WINTER 1983

# Ohio Geology Newsletter

Division of Geological Survey

## OHIO'S COAL INDUSTRY

*Flippity, floppity, flap,*
*Ohio's coal is full of crap,*
*Shut down the hole,*
*Put the men on the dole,*
*It's an eco-political flap.*

—Christian Van Buskirk

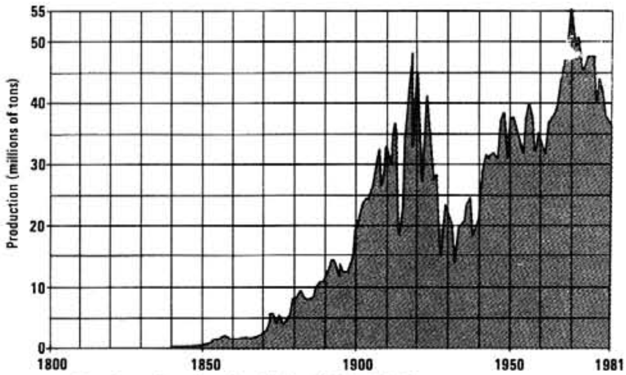
This bit of doggerel poignantly summarizes the current status of Ohio's coal industry, which is not only suffering from the general economic downturn pervading the nation at present, but also from a seemingly inescapable, decade-long, downward spiral. Harking back to the second line of our limerick, this downturn is due to the geologic fact that Ohio's coal is relatively high in substances that have been judged by the U.S. Environmental Protection Agency to yield undesirable products of combustion. The problem, simply stated, is that Ohio coal is high in sulfur, and when burned the coal yields an amount of sulfur dioxide that exceeds federal clean-air standards. This problem is well known and easily understood, but solutions are complex and not immediately apparent to those involved in the search for answers. The solutions involve considerations that are in part geologic, economic, political, and technological. Considerable rhetoric has accompanied the debates on the solutions to the problem but no clear-cut answers have emerged.

Because of coal's long-standing and potential future importance to the state of Ohio, the answer to the sulfur problem is perhaps one of the most critical problems facing the state and must be dealt with in an effective and innovative manner if Ohio is to maintain its past industrial importance. This article summarizes some of the more important facts and history of Ohio's most important mineral resource.

The value of coal produced in Ohio currently exceeds a billion dollars, and at peak production more than 25,000 people were involved in the coal-mining industry in the state. Coal is important to Ohio, not only from the standpoint of dollars and jobs but also because of the electricity it generates. Ninety-eight percent of the electricity used in Ohio comes from coal-fired power plants and Ohio consumes more coal than any other state in the Union. Today just over half of the more than 45 million tons of coal used by Ohio's electric utilities comes from coal fields of eastern Ohio. In 1970, by comparison, about 70 percent of this coal was from Ohio. In addition to coal burned by Ohio utilities, a substantial export market for Ohio coal formerly existed in the Great Lakes region. Today, Ohio's electric utilities import about 22 percent of their coal from Kentucky, 16 percent from West Virginia, and 11 percent from other states, including about 5 percent western coal from Wyoming.

## PRODUCTION AND MINING

The presence of coal in Ohio has long been known. A map published in 1755 by Lewis Evans and titled *A general map of the middle British colonies, in America* indicated the presence of coal in the vicinity of southern Stark and northern Tuscarawas Counties and in Athens County. There is no record of prehistoric use of coal for fuel in Ohio, although artifacts fashioned from coal have been discovered.



*Coal production in Ohio, 1800-1981*

Local use of coal as a fuel undoubtedly began with the settlement of the Ohio country, and by the 1790's its use was probably widespread in eastern Ohio. In 1800, the first year for which production figures are recorded, Jefferson County produced 100 tons of coal. Although early production of coal in Ohio was relatively small in terms of tonnage, there were certainly numerous small mines of the "dog hole" variety throughout the outcrop area of eastern Ohio. Surprisingly, as late as 1836 there were persistent rumors of coal deposits in western Ohio—accompanied, perhaps, by swindlers and fruitless prospecting in rocks now recognized to have been deposited long before plants occupied the land in sufficient quantities to contribute to the formation of coal. One of the objectives of the first Geological Survey of Ohio (1837-1838), under the direction of State Geologist W. W. Mather, was to dispel these rumors on the basis of sound geological information.

Coal production in Ohio remained modest until after the Civil War, when the industrial revolution began to require significantly larger quantities of fuel. Production accelerated rapidly after the turn of the century, and by 1918, the last year of World War I, production peaked at 48 million tons. This figure

*continued on next page*

ODNR

Richard F. Celeste, Governor • Lt. Gov. Myrl H. Shoemaker, Director

## Chief's corner by Horace R. Collins

The state geologist from Ohio's neighbor to the northeast recently titled an editorial with the question "So what's the worth of a geologic report?" This is a darn good question and one that with variations has frequently been asked of our Survey. Some older Geological Survey reports have, at times, been subjected to the criticism that they are out-of-date and that not very many of a particular report were sold in a given year. These are not valid observations, however. The age of a geologic report or map is seldom a reason for not using the information. Geology in human terms is essentially timeless. Although a map may have been made many years ago, the basic geology has not changed. Concepts concerning the origin or use of mineral resources may change, but the resources themselves do not. Research geologists commonly utilize reports written well over a hundred years ago. The number of copies of a report sold also has little meaning. The availability of the information is the important factor.

