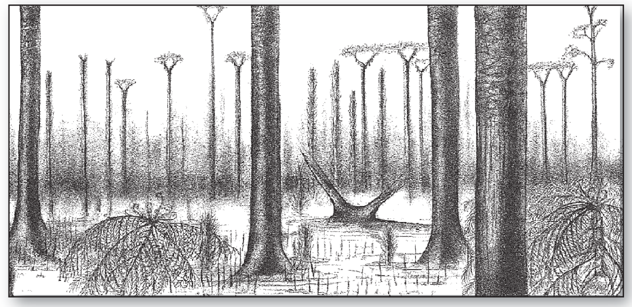
The coal we use is combustible sedimentary rock composed of carbon, hydrogen, oxygen, nitrogen, sulfur, and various trace elements (it has a carbonaceous content of more than 50% by weight and more than 70% by volume). Pennsylvanian rocks have been divided into four groups based primarily on their mineable coal content: Pottsville, Allegheny, Conemaugh, and Monongahela. More than 95% of Ohio's coal production comes from the Allegheny and Monongahela Groups. Permian rocks of the Dunkard Group overlie the Pennsylvanian rocks and do not contain significant coal resources in Ohio.

FORMATION OF COAL

Peat-forming environments are poorly drained; they have a high water table (intermittently or permanently covered with water) and contain stagnant, anoxic (oxygen-poor) water that inhibits microscopic organisms, such as bacteria and fungi, from decomposing plant materials. Over a long period of time, this debris accumulates, partially decomposes, and becomes peat. Plant production is fastest in hot, humid areas and slowest in dry, cool areas; the rate of accumulation of peat is estimated to be 3 feet per 500–600 years in a tropical climate and 3 feet per 1,500–1,700 years in a cool climate. Peat is compacted to approximately one-tenth of its original thickness when it forms coal, so environmental conditions have to remain stable for thousands of years before it can form mineable coal.

During the Coal Age, Ohio was located at or near the Equator, experiencing climatic conditions similar to the present-day Amazon River delta. Thus, a 6-foot-thick Ohio coal seam would have required approximately 60 feet of peat that formed over a period of 11,000 years.

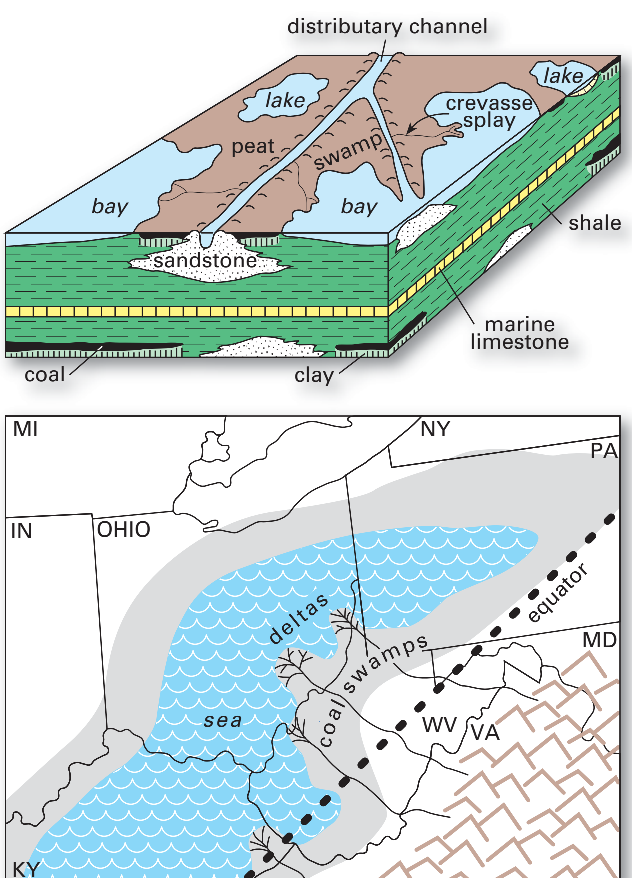
The fossil record of Ohio's Coal Age plants shows an almost total absence of growth rings, suggesting little climatic difference between seasons. In addition, the plants that formed coal had giant leaf fans and thin barks that are characteristic of tropical and subtropical rainforest plants. The Pennsylvanian peat swamps were dominated by tree-like lycopods (giant relatives of modern club mosses, spike mosses, and quillworts), which stood more than 100 feet tall, and later by tree ferns that grew more than 30 feet tall. Other tree-like plants that contributed to the formation of peat included sphenopsids (related to today's horsetails) and seed ferns that are possibly linked to modern conifers such as spruce, pine, and tamarack. Sphenopsids and some lycopods grew in areas of standing water. As the peat substrate thickened and reached the water surface, larger trees and ferns began growing in the substrate.



