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Chapter A

Executive Summary—Coal Resource Assessment of Selected Coal Beds and Zones in the Northern and Central Appalachian Basin Coal Regions

By Leslie F. Ruppert

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Kentucky Geological Survey
Maryland Geological Survey
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Pennsylvania Bureau of Topographic and Geologic Survey
Virginia Division of Mineral Resources
West Virginia Geological and Economic Survey

2000 RESOURCE ASSESSMENT OF SELECTED COAL BEDS AND ZONES IN THE NORTHERN AND CENTRAL APPALACHIAN BASIN COAL REGIONS

By Northern and Central Appalachian Basin Coal Regions Assessment Team

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CHAPTER A—EXECUTIVE SUMMARY—COAL RESOURCE ASSESSMENT OF SELECTED COAL BEDS AND ZONES IN THE NORTHERN AND CENTRAL APPALACHIAN BASIN COAL REGIONS

By Leslie F. Ruppert[1]

INTRODUCTION

This study is part of a five-region project by the U.S. Geological Survey (USGS) designed to provide a geologic assessment of the top-producing coal beds and coal zones in the United States. The five regions (fig. 1) include the (1) northern and central Appalachian Basin (this CD-ROM), (2) Gulf Coast (USGS Professional Paper 1625–E), (3) Illinois Basin (USGS Professional Paper 1625–D), (4) Colorado Plateau (USGS Professional Paper 1625–B), and (5) Northern Rocky Mountains and Great Plains (USGS Professional Paper 1625–A). In 1998, about 1,082 million short tons of coal, constituting 93 percent of the total U.S. production, were produced from these five regions (Freme and Hong, [1999]). About 40 percent of the total was produced in the northern and central Appalachian Basin coal regions, 10 percent in the Illinois Basin, 5 percent in the Gulf Coast, 9 percent in the Colorado Plateau, and 36 percent in the Northern Rocky Mountains and Great Plains (fig. 2). The USGS coal resource assessments have produced coal resource maps and descriptions, or models, that identify and characterize the coal beds and coal zones that will provide the bulk of the U.S. production for the next several decades. The assessments are designed to provide geoscientists, policy makers, planners, and the general public with concise geologic information on the quantity and quality of the remaining coal resources. National Coal Resource Assessment (NCRA) geochemical databases will provide accurate and comprehensive information to aid in the prediction of potential emissions from the combustion of coal from of those coal beds and coal zones. In addition, NCRA data can directly aid in the delineation of areas with potential for coal-bed methane production, mine flooding, surface subsidence, and acid mine drainage.

The Appalachian Basin is one of the most important coal producing regions in the Nation and the world. The Basin historically has been subdivided into three coal regions based on regional geologic structure and stratigraphy. The northern region includes western Pennsylvania, eastern Ohio, western Maryland, and northern West Virginia; the central region includes west-central and southwestern West Virginia, eastern Kentucky, northern Tennessee, and southwestern Virginia; and the southern region includes southern Tennessee, northern Alabama, and northwestern Georgia (fig. 3). Historic and recent production records (Milici, 1999; see Appendix 1 of this chapter, this CD-ROM) show that about 34.5 billion short tons of coal have been produced in the three regions, with most of the production originating in the northern (18.4 billion short