What is a report worth if it locates valuable mineral resources that can be produced, thus providing jobs to miners and to manufacturers of products made from rock and mineral resources? How valuable is the electricity, bricks, cement, aggregates, chemicals, wallboard, lubricating oil, kerosene, glass, and other products manufactured from rocks and minerals? How important are the jobs these mineral-based industries provide to Ohioans? What is the value to society of reports that aid in the wise development of our land? What is the value of a report that provides information to prevent unsafe practices in the disposal of hazardous wastes? What is the value of a report that supplies geologic data vital to the protection of ground and surface waters from contamination? How many reports on geologic hazards must be sold if one life is saved from the collapse of a mine shaft under a home or school? If a nuclear-power plant or a dam is prevented from being located on geologically unstable ground, how much is a report worth that brings this fact to public attention?

The real measure of a geologic report lies not in its date of publication or in the number of copies sold each year, but rather in its value to society. The value is measured by the jobs which may be created because of the technical information presented, by money saved through prevention of unwise or improper development of our land, and by the protection of our citizens from geologic hazards to life, limb, and property.

### OHIO ACADEMY OF SCIENCE MEETING IN APRIL

The 92nd Annual Meeting of the Ohio Academy of Science will be held on April 22-24, 1983, at Bowling Green State University, Bowling Green. The theme for this year's meeting is "Confronting the crisis in science and math education."

Section C, Geology, promises to be well attended by a large number of Ohio geologists, many of whom will present papers on various aspects of Ohio geology during the technical sessions on Saturday, April 23. For further information on registration, contact the Ohio Academy of Science, 445 King Avenue, Columbus, Ohio 43201.


OHIO GEOLOGY

A newsletter published quarterly by the Ohio Department of Natural Resources, Division of Geological Survey, Fountain Square, Columbus, Ohio 43224.

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News items, notices of meetings, etc. should be addressed to the attention of the editor. Change of address and new subscriptions should be addressed to the attention of the secretary.


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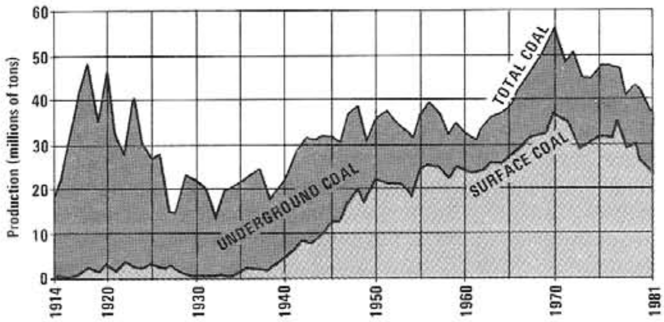
stood until 1970, when the all-time high of 55 million tons was reached. In the last decade, however, production has slowly declined to less than 37 million tons per year because of the lowered demand for high-sulfur coal.




*Coal production in Ohio from underground and surface mines, 1914-1981*

Although coal was mined by surface methods as early as 1914 in Jefferson County, underground mining dominated the industry until after World War II. By the mid-1960's surface mining (strip and auger) accounted for more than 70 percent of the state's production. Since that time there has been a gradual decrease in the percentage of surface-mined coal; in 1980, 64 percent of production was by surface methods. Surface mining in Ohio employs some of the largest earthmoving equipment in the world and is subject to stringent reclamation laws.

Underground mining in the state has been almost exclusively by the room-and-pillar method, in which rectangular "rooms" are formed when the coal is extracted. Each room is separated by a block of coal, known as a "pillar," that is left to support the roof of the mine. With this mining method as much as half of the coal, and in some cases even more, is left in the mine. The longwall method of mining, long popular in Europe, is beginning to be used to a small degree in Ohio. In this method, mining proceeds continuously along one end of a very large block of coal leaving no pillars. The roof of the mine along this working face is supported by a series of steel supports or chocks. The chocks move hydraulically as the mining proceeds and the mine roof is allowed to collapse behind the working face. This method has the advantage of a high recovery rate of the coal, but longwall-mining equipment is very expensive, the method is sensitive to labor disruptions, and subsidence of the ground surface above the mine commonly results.

Most underground mines in Ohio reach depths of only a few hundred feet; the deepest currently active mine in Ohio is the Cadiz Portal mine in Harrison County at a depth of 529 feet. Mining technology is adequate to exploit the deepest coal beds in southeastern Ohio, at depths approaching 1,000 feet. These deeper beds have not been mined because of a lack of information on them and because of the ready availability of shallow, more easily mined coal.