Reconstruction of a Pennsylvanian-age swamp dominated by widely spaced trunks of the lycopod Lepidophloios. *Based on an array of tree trunks found in the Sterling North Mine, Jefferson County. From Hook and Miller, 1996, p. 4.*

Ohio's fossil record shows that swamps of the Coal Age were also alive with amphibians, reptiles, fishes, and insects. Amphibians and reptiles ranged in appearance from alligator-sized species to limbless, serpentine forms to agile, lizard-like species. Sharks and a great number of bony fishes, including air-breathing and armored species, inhabited freshwater lakes of the Coal Age swamps. The insects of the Coal Age included millipedes, cockroaches, and long-legged flying insects.

During most of the Coal Age, Ohio experienced a wet tropical climate. However, through long periods of Conemaugh time and into Permian time, Ohio experienced a drier climate that led to a decline in lycopods, a rise in tree ferns, and a general decline in peat formation. Changing sea levels and an increased seasonality of rainfall limited vegetative growth and left organic debris vulnerable to decomposition. Rivers meandering through swamps and the erosion of peat also interrupted local peat accumulation. Eventually peat swamps were buried by marine or freshwater sediments such as sand, mud, and lime-bearing sediments (sandy sediments would later become obstructions to the coal-mining process). After the peat was buried, the coal-forming process, called coalification, began.



Top, block diagram showing a portion of a delta lobe illustrating environments of deposition and associated rock types. Bottom, generalized paleogeography of Ohio and adjacent areas during the Pennsylvanian Period.

ENERGY FROM COAL

The energy stored in coal began as energy stored in plants. During photosynthesis, a plant absorbs carbon dioxide and water. Using chlorophyll and sunlight, the plant converts carbon dioxide and water into carbon compounds consisting of starch, sugar (glucose, $C_6H_{12}O_6$), and cellulose ($C_6H_{10}O_5$), and releases oxygen into the atmosphere. As the plant dies and organic debris accumulates in the swampy, anoxic area, the underlying debris is compressed and undergoes gradual decomposition, so that cellulose is chemically changed, producing carbon dioxide (CO_2), methane (CH_4), water (H_2O), and peat ($C_{26}H_{20}O_2$). As the peat is buried, the weight of overlying sediments exerts increasing pressure and temperature on it, driving off water and gases and changing the peat into coal.

Coals are classified by rank according to their percentage of fixed carbon and heating value. Fixed carbon is the carbon residue that remains when coal is heated—without combustion—to drive off volatile matter. Volatile matter includes gases and vapors released by coal when heated. Generally, a coal's heating value and percentage of carbon (ex-

Right: Coalified compression of a Pennsylvanian seed fern, Mariopteris muricata*, preserved on Brookville shale (Allegheny Group), near Strasburg, Tuscarawas County. From Feldmann and Hackathorn, 1996, p. 467.*

*Above: A fin-back reptile (*Edaphosaurus*), an amphibian (*Eryops*), and a large dragonfly amidst a flora of sphenopsids, lycopods, and ferns. From Carnegie Museum of Natural History diorama* in *Feldmann and Hackathorn, 1996, p. xviii.*

cept in anthracite) have an inverse relationship with its moisture and volatile matter content. A Btu (British thermal unit) is the standard unit of measurement for heating value and is defined as the amount of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit (°F).

Lignite is the lowest rank of coal. It represents the 1st step in the metamorphosis from peat to coal. Lignite, commonly referred to as brown coal, has a fibrous, earthy texture and is crumbly. It has a high moisture content, low heating value (less than 8,300 Btus), and forms 9% of the nation's coal reserves. Lignite is mined primarily in Texas and North Dakota; it is not found in Ohio. If additional pressure and temperature are exerted, lignite is changed into subbituminous coal.

Subbituminous coal has a moisture content less than that of lignite, and a heating value that ranges from 8,300 to 11,500 Btus. Subbituminous coal makes up 38% of the nation's coal reserves and is mined in Wyoming and Montana; it is not found in Ohio.

Bituminous coal, the next highest rank, is generally black and blocky. It has a low moisture content, a carbon content that ranges from 69 to 86%, a volatile matter content that ranges from 15 to 50%, and a heating value that ranges from 10,500 to 15,500 Btus. All of Ohio's coal and more than half of the nation's coal reserves are of this rank. Bituminous coal is mined primarily in Alabama, West Virginia, Kentucky, Illinois, Indiana, Ohio, and Pennsylvania.