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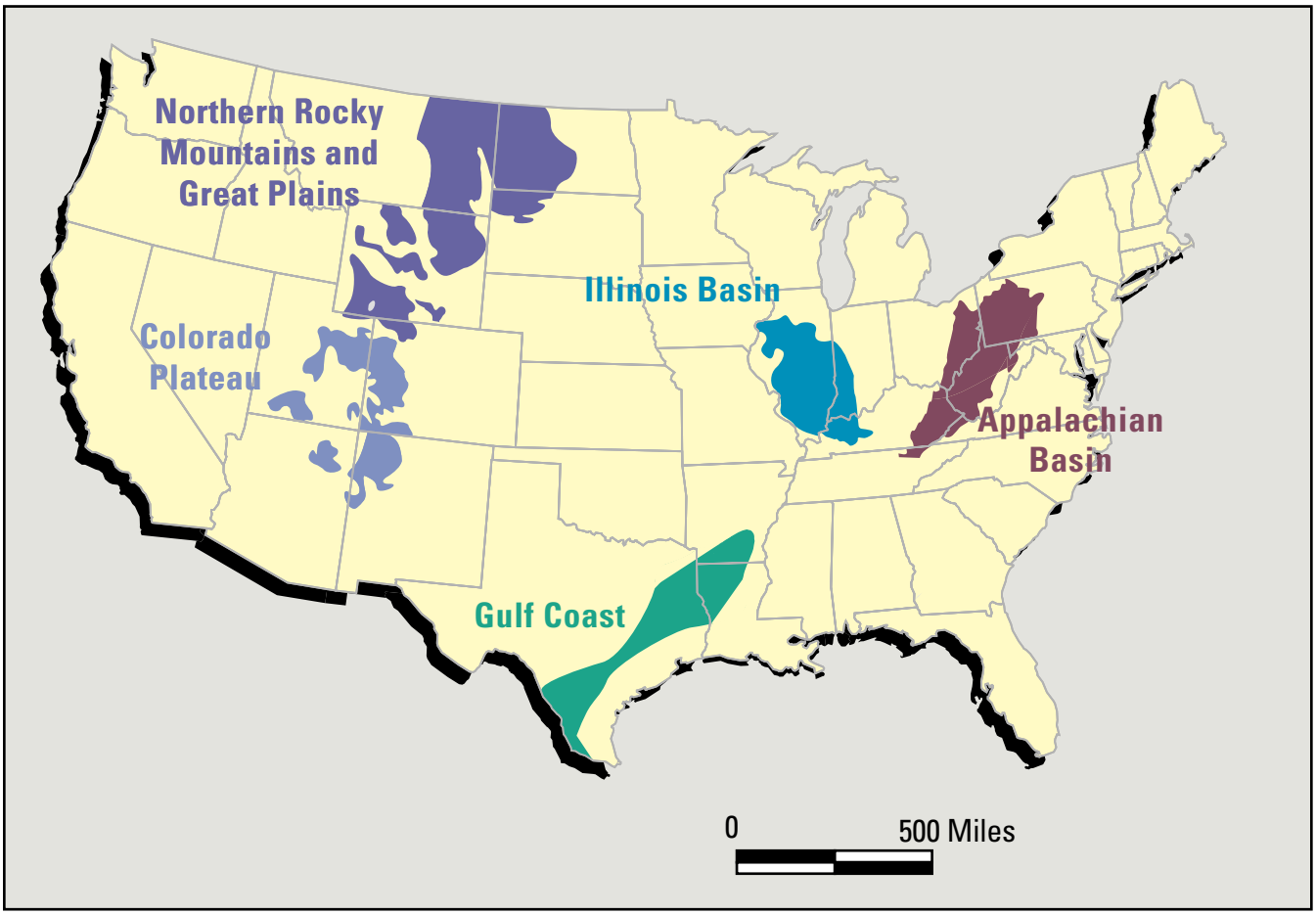

Figure 1. Map showing coal regions in the contiguous United States assessed in USGS's 2000 National Coal Resource Assessment project. The five assessed regions produce about 93 percent of the Nation's coal (Energy Information Administration, 2000).

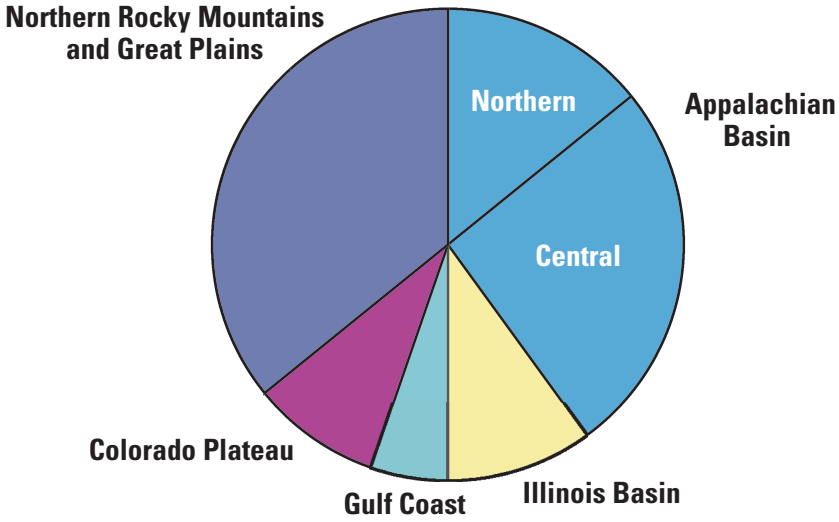

Figure 2. Chart showing 1998 coal production in the five regions studied in the USGS National Coal Resource Assessment. Data from Freme and Hong [1999].