Underground mines are of three types, according to the method of entry into the coal seam, and all three have been utilized in Ohio. Drift mines are nearly horizontal tunnels driven directly into the seam from the side of a hill. Numerous small, abandoned drift mines dot eastern Ohio. Slope and shaft mines have sloping or vertical entries, respectively, to reach a coal seam that lies below drainage.

From about 1950 to 1970 there was a significant decrease in the number of coal mines operating in Ohio; however, production during this period continued to rise. This fact is explained by greater productivity owing to advances in equipment and technology and to a trend towards larger individual mines. The decrease in the number of mines can be attributed to the closing of small mines which could not remain competitive in a time of expensive technological advances and to a complex and restrictive regulatory and economic environment. From 1970 to the present, however, additional regulatory restrictions and economic conditions have resulted in dramatically falling productivity.

Since the 1950's the Pittsburgh (No. 8) coal has been the leading producing seam in the state. The Pittsburgh seam forms a nearly continuous deposit over parts of eastern Ohio, western Pennsylvania, and northern West Virginia. This coal bed has been called the most valuable mineral deposit in the world and is the principal reason for establishment of an extensive iron and steel industry in the upper Ohio Valley. High production from Belmont, Jefferson, Harrison, and Monroe Counties is mainly from Pittsburgh coal. The Meigs Creek (No. 9), Middle Kittanning (No. 6), Lower Freeport (No. 6A), and Waynesburg (No. 11) seams also have been important coal producers in Ohio in recent years.


*1981 coal production by county (in millions of tons)*

ESTIMATED ORIGINAL RESOURCES
AND CUMULATIVE PRODUCTION OF COAL
IN OHIO BY COUNTY

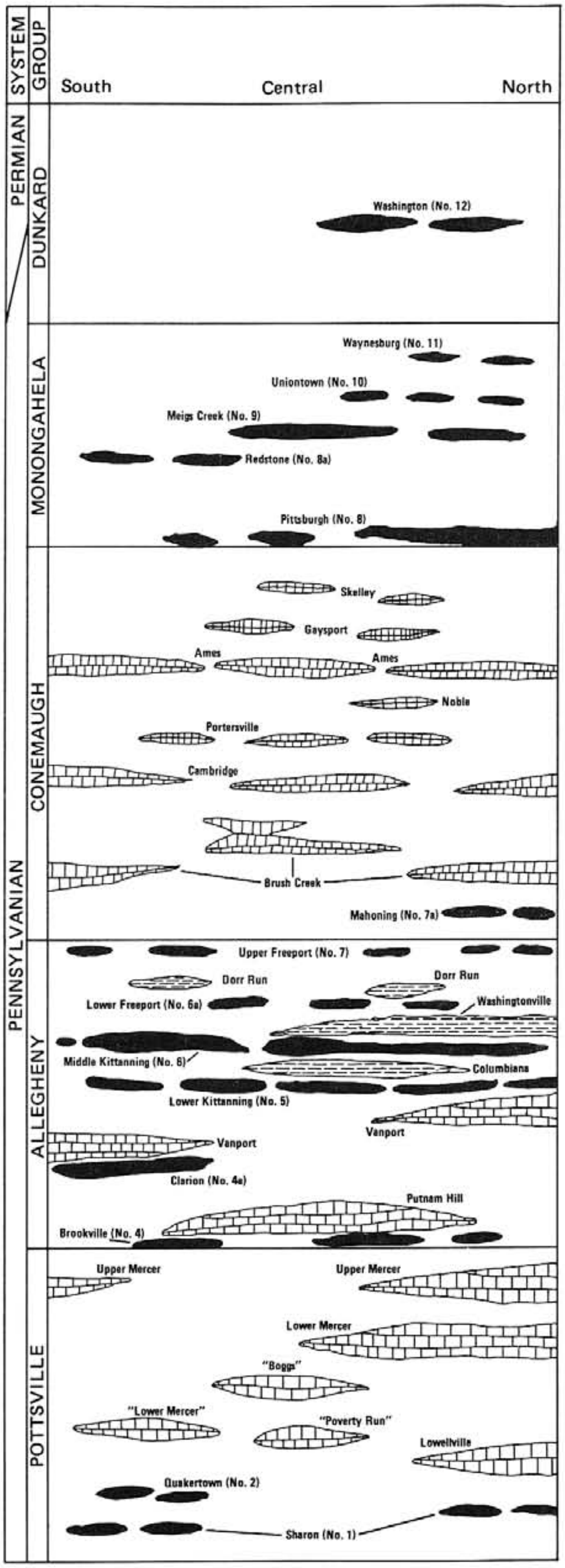
| County | Estimated original resources | Cumulative production 1800 to 1981 |
|---|---|---|
| | (in thousands of short tons) | |
| Athens | 2,225,354 | 199,822 |
| Belmont | 5,759,456 | 681,590 |
| Carroll | 2,497,412 | 35,143 |
| Columbiana | 2,803,343 | 84,504 |
| Coshocton | 716,478 | 77,714 |
| Gallia | 1,642,616 | 18,760 |
| Geauga | 2,880 | – |
| Guernsey | 3,016,904 | 139,607 |
| Harrison | 2,985,459 | 353,412 |
| Hocking | 347,699 | 82,761 |
| Holmes | 352,083 | 11,499 |
| Jackson | 1,009,996 | 80,140 |
| Jefferson | 3,433,759 | 363,545 |
| Lawrence | 1,862,713 | 19,921 |
| Licking | 28,000 | 106 |
| Mahoning | 1,049,678 | 33,225 |
| Medina | 73,000 | 4,755 |
| Meigs | 942,190 | 68,554 |
| Monroe | 2,985,416 | 20,956 |
| Morgan | 1,419,433 | 42,929 |
| Muskingum | 2,029,340 | 113,320 |
| Noble | 1,415,084 | 71,740 |
| Perry | 1,148,247 | 199,860 |
| Pike | no estimate | 33 |
| Portage | 111,824 | 6,848 |
| Scioto | 87,252 | 320 |
| Stark | 1,442,857 | 66,728 |
| Summit | 228,000 | 10,363 |
| Trumbull | 149,760 | 12,990 |
| Tuscarawas | 2,126,110 | 149,273 |
| Vinton | 1,172,123 | 33,463 |
| Washington | 1,262,721 | 5,540 |
| Wayne | 261,064 | 8,824 |
| Total | 46,588,251 | 2,998,245 |