Anthracite is the highest coal rank. This coal is commonly referred to as hard coal and is black and brittle with a glassy appearance. Anthracite coal has a carbon content that ranges from 86 to 98% and a slightly lower heating value than bituminous coal due to a low volatile-matter content (less than 7%). It makes up 2% of the nation's coal reserves and is mined primarily in Pennsylvania; it is not found in Ohio.

Ohio's bituminous coals are noted for their high sulfur content, which calls for clean coal technologies; most of Ohio's coal is classified as high sulfur, containing an average sulfur content greater than 3.5%. Sulfur in Ohio's coal occurs as pyritic sulfur (FeS_2), organic sulfur, and sulfate sulfur in the form of gypsum ($CaSO_4$). An average piece of Ohio coal contains approximately 2.2% pyritic sulfur, 1.3% organic sulfur, and 0.01% sulfate sulfur.

Organic sulfur was originally part of a plant before it died. The pyritic sulfur in coal is the result of the influence of ancient sea water during the coal-forming process. Sea water contains high levels of sulfate (SO_4^{-2}) ions, which readily combine with dissolved iron to form pyrite under the chemical conditions in which peat forms. Coals that have high concentrations of pyritic sulfur were derived from coastal peat swamps where high concentrations of sulfate ions were brought into the swamps by tides containing brackish water (or through gradual burial of the swamp by marine sediments). Coals having a low pyrite content originated in swamps beyond any tidal influence that were buried by freshwater sediments. Unfortunately, a large percentage of Ohio's coal is the product of marine influences on Coal Age peat swamps. Therefore, Ohio has very little low-sulfur coal.