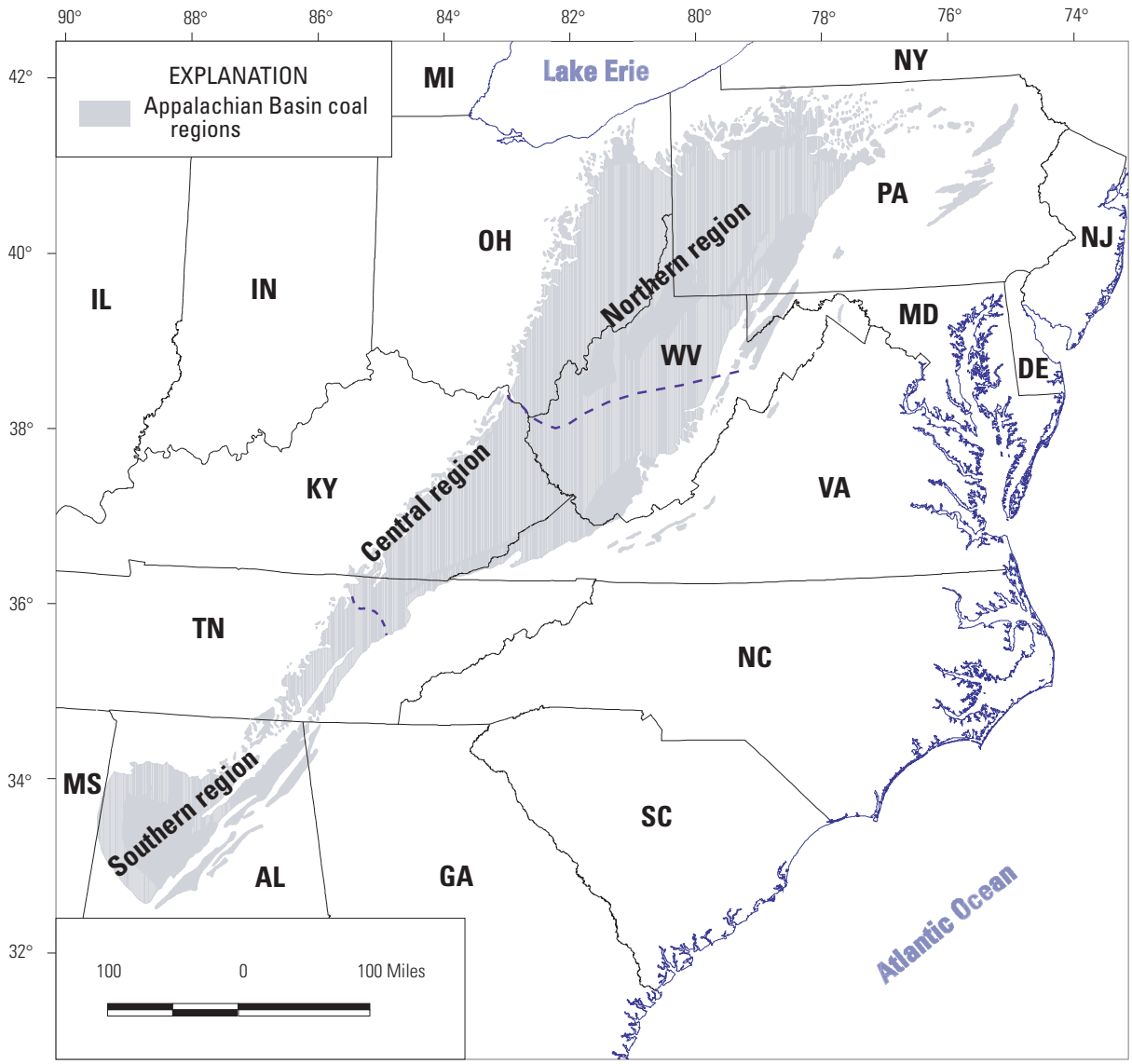

Figure 3. Map showing locations of the northern, central, and southern Appalachian Basin coal regions (shaded, divided by green lines). Areas of bituminous coal are shown by the shaded area. Assessments were conducted on coal beds in the northern and central regions where about 32 and 63 percent, respectively, of Appalachian bituminous coal is produced (Energy Information Administration, 2000).

tons) and central (14.4 billion short tons) coal regions. Because only about 5 percent of the Appalachian Basin production has occurred in the southern coal region, this report, given the scope of the NCRA, focuses exclusively on coal beds, coal zones, and coal production in the northern and central Appalachian Basin coal regions.