Some coal fields that were formerly important, such as the Hocking Valley field in Athens, Hocking, and Perry Counties (Middle Kittanning and Upper Freeport coals) and the Cambridge field (Upper Freeport coal) in Guernsey County, have been largely worked out.

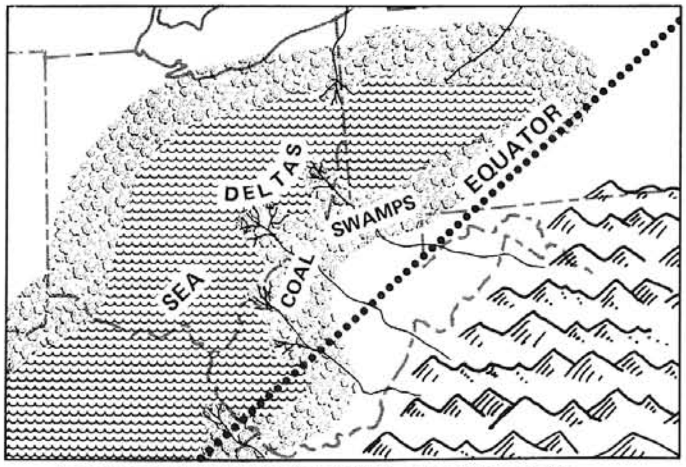
## GEOLOGY OF OHIO COAL

The coal-bearing rocks in Ohio have a long and complex geologic history. During the geologic periods known as Pennsylvanian and Permian, eastern Ohio was covered by a shallow inland sea into which were built a series of deltas similar in many aspects to the delta of the modern Mississippi River. These deltas were covered in part by swamps and a lush growth of tropical vegetation, which slowly filled up the swampy areas, decayed, and formed peat, which in turn was converted to coal through a series of chemical and physical changes.

These deltas were constantly shifting their sites of deposition; as a result individual beds of Pennsylvanian and Permian rocks cannot be traced laterally for great distances, and the coal beds and their enclosing rocks tend to occur in repetitive vertical sequences. Geologists have been able to utilize the delta model of deposition as an aid in exploration programs for coal deposits.




*Distribution of principal coal beds and marine units in the Pennsylvanian and Permian rocks of Ohio, emphasizing their lenticular nature. Distributions generalized along a line from Lawrence County (south) through Muskingum County (central) to Columbiana County (north). Marine units modified from G. K. Merrill (1974), Ohio Geological Survey Guidebook 3.*




*Generalized paleogeography of Ohio and adjacent areas during the Pennsylvanian Period*

More than 60 separate coal beds have received formal geologic names in Ohio, although only about 14 of these seams can be considered of economic importance. All coal in Ohio is found in rocks of the Pennsylvanian and Permian Systems; these rocks cover a 30-county area of 12,340 square miles and average about 1,740 feet in total thickness. Coal, however, accounts for only a very small portion (about 3 percent) of this total thickness. The coal-bearing rocks of eastern Ohio have a very gentle tilt or dip to the southeast, so that a coal at the surface in the vicinity of Zanesville will be many hundreds of feet below the surface at Bellaire on the Ohio River.