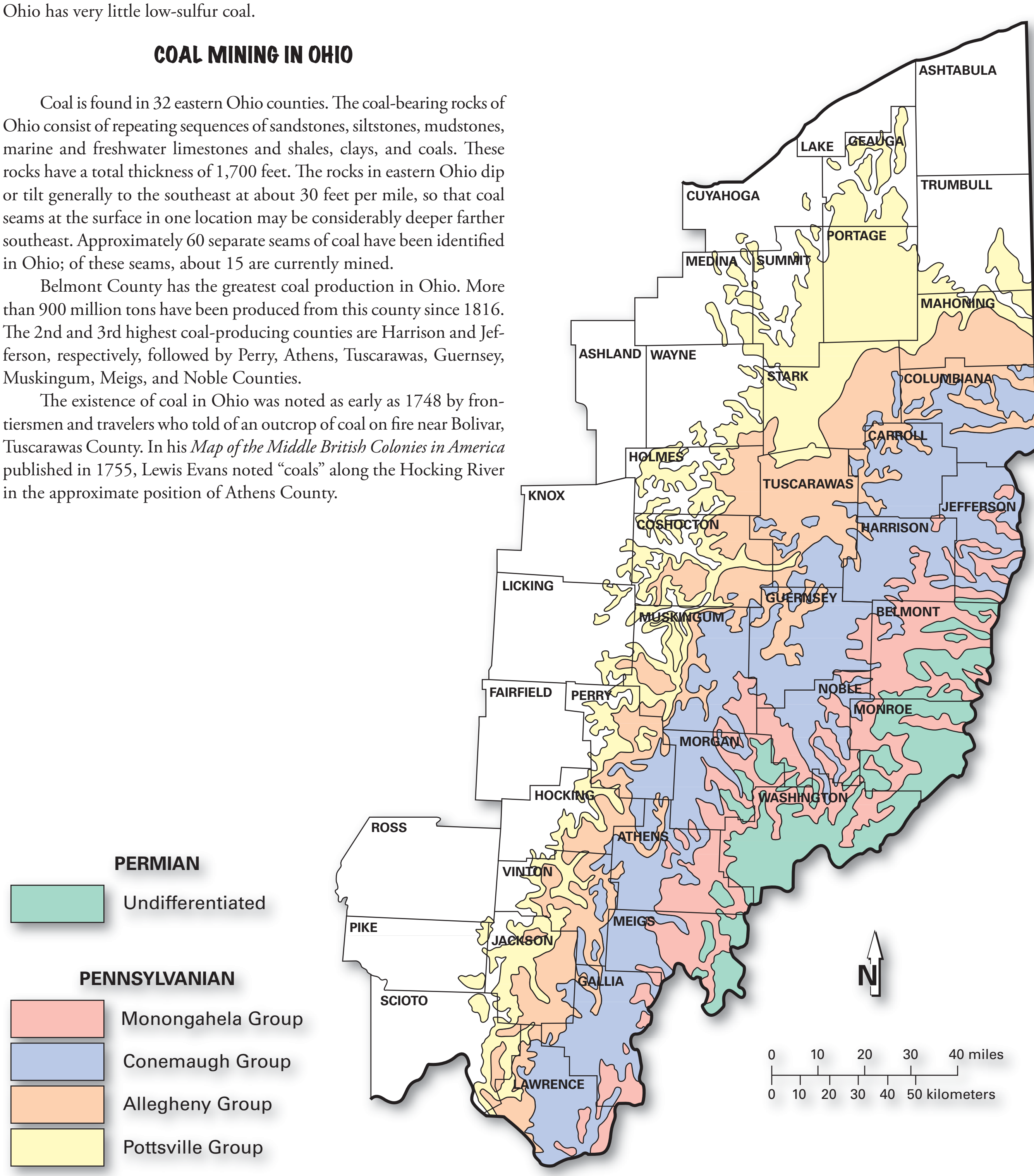
COAL MINING IN OHIO

Coal is found in 32 eastern Ohio counties. The coal-bearing rocks of Ohio consist of repeating sequences of sandstones, siltstones, mudstones, marine and freshwater limestones and shales, clays, and coals. These rocks have a total thickness of 1,700 feet. The rocks in eastern Ohio dip or tilt generally to the southeast at about 30 feet per mile, so that coal seams at the surface in one location may be considerably deeper farther southeast. Approximately 60 separate seams of coal have been identified in Ohio; of these seams, about 15 are currently mined.

Belmont County has the greatest coal production in Ohio. More than 900 million tons have been produced from this county since 1816. The 2nd and 3rd highest coal-producing counties are Harrison and Jefferson, respectively, followed by Perry, Athens, Tuscarawas, Guernsey, Muskingum, Meigs, and Noble Counties.

The existence of coal in Ohio was noted as early as 1748 by frontiersmen and travelers who told of an outcrop of coal on fire near Bolivar, Tuscarawas County. In his *Map of the Middle British Colonies in America* published in 1755, Lewis Evans noted "coals" along the Hocking River in the approximate position of Athens County.

Although the date when coal was first mined in Ohio will probably never be known, the first reported production of coal was in 1800, three years prior to Ohio's entrance into the Union as the 17th state. Since 1800, more than 2.4 billion tons of coal has been produced from Ohio's underground mines and more than 1.3 billion tons from its surface mines.

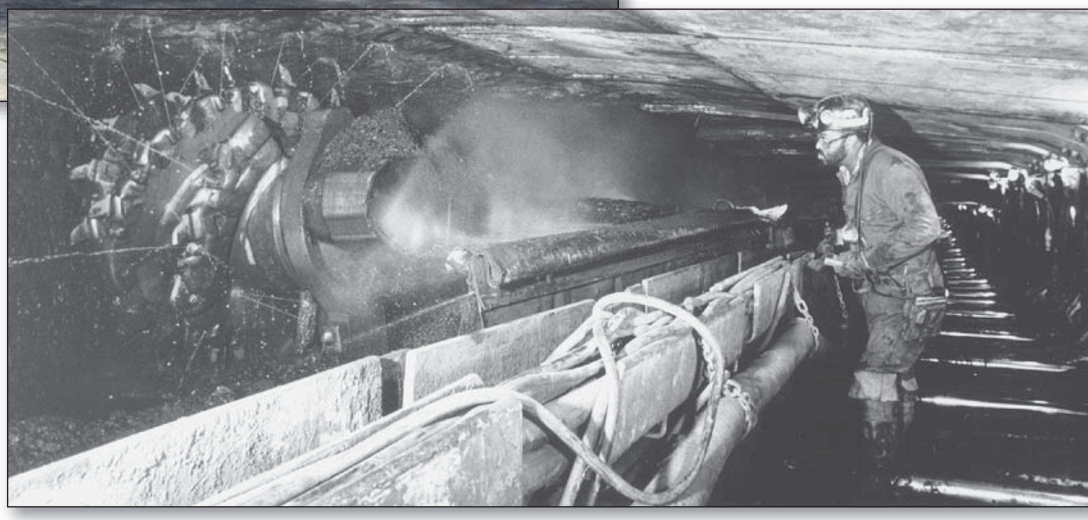


Generalized geologic map of the coal-bearing rocks of Ohio.