Appalachian Basin bituminous coal has been mined throughout the last three centuries. Currently, the coal primarily is used within the eastern U.S. for electrical power generation, but some of it is suitable for metallurgical uses. Although the number of coal mines operating in the northern and central Appalachian Basin coal regions is decreasing, the remaining mines are increasingly productive. In 1989, 424 million short tons of coal were produced from 1,255 underground and 1,020 surface mines (Energy Information Administration, 1990); by 1998, 452 million short tons were produced from just 701 underground and 614 surface mines (Energy Information Administration, 2000). The increase in productivity is due to large longwall underground mines in the Pittsburgh coal bed (figs. 4 and 5) and Pocahontas No. 3 coal bed (figs. 4 and 6), as well as mountain-top-removal surface mines in the Coalburg, Stockton, and the No. 5 and No. 6 Block coal zones (fig. 7). Sufficient high-quality, thick, bituminous resources remain in these coal beds and coal zones to last for the next one to two decades at current production. After these beds are

SYSTEM	SERIES	GROUP	ASSESSED COAL BED or ZONE
PENNSYLVANIAN	UPPER	Monongahela Group	Pittsburgh coal bed
		Conemaugh Group	
	MIDDLE	Allegheny Group	Upper Freeport coal bed Lower Kittanning coal bed
		Pottsville Group	Fire Clay coal zone Pond Creek coal zone
	LOWER		Pocahontas No. 3 coal bed

Figure 4. Generalized stratigraphic column showing the positions of the six coal beds and coal zones assessed in this study.

mined, given current economic and environmental restrictions, Appalachian Basin coal production is expected to decline. The Upper Freeport and Lower Kittanning coal beds and the Fire Clay and Pond Creek coal zones, which are the other top-producing coal units (fig. 4) already have peaked in production and the remaining coal is deeper (>1,000 ft), thinner (<3.5 ft), and (or) contains environmentally less desirable medium-to-high ash yields and sulfur contents. See Chapters C through H in this report for individual assessments of the previously mentioned coal beds and zones.

Assessment results will be used by the USGS to determine the total amount of coal from the Pittsburgh coal bed that is available for mining (see Watson and others, 2000) and recoverable from mining operations under different cost scenarios. Studies of the Pittsburgh coal bed are modeled after coal availability and recoverability studies done by the USGS in cooperation with coal-producing States, at scales ranging from 1:24,000 to 1:250,000. The USGS and State geological surveys of Pennsylvania, West Virginia, Ohio, Kentucky, and Virginia have completed 32 1:24,000-scale coal availability studies and 25 coal recoverability studies and concluded that only a fraction of the original coal resource can be extracted and marketed economically under current conditions given social and technological restrictions. Detailed methodology and results for the completed and in-progress northern and central Appalachian Basin coal availability and recoverability studies are discussed in Chapter J.

The coal resource assessments were conducted in cooperation with State geological surveys. The West Virginia Geological and Economic Survey (WVGES), the Pennsylvania Bureau of Topographic and Geologic Survey (PAGS), the Ohio Division of Geological Survey (OGS), and the Maryland Geological Survey (MGS) cooperated with the USGS in the assessments of the Pittsburgh, Upper Freeport, and Lower Kittanning coal beds. The Pond Creek and Fire Clay coal-zone assessments were conducted in partnership with the Kentucky Geological Survey (KGS), the Virginia Division of Mineral Resources (VDMR), and the WVGES. The VDMR and the WVGES worked with the USGS to assess the Pocahontas No. 3 coal bed.

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Many individuals contributed to the success of this project and are especially thanked by the author. Marc Levine provided technical and staff support and his suggestions solved many problems. I especially want to acknowledge Don Johnson for his computer abilities and his gracious support of the project and all the project members. Rachel Wallack, David Butler, and Phillip Freeman worked on the project for long periods with grace and dedication. Scott Kinney, (independent consultant, Denver, Colo.) performed the painstaking task of producing the interactive ArcView CD-ROM (Disc 2). Tracey Mercier (True North Mapping) was an invaluable GIS and graphics resource. The stratigraphic databases could not have been built without programming and database management magic of Jon Haacke (Independent consultant, Denver, Colo.). Jon was always there when needed and his help is very much appreciated. Thanks also to Hal Gluskoter for his support of this assessment project and willingness to review many of the manuscripts, including early drafts; and to Brenda Pierce for writing a successful contract for this project and for dealing with critical coordination issues. Craig Brunstein and Carol Quesenberry of the Central Region Publications Group provided initial editing and design support. Elizabeth Koozmin of the Eastern Region Publications Group was responsible for the final editing, design, and layout of each chapter. Her detailed knowledge of Appalachian stratigraphic nomenclature, her willingness to lead us through a long and sometimes frustrating process, and her constant grace is gratefully acknowledged. Robert Crangle, Jr., Eric Morrissey, David Murphy, David Traudt, Michael Trippi, and John Watson were responsible for the final review and production phases.