## CHEMICAL CHARACTERISTICS OF OHIO COAL

Coal is classified in a variety of ways in order to convey certain information to coal consumers. The American Society for Testing and Materials (ASTM) divides coals into four major classes depending upon the degree of change that the coal-forming peat has undergone due to heat and pressure. These classes, in order of alteration from least altered to most altered, are: (1) lignite, (2) subbituminous, (3) bituminous, and (4) anthracite. All of Ohio's coals are bituminous and fall into the high-volatile rank with a rating of about 10,000 to 13,000 Btus per pound. The British Thermal Unit or Btu is a measure of the amount of heat energy contained in a pound of coal. Btu is determined by burning a small quantity of a coal and measuring the temperature rise of a fixed amount of water.

The principal chemical constituents of coal are carbon, hydrogen, oxygen, nitrogen, and sulfur, but a large number of other elements, commonly termed trace elements, can be found in the mineral matter associated with coal. Two of the most important chemical constituents of Ohio coal, in terms of its marketability and usage, are ash and sulfur content. The ash content of a coal refers to mineral matter that was introduced into the peat swamp and became part of the coal. High-ash coals are more resistant to burning and present a fly ash and disposal problem for the coal user. Most Ohio coals range between 5 and 20 percent ash.

The high sulfur content of Ohio coals has received considerable publicity and is the principal factor in the decline of the coal industry in Ohio. When burned, the sulfur in coal combines with oxygen to form sulfur dioxide, a compound for which stack emissions are strictly limited by federal clean-air standards. Ohio coals range from just under 1 percent to about 6 percent sulfur. Low-sulfur coals are those with 1.0 percent sulfur or less, medium-sulfur coals are those with 1.1 to 3.0 percent sulfur, and high-sulfur coals are those with greater than 3.0 percent sulfur. Most Ohio coals fall into the medium- to high-sulfur range. The principal reason that Ohio coals are high in sulfur is because they were deposited in swamps near the sea where marine waters rich in sulfate could invade the coal swamp (see accompanying article, *The origin of sulfur in Ohio coal,* by R. W. Carlton).

On the average about half of the sulfur in Ohio coals is in the form of iron pyrite or "fool's gold," which may occur either as thick bands and large nodules or be scattered throughout the coal as extremely fine microscopic particles. Most Ohio coals cannot be sufficiently cleaned by present methods to be considered low sulfur, although the washing process does lower the sulfur content significantly in many cases. However, the ash content of most Ohio coals is lowered considerably by washing, thus contributing to a reduction in fly ash.

Sulfur occurs in two other forms in coal—in minerals such as gypsum (calcium sulfate), which generally are present in only minor amounts and are not considered a problem; and in organic compounds in the coal, which cannot be removed by washing.

## THE FUTURE

The recoverable reserves of high-Btu coal in Ohio are enormous and constitute a valuable and strategic source of future energy for the state and the nation. Advantageous to Ohio's future in coal are factors, in addition to large reserves, such as proximity to a large market, an adequate and well-trained labor force, availability of good transportation, a good water supply, and an improving geologic data base. Negative factors are dominated by the high sulfur content of Ohio coal and to a lesser degree by decreasing productivity brought about by state and federal regulations and periodic strikes by the labor force.

The sulfur problem is by far the most critical element in the future of Ohio coal, and how this problem is dealt with, whether it be through regulation or through technology, will probably be the determining factor in the health and perhaps survival of the Ohio coal industry. It is a complex and difficult problem for which there appear to be no easy solutions.

Although debate continues over the potential long-term health hazard of sulfur dioxide emissions from coal-fired power plants and the contribution of these emissions to the acid-rain problem, it seems unlikely that federal emission standards will be lowered to accommodate the burning of Ohio's high-sulfur coal. A decade of lobbying effort by electric utilities, industry representatives, and political leaders has produced little improvement in the marketability of Ohio coal. Electric utilities have resisted large capital expenditures for devices (scrubbers) to clean stack emissions, preferring to import coal at an annual additional cost of nearly a half billion dollars to Ohio electric consumers. At question to the utility industry is the reliability and cost of scrubbers versus the acceptability to the EPA of imported low-sulfur coal.

What is the answer to the sulfur problem? It is unlikely, owing to geologic considerations, that significant new reserves of low-sulfur coal will be discovered in Ohio, so the solution to the problem must come about through techniques of cleaning the coal before burning or by removing objectionable substances after combustion. Much research has been conducted in these areas but a major financial commitment has been lacking. Solutions will not be inexpensive nor will they be rapid. The alternative, the continued downward spiral of the Ohio coal industry, will be of major consequence to the economy of the state.

## COAL AND THE SURVEY

The 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 common rumor that coal existed in western Ohio. Because coal has long been Ohio's principal mineral resource, the Survey has expended considerable effort over a period of many years 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 maps on coal and coal-bearing rocks. A list of Survey publications pertaining to Ohio coal is available without charge from the Survey. Extensive unpublished data, much of which has been assembled on open-file maps, are available for consultation in the Survey offices.