A pair of miners loading coal by hand in an underground coal mine in eastern Ohio, circa *early 1900s. Coal was lifted or shoveled onto a chain conveyor, which loaded a mine car. Until the mid-1930s and the development of automatic coal-loading machines, coal was loaded into mine cars by hand. From Crowell, 1995, p. 63; photo courtesy of the Ohio Historical Society, from the Jeffery Mining Equipment collection.*

Two drift openings in the Middle Kittanning (known commercially as the No. 6 coal) operated by the Buckingham Coal Company at Glouster, Athens County, 2001. Photo by Mike Williams.

Hydraulic excavator loading coal into a truck at an Ohio surface mine of the Oxford Mining Company, 2003. Photo by Mike Williams.



Longwall mining operation at the Southern Ohio Coal Company Meigs No. 31 mine in Salem Township, Meigs County, and Wilkesville Township, Vinton County, circa 1990. From Crowell, 1995, p. 37; photo courtesy of American Electric Power Service Corporation.

There are two basic methods of mining coal: surface mining and deep or underground mining. Surface mining in Ohio was first reported in 1810. Early surface mining consisted of using picks and shovels, and in some cases, horse-drawn scrapers on coal outcrops found along hillsides. The coal and cover material were excavated back into the hillside, perhaps 10 feet or more, until removal of the cover material was too impractical or difficult, and then underground methods were used.

In general, surface mining is the most efficient method of extracting coal from the ground. This method is used where coal seams lie close to the surface. Surface mining involves removing layers of soil and rock above the coal seam (overburden) and extracting the coal. In surface mining, generally 80% of the coal is recovered; the remainder becomes mixed with overburden and is buried as the mine is reclaimed. Reclamation is a process that systematically restores mined land to productive, attractive, and useable areas.

Mechanized surface mining began in Ohio during the 1880s in conjunction with the construction of railroads. However, surface mining remained minimal until 1914, when large amounts of coal were needed as fuel for World War I. By 1948, surface mining became the predominant method by which coal was produced in Ohio and remained the predominant method until 1995, when more coal was produced in Ohio by underground mining than by surface mining.

From 1800 to 1948, the principal means of mining coal in Ohio was by underground methods. There are three types of underground mines, each named for the type of opening used to gain access to the coal. Drift mines use a horizontal opening to mine coal that occurs above stream level. Shaft and slope mines use vertical and inclined openings, respectively, to reach coal at greater depths below stream level.

Room-and-pillar is a common method of underground mining in Ohio. A series of rooms are cut into the coal bed and pillars of coal are left for roof support. Wooden timbers and roof bolts are used as additional roof supports. As room-and-pillar mining advances, a grid-like pattern is formed. In this style of mining, generally 50 to 70% of the coal is recovered and the remainder is left as roof support.

Longwall mining is another method of underground mining in Ohio. In longwall mining, coal is mined from one long face, hence the name longwall. The area to be mined can be up to 3 miles long and 1,100 feet wide. Nearly 80% of the coal can be removed using this method. This technique has significantly increased productivity and reduced costs, so that underground mining remains competitive with surface mining.

Another type of coal mining used in Ohio is auger mining, which is a combination of surface and underground methods. In auger mining, coal is extracted by drilling horizontal holes into the seam using augers, which resemble giant drill bits. Auger mining is used where the overburden is too thick for surface mining and coal may be too thin for underground mining.

COAL CLEANING

Because of federal clean air regulations that limit the amount of sulfur dioxide (SO_2) that can be produced by burning coal, post-mining technologies that clean coal, such as washing and scrubbing, are being used in Ohio.

Coal washing is a precombustion cleaning process in which some of the impurities contained in coal are removed before the coal is burned. Coal-cleaning or coal-washing technologies are based on the principle that coal is lighter (less dense) than its associated rock and impurities. In coal-washing plants, agitating liquids, high-velocity liquids, and magnetite-water suspensions in a variety of physical and chemical processes are used to separate impurities from crushed coal. This cleaning process generally can remove 30–50% of pyritic sulfur and approximately 60% of ash-forming minerals (residue left after coal has been burned). As a result of washing, the SO_2 emissions from burned coal can be reduced by almost 50% under ideal conditions. Approximately 70% of the coal produced in Ohio is washed before burning.