Although these publications on Ohio coal constitute an impressive body of research, much remains to be done. The deeper coal-bearing rocks in eastern Ohio have not been explored in detail, a situation that is gradually being remedied by the Survey through a series of projects using a core-drilling rig to search for deep coal. Detailed bedrock 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 done several decades ago and are in need of updating and revision. Bedrock mapping should eventually be completed under the provision of House Bill 385, which established the Survey's county-mapping program in late 1981. In recent years the Survey has begun a program of chemical and mineralogical evaluation of Ohio coals, principally as an aid in developing technology for using high-sulfur coal. Technological advances such as gasification, liquefaction, fluidized-bed combustion, and better washing techniques will rely heavily on detailed information on the chemical and physical nature of the coals.

As important as coal is to the state of Ohio and as impressive as the body of knowledge accumulated by the Survey is, there has never been a significant financial commitment by the state to establish a major and continuing program of research on Ohio coal. Other states have made such ventures and significant results have been realized. The Survey stands ready to offer its expertise to the betterment of Ohio's future in coal.

—Michael C. Hansen

## 1983 OHIO GEOLOGY SLIDE CONTEST

The Ohio Geology Slide Contest will be repeated in 1983. In addition to the presentation of attractive award plaques to the winners, the first-place slide will be incorporated into the ODNR *Ohio Naturally* Calendar, provided the slide fits the calendar format.

Principal requirements of the contest are that the entry be a 35-mm color slide and that it portray some aspect of Ohio geology. For a list of rules and an official entry form, write: Ohio Geology Slide Contest, Ohio Department of Natural Resources, Division of Geological Survey, Fountain Square, Bldg. B, Columbus, Ohio 43224. Entries must be submitted by May 31, 1983.

## THE ORIGIN OF SULFUR IN OHIO COAL

Since 1970, federal regulations have limited the amount of sulfur dioxide ($SO_2$) which can be produced from the combustion of coal. As a result, the mining of high-sulfur coal in Ohio has steadily declined over the past 12 years. Because of the stringent $SO_2$ standards, the coal industry in Ohio is now seriously depressed and many Ohioans, particularly in the coal-producing counties, have lost jobs, with a subsequent loss of tax revenues to local governments.

News stories about the depressed coal market and ways of reducing sulfur in coal are quite common, but what are some of the more basic questions concerning sulfur in coal? How did the sulfur get in the coal in the first place? Why does Ohio's coal have so much sulfur? Why are western coals and some eastern coals so low in sulfur?

Before these questions are answered it should be pointed out that sulfur exists in coal in two principal forms. Generally most of the sulfur in high-sulfur coal is combined with iron to form the minerals pyrite or marcasite ("fool's gold") and is termed pyritic sulfur. The second principal form of sulfur is called organic sulfur and is chemically combined with the coal. In low-sulfur coals organic sulfur is generally the dominant form of sulfur. When coal is burned, most of the sulfur is released to the atmosphere, where it combines with oxygen to form $SO_2$, a major environmental pollutant.

To answer the question concerning the origin of sulfur in coal, one must go back to the beginning of the geologic period called the Pennsylvanian. All of Ohio's coal formed during this period, 310 to 280 million years ago, except for a few thin coals found in a younger geologic period called the Permian.

During most of Pennsylvanian time much of the eastern United States was the site of a vast swampy coastal lowland. Modern examples of Pennsylvanian geography are deltas and associated environments such as the Mississippi River delta. At times during the Pennsylvanian Period, inland seas flooded the area and deposited marine limestones and shales; at other times rivers carrying heavy loads of sediment from distant highlands built the shoreline seaward, forming low coastal plains. Vegetation accumulating in swamps on and surrounding the Pennsylvanian deltas eventually formed vast peat deposits, which later became coal. Millions of years of subsequent uplift and erosion have destroyed the geologic record of many of these coal deposits.

The pyritic sulfur, as well as the organic sulfur, in these coals was part of the original chemical make-up of the earth. Through erosion of rocks and volcanic activity, sulfur and sulfur compounds were exposed to the earth's atmosphere, where the sulfur combined with oxygen to form sulfate ($SO_4^{=}$). Much of this sulfate was washed into the sea and was concentrated in the oceans. Seawater averages about 2,650 parts per million sulfate, whereas average river water only contains about 11 parts per million sulfate. (By comparison, seawater averages about 29,000 parts per million salt (NaCl).) Peat swamps tend to have chemical environments in which sulfate and iron are quickly formed into pyrite ($FeS_2$), or less commonly marcasite (also $FeS_2$, but with a different crystal structure).

A number of factors control the availability of sulfate in the peat environment. At times during the Pennsylvanian Period marine waters would gradually flood the peat swamps, bringing in high concentrations of sulfate. When peat swamps were succeeded by a river or lake environment, sulfate, because of lower levels in fresh water, was not as likely to be available for the formation of pyrite in the peat. In addition, the burial of the peat by nonmarine sediments seems to have acted as a barrier to the later entry of seawater into the peat. The effectiveness of these sediment barriers has been found at least in some cases to be directly related to the type of sediment deposited. Sediments which are easily penetrated, such as coarse sand, allow later marine water to flow down into the peat bed, whereas fine-grained sediments such as clay are less susceptible to penetration and tend to block the flow of water. Generally, for a given coal, sulfur content is higher in areas where the coal is overlain by marine sediments than in areas where the same coal is overlain by fresh-water sediments. On a local scale, a coal overlain by sandstone in one area and by shale in another will generally have higher sulfur content beneath the sandstone.

The relative position of the swamp to the sea influences the occurrence of pyrite in Pennsylvanian coals in much the same manner as the overlying sediments. Swamps close to the ocean, possibly separated only by a sand bar, were more likely to be subject to occasional flooding by the sea, and thus to the introduction of high concentrations of sulfate. Swamps farther from the coastline were less likely to be subjected to marine flooding and were more likely to be buried by fresh-water sediments.

Substantial deposits of low-sulfur coal are found in southern West Virginia and parts of eastern Kentucky. These low-sulfur coals were deposited in essentially the same environments as those in Ohio. However, a number of investigators who have studied coal deposits in detail believe that during the Pennsylvanian Period, swamps in eastern Ohio, western Pennsylvania, and northwestern West Virginia rested on a slowly subsiding platform. Sedimentation rates were low on the stable platform and chemical activity (pyrite formation) was high and prolonged. In contrast, low-sulfur coals in southern West Virginia and parts of eastern Kentucky were probably deposited in fresher water than those on the platform and, in addition, were quickly buried in a rapidly subsiding trough. The rapid burial and hence rapid compaction of the peat may have squeezed sulfate-carrying water from the peat before chemical reactions (such as pyrite formation) could occur, or possibly rapid burial of the peat sealed it off from prolonged contact with later seawater.

The western United States contains enormous reserves of low-sulfur coal. There are a number of reasons why the west has such a seemingly disproportionate amount of this more environmentally acceptable coal. Most coals in the western United States were deposited during the geologic periods known as the Cretaceous (about 136 to 66 million years ago) and the Tertiary (about 66 to 2 million years ago). Many of the western coals of Cretaceous age were deposited in deltas and associated environments similar to those of the Pennsylvanian Period in the interior and eastern United States, but by Tertiary time the seas were gone from the areas of coal deposition in the west. Instead, most western coals of Tertiary age were deposited in relatively small, rapidly subsiding basins in association with fresh-water sediments. The fact that western coals are associated with fresh-water sediments is probably the single most important factor in the low sulfur content of western coals. However, many of the western Cretaceous coals which are associated with marine sediments also are low in sulfur. The low-sulfur Cretaceous coals of the west may be the result of a fundamental difference between the depositional cycles of the western Cretaceous deltas and the Pennsylvanian deltas of the interior and eastern United States. In many areas of the east and interior, the seas spread slowly over the extensive peat swamps, sediments were slowly deposited, and sea water was in close contact with the peat for long periods of time. In the west, the Cretaceous peats were more rapidly covered with sediments and less exposed to the pyrite-forming environments.

Because of geologic processes and geographic location, Ohio has very little low-sulfur coal. This is a fact Ohioans must accept. Ohio must promote and support research directed at reducing the sulfur content of Ohio coal after it is mined. Efficient low-cost methods of dealing with sulfur are needed to once again make Ohio coal competitive.

—Richard W. Carlton
Regional Geology Section

## COAL RESOURCE CLASSIFICATION—OR, HOW MUCH COAL DO WE HAVE LEFT IN OHIO?

Look through any series of reports on estimates of the amount of coal remaining in the ground in any particular area and a multitude of numbers will emerge, all seemingly arriving at different figures for the same thing. This apparent confusion arises mainly because the authors of the various reports were talking apples and oranges, although that distinction is not commonly spelled out to the reader. Considerable effort has been expended in recent years by federal and state agencies, including the Division of Geological Survey, to precisely define the various categories of coal resources with the objective of arriving at estimates that are not only as accurate as the data will allow but also intelligible to anyone who must use these figures.

Generally, the greatest confusion surrounds the usage of the terms *resource* and *reserve*. In many reports, and particularly in the popular media, these terms are used interchangeably and commonly without any definition. Simply stated, resources include all coals, both presently mineable and nonmineable; a coal may not be mineable because it is too thin, of low quality, inaccessible, or legally restricted. Reserves, on the other hand, are coal deposits that have been reliably identified and can be mined with current technology and under present economic conditions. Obviously a reserve estimate will be considerably smaller than a resource estimate.

In actual practice the story becomes a bit more complicated, and rather precise definitions must be used in order to arrive at figures that are meaningful. Couchot and others (1980) have outlined the various resource and reserve categories, as given below:

*Measured resources* are those resources lying within ½ mile of a point of measurement. The points of observation and measurement are so closely spaced and the thickness and extent of the coal so well defined that the calculated tonnage is judged to be accurate within 20 percent of true tonnage. This category is equivalent to the proven reserve category used in some previous Division of Geological Survey studies.

*Indicated resources* are those resources beyond ½ mile from a control point but within 2 miles of that same control point and are equivalent to the probable reserve category of some previous Division of Geological Survey studies.