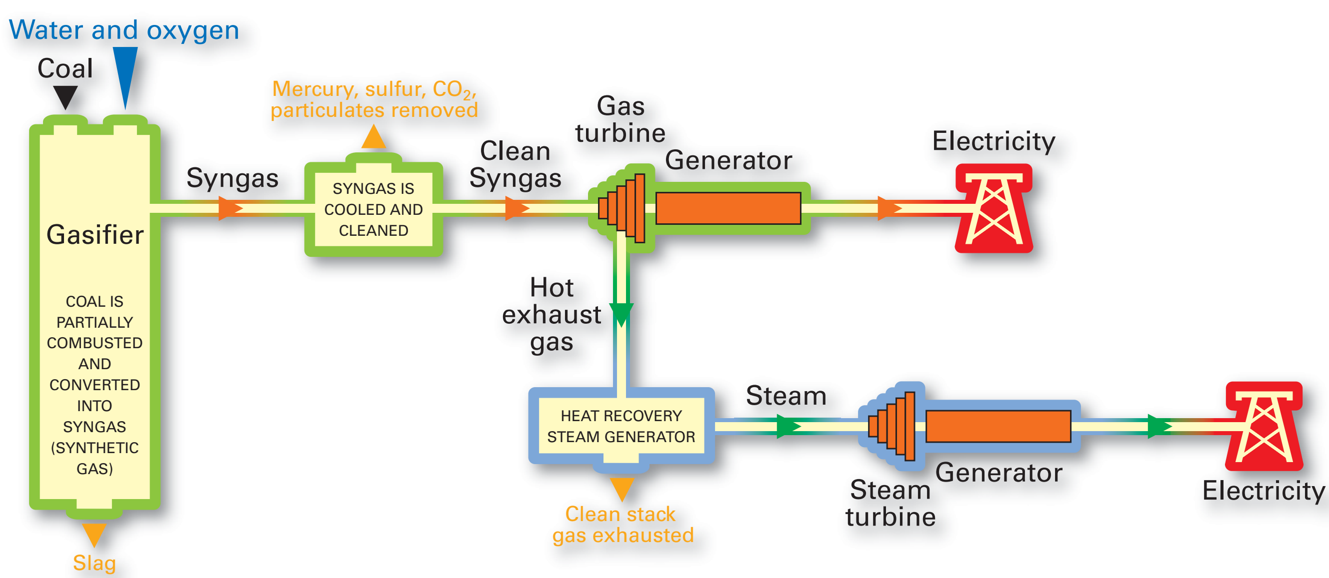
Scrubbing is a postcombustion cleaning technology located between the boiler (where crushed coal is burned) and the smoke stack. In this technology, a slurry of finely ground limestone or lime is injected into the flue gas. The SO_2 in the flue gas reacts chemically with the slurry to produce calcium sulfite, which can be oxidized to produce calcium sulfate, or gypsum. Flue-gas scrubbing technology is capable of achieving up to 90% SO_2 reduction. There are plans to install 24 additional scrubbers at 8 coal-fired Ohio powerplants, which is approximately one-third of existing powerplants in Ohio, by 2010.

Recent and probably future regulations will require removal of up to 90% of mercury, nitrous oxides, and CO_2 from flue gas (in addition to removing SO_2). To meet these regulations, much research is now focused on new scrubber technologies for removal of multiple pollutants, and on utilizing the by-products of flue gas cleanup.

CLEAN COAL TECHNOLOGIES

National security issues, high oil and gas prices, and concerns over global climate change, among other economic and political factors, are pushing the U.S. Government and its citizens to re-examine our past, present, and future energy resources. Large amounts of private and public funding are now dedicated to developing and improving technologies to use coal more efficiently and to produce clean liquid and gaseous fuels. One of these promising new technologies is to generate electric power from domestic coal in an Integrated Gasification Combined Cycle (IGCC). In the IGCC process, coal is gasified in a high-pressure, high-temperature environment in the presence of oxygen. The resulting gas, often called syngas, is cooled and stripped of contaminants such as sulfur, carbon dioxide, and mercury, then used to fire gas and steam turbines that generate electricity. Integrated Gasification Combined Cycle plants are up to 30% more efficient than conventional coal-fired electricity-generating facilities and much more environmentally friendly. The waste product from this process, bottom-ash or slag, is non-leachable and can be marketed and used for construction materials like those that comprise road beds. Experimental commercial-scale IGCC plants have been operating in Indiana and Florida since the mid-1990s.

Another technology that uses coal to produce energy, which is receiving serious consideration from government and industry, is the coal-to-liquids (CTL) process invented by two German scientists, Fisher and Tropsch, in the 1920s. In the CTL process, coal is gasified (similar to IGCC); the resultant hydrogen and carbon monoxide are then passed over a catalyst and reassembled into liquid fuels. Sulfur, hydrogen, and carbon dioxide are removed in the process and can be sold as by-products. The gasoline and diesel fuel that are produced meet today's most stringent environmental requirements, and the U.S. Air Force is testing



A simplified diagram of an Integrated Gasification Combined Cycle (IGCC) unit. In the IGCC process, coal is gasified in a high-pressure, high-temperature environment in the presence of oxygen. The resulting gas, often called syngas, is cooled and stripped of contaminants such as sulfur, carbon dioxide, and mercury, then used to fire gas and steam turbines that generate electricity.