*Inferred resources* are those resources lying more than 2 miles from a control point but within 4 miles of that same control point. Inferred resources are equivalent to the strongly inferred reserve category of some previous Division of Geological Survey studies.

The *identified economic resource* is a collective term for measured, indicated, and inferred resources.

The *reserve base* is the sum of the measured and indicated resources from which recoverable reserves are calculated. The *recovery factor* is that percentage by which the reserve base is multiplied to arrive at a recoverable reserve figure. For coal less than 100 feet below the surface the recovery factor is 80 percent; for coal deeper than 100 feet below the surface the recovery factor is 50 percent. These are generally accepted factors based on numerous evaluations and industry practice (Averitt, 1974). Coal is generally divided into three major categories by thickness of overburden: (1) 0 to 1,000 feet of cover, (2) 1,000 to 2,000 feet of cover, and (3) 2,000 to 3,000 feet of cover (Averitt, 1974). . . .

The *recoverable reserve* is the portion of the reserve base which is deemed extractable by present mining methods.

*Hypothetical resources* are those resources that may reasonably be expected to exist under known geologic conditions and, in general, are in areas of coal fields where points of observation are absent. Evidence for hypothetical resources is based on distant outcrops, drill holes, or wells. This category is essentially equivalent to the weakly inferred reserve category of some previous Division of Geological Survey studies.

*Paramarginal resources* are those resources which border on being economically producible or which are not available because of legal or civil restrictions. Paramarginal resources include such occurrences as coal in barrier pillars left around oil and gas wells, coal under roads where the coal has less than 100 feet of cover, and coal underlying cemeteries and incorporated towns.

*Submarginal resources* are those resources which, if produced, would entail a substantial increase in the cost of extraction or a major advance in mining technology. Submarginal resources include coal remaining in abandoned underground mines, coal less than 100 feet below a reservoir, coal 14 to 28 inches thick at depths greater than 100 feet, and that portion of the reserve base not recoverable under present technology.

Back to the original question—how much coal do we have left in Ohio? The honest answer to this question, to the

*continued on next page*

## SURVEY STAFF NOTES

*Bill Buschman*

*Jean Lesher*

Bill Buschman handles all Survey fiscal and purchasing activities, in addition to a number of other administrative duties. Bill, a Columbus native, received a degree in geology from the Ohio State University after completing military service during World War II. He served with the U.S. Air Force in the Asiatic-Pacific theater and participated in 26 combat missions.

Bill came to the Survey in 1965 after working for 16 years as a petroleum geologist in Venezuela and Columbia. He served for several years as head of the Subsurface Geology Section until assuming his present administrative duties. Bill is an avid fan of Ohio State athletics and he and his wife, Gwen, attend nearly every home football and basketball game.

Jean Lesher has responsibility for preparing phototype and mounting copy for all Survey publications. She has served in this technical and highly skilled position since she came to the Survey in 1963. The high quality of Survey publications owes a great deal to Jean's efforts and pride in her work.

Jean, a native of Frazeysburg in Muskingum County, lives in Columbus with her husband. She has three grown children and enjoys sewing and riding her horse.

surprise of many people, is we really don't know. Ohio has not been explored completely, geologically speaking. We do have a considerable amount of information pertaining to coal present on or near the surface, but the coal-bearing rocks in Ohio dip to the southeast, so that beds at the surface along the western edge of the coal fields may be at depths of nearly a thousand feet in southeastern Ohio, and little is known about the thickness and extent of the various coal seams there. The Survey core rig is attempting to close this information gap, but it is a slow and expensive process.

The Survey currently estimates Ohio's original coal resources (coal in the ground before mining) at 46,588,251,000 tons. This figure includes coal in the 14- to 28-inch category, which in most cases is too thin to be mined economically with current technology. In order to be more realistic, only coal greater than 28 inches thick should be included in the estimate. The amount of coal greater than 28 inches thick is estimated at 26,820,000,000 tons, from which must be subtracted the amount of coal mined through 1981—2,998,244,000 tons—and an equal amount (50 percent recovery factor) of coal lost to mining, giving a remaining tonnage of 20,823,512,000 tons. Standard practice indicates that this figure should be divided in half to account for coal that is unavailable for mining owing to its presence beneath cities, towns, reservoirs, highways, or other restrictions, so that ultimately 10,411,756,000 tons of coal could be produced in Ohio with current technology and under present economic conditions. Using a liberal estimate of 50,000,000 tons mined per year, Ohio would have about a 208-year supply of coal.

Obviously this figure is a ballpark estimate, but it is not too unrealistic at this time. This figure is based, at least, on the most reliable data currently available and certainly has more realism than figures commonly seen in the popular press. The figure will change, perhaps significantly, as exploration continues and we gain an increasingly better insight on the thickness and distribution of coal in the state. New mining technology, economic conditions, and perhaps alternative fuels may change the rate of coal production drastically, in either direction.

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