CTL fuel for use in aviation. South Africa currently produces 150,000 barrels of CTL fuels per day.

Currently, there are plans to build IGCC and CTL plants in Ohio. Because most pollutants are removed prior to combustion in these processes, Ohio's high sulfur and relatively high Btu-content coal can become marketable again. Should these plants (and others) be built, the use of their technologies could lead to a significant increase in Ohio coal and energy production.

Carbon dioxide (CO_2) is separated before combustion in both the IGCC and CTL processes, and technologies exist for its compression, transportation, and long-term disposal (carbon sequestration). Geologic sequestration strategies include disposal in deep porous formations and unmineable coal seams, which can also enhance oil and gas production and/or stimulate coalbed methane production. The Ohio Division of Geological Survey, in partnership with neighboring states, the Ohio Coal Development Office, Battelle, and the U.S. Department of Energy, is researching suitable geologic formations for carbon sequestration and CO_2-assisted enhanced oil recovery.

USES OF COAL AND COAL BY-PRODUCTS

Coal is used in all 50 states. Ten states account for about half of the total coal consumed. Of these 10 states, Texas, Ohio, and Indiana consume the largest amounts. The electric utility industry is the largest consumer of coal in the nation. Approximately 80% of the nation's coal and 90% of Ohio's coal is consumed by coal-fired electric power plants.

Another use of coal is to make coke for the iron and steel industry. Coke is used primarily to smelt iron and iron-bearing materials in blast furnaces, acting as a source of heat and as a chemical reducing agent to produce pig iron. Lesser amounts of coal are used for industrial boilers and home heating, and for transportation needs, such as coal-fired steam locomotives used in the tourist industry.

Coal and coal by-products (benzene, coal tars, and naphtha) are used to manufacture diverse products, such as solvents, varnishes, paint, waxes, perfumes, medicines, inks, absorbents, adhesives, plastics, acetate yarns, rubber, carbon and graphite electrodes, carbon black, carbon paper, and electric insulating materials. Gypsum produced from flue gas scrubbers is used to create wallboard for the building industry and has displaced the need for mining large quantities of this commodity.

New by-products from the proposed IGCC and CTL plants include pure CO_2, elemental sulfur, and hydrogen. Carbon dioxide is used in large-scale refrigeration (dry-ice), fire-extinguishers, carbonated drinks, and medicine. Sulfur is mainly used to produce sulfuric acid, one of the most important chemicals used in industrial processes. Hydrogen can be used in fuel cells and to produce ammonia, fertilizers, and many other manufactured products.

Research on the uses of IGCC and CTL bottom-ash is ongoing, but early results indicate that bottom-ash could potentially be used as an aggregate in construction, backfill, and reclamation materials. Many IGCC and CTL plants will be located near major water and rail corridors, not only for ease of importing raw materials, but to reduce the cost of transporting the by-products to industrial users. For example, low-cost transportation is critical to aggregate production, as truck transportation for distances as short as 20 miles can double a customer's cost. Aggregates produced from IGCC or CTL bottom-ash may be economically competitive in urban areas along the Ohio River, such as Cincinnati, which would displace some local sand and gravel operations.

ABANDONED UNDERGROUND MINES

Abandoned underground mines are mines that ceased operation before current mining and reclamation laws came into effect. They can be a hazard if they collapse. This collapse, called mine subsidence, is when the Earth's surface lowers into a mined area due to a collapse of bedrock and unconsolidated material into the mine void. Subsidence can risk human life, cause damage to building foundations and highways, and disrupt underground utilities.

The Ohio Division of Geological Survey maintains an extensive database on available abandoned underground mine information that includes data sheets, detailed maps of abandoned underground mines, and mine outlines plotted on U.S. Geological Survey topographic quadrangle bases (scale 1:24,000 or 1 inch equals 2,000 feet). The Division has detailed abandonment maps for more than 4,300 under-

An area of the Wilds conservation center in Muskingum County, 2007. In 1986, American Electric Power donated approximately 10,000 acres of reclaimed strip mine land to develop the center, which provides habitat for wildlife from Africa, Asia, and North America.

ground mines, most of which are coal mines. The Division has records for 2,229 additional mines for which no detailed maps of the mine workings are available.

For homeowners, realtors, builders, planners, and government agencies that are concerned about mine subsidence, the Division also maintains an Abandoned Underground Mine (AUM) Geographic Information System (GIS) and address locator system on its website. The AUM GIS system was developed with funding from the Ohio Department of Transportation and cooperation from the Ohio Mine Subsidence Insurance Underwriting Association and can be accessed at <http://www.ohiodnr.com/geosurvey/OMSIUA/home.htm>.

GEOLOGICAL RESEARCH

The Ohio Division of Geological Survey has maintained an active coal research program throughout its existence, beginning in 1837 with attempts to identify major coal beds in eastern Ohio and to dispel the rumor that coal existed in western Ohio. Because coal has long been one of Ohio's principal mineral resources, the Division has expended considerable effort to gather detailed information concerning the distribution, thickness, and quality of Ohio's coals. These data consist of thousands of measurements, drilling records, and chemical analyses, many of which have served as the basis for numerous published reports and geologic maps on coal and coal-bearing rocks. Extensive unpublished data, much of which has been assembled on open-file maps, are available for consultation in the Ohio Department of Natural Resources, Division of Geological Survey offices. A list of publications and open-file information is available at <http://www.ohiodnr.com/geosurvey/>.

Although these publications and unpublished data on Ohio coal constitute a large body of research, much research work remains. The relatively deep coal-bearing rocks in eastern Ohio have not been explored in detail. Detailed bedrock-geologic mapping in the coal-bearing counties of eastern Ohio has been completed for fewer than half of the counties known to contain significant coal deposits, and a number of these county reports were completed several decades ago, so they are in need of updating and revision. Also, the methane potential of Ohio's coal beds has not been examined in detail. One published report estimates the amount of Ohio's total coal-bed methane to be approximately 4 trillion cubic feet and also estimates that some coal beds have total gas values of as much as 252 cubic feet per ton.

In recent years, in cooperation with the U.S. Geological Survey, the Ohio Division of Geological Survey has conducted a program to digitize coal and coal-bearing rock data to aid the production of detailed coal resource/reserve maps and coal availability estimates. The Division also continues to evaluate the chemical and physical characteristics of Ohio coals. The electricity industry will rely heavily upon detailed chemical and physical data on Ohio coal while it is in the process of meeting emission standards for SO_2 and other potentially hazardous air pollutants from burned coal, such as mercury, lead, arsenic, thorium, and uranium. Updated coal resource information is also vital to technological advances such as gasification, liquefaction, fluidized-bed combustion, and improved washing techniques.

FURTHER READING

Crowell, D. L., 1995, History of the coal-mining industry in Ohio: Ohio Division of Geological Survey Bulletin 72, 204 p.

Crowell, D. L., 1997a, Mine subsidence: Ohio Division of Geological Survey GeoFacts 12.

Crowell, D. L., 1997b, History of coal mining in Ohio: Ohio Division of Geological Survey GeoFacts 14.

Crowell, D. L., 1997c, Coal mining and reclamation: Ohio Division of Geological Survey GeoFacts 15.

Crowell, D. L., 1997d, Coal and electricity: Ohio Division of Geological Survey GeoFacts 16.

Feldmann, R. M., and Hackathorn, Merrianne, eds., 1996, reprinted with minor revisions 2005, Fossils of Ohio: Ohio Division of Geological Survey Bulletin 70, 577 p.

Hook, R. W., and Miller, T. R., 1996, An underground forest: Ohio Division of Geological Survey, Ohio Geology, Spring, p. 1, 3–4.

Lyons, P. C., 1997, Central-northern Appalachian coalbed methane flow grows: Oil & Gas Journal, July 7, 1997, p. 76–79.

National Research Council, 1995, Coal, energy for the future: Washington, D.C., National Academy Press, 288 p.

Ohio Division of Geological Survey, Annual report on Ohio mineral industries. Can be accessed at <http://www.ohiodnr.com/geosurvey/ogcim/minstat/minstat1.htm>.

Stith, D. A., Berg, T. M., Ault, C. H., Dever, G. R., Jr., Masters, J. M., Berkheiser, S. W., Jr., Simard, C. M., and Hester, N. C., 1997, Limestone and dolomite availability in the Ohio River valley for sulfur sorbent use, with observations on obtaining reliable chemical analyses: Ohio Division of Geological Survey Information Circular 59, 16 p.

Originally authored by Douglas L. Crowell
Revised by Mark E. Wolfe and Larry Wickstrom, 2008

Cover: An Eimco 2810-3 continuous miner in operation at the Buckingham Coal Co., Inc., underground coal mine in Athens County. The miner is capable of mining 39 tons of coal each minute. Photo by Mike Williams.

World Wide Web site: <http://www.ohiodnr.com/geosurvey/>
email: geo.survey@dnr.state.oh.us

Equal opportunity
employer M/F/H