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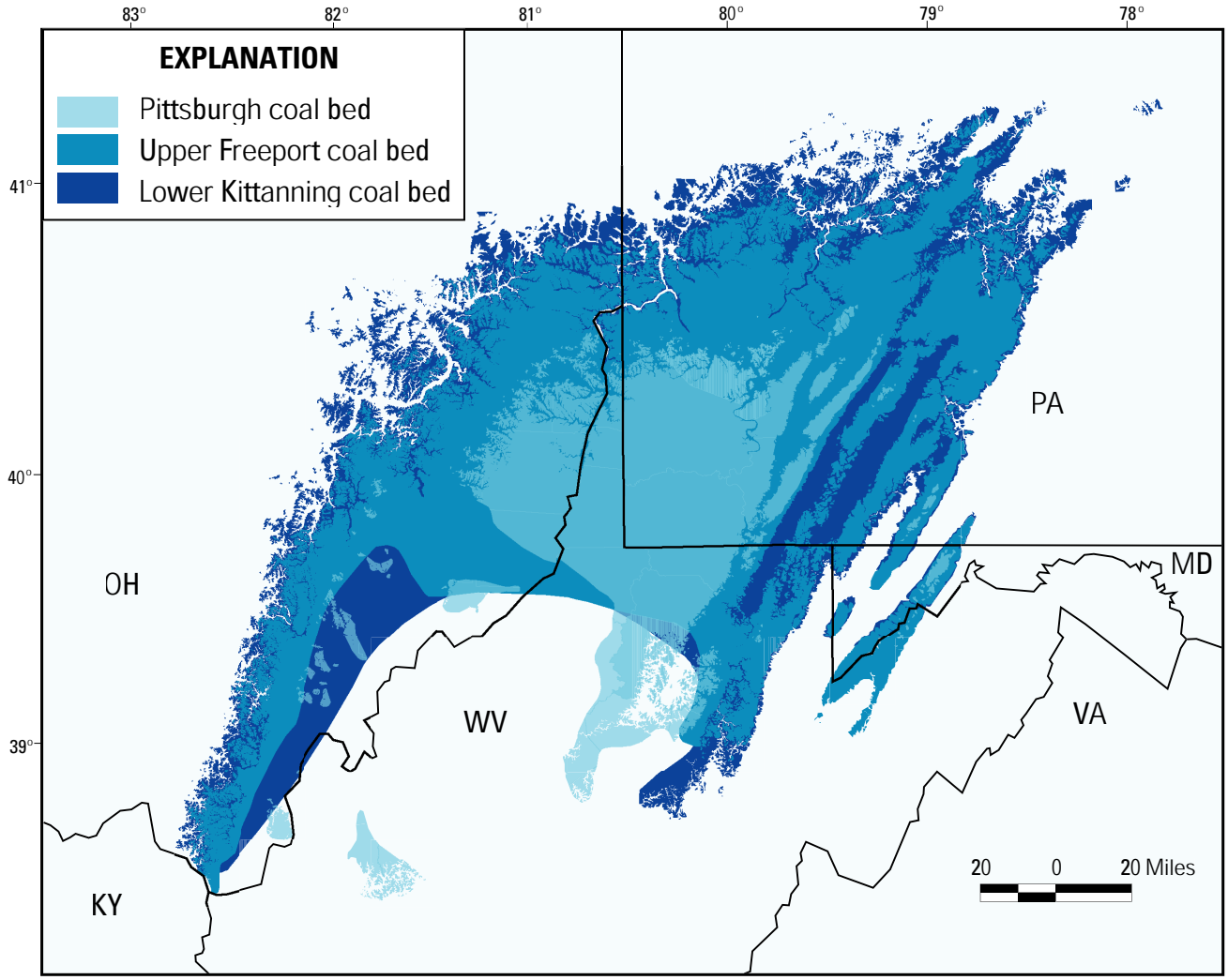

Figure 5. Map showing the three assessed coal beds in the northern Appalachian Basin coal region in descending stratigraphic order, the Pittsburgh, Upper Freeport, and Lower Kittanning. The three coal beds overlie one another and extend across parts of Ohio, West Virginia, Pennsylvania, and Maryland.

encouragement, good cheer, and ability to share ideas and plans. Laura Roberts and Margaret Ellis were always available with novel solutions to problems. Robert Milici provided the project with expertise, drive, and wry humor. An especially heartfelt thanks is extended to Susan Tewalt and Linda Bragg for their professionalism, trust, expertise, friendship, and dedication to this project, without which this project never would have been accomplished.

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Finally, I acknowledge Ronald Stanton, my friend and my mentor. Ron was a superb geologist and the best supervisor I could ever hope to have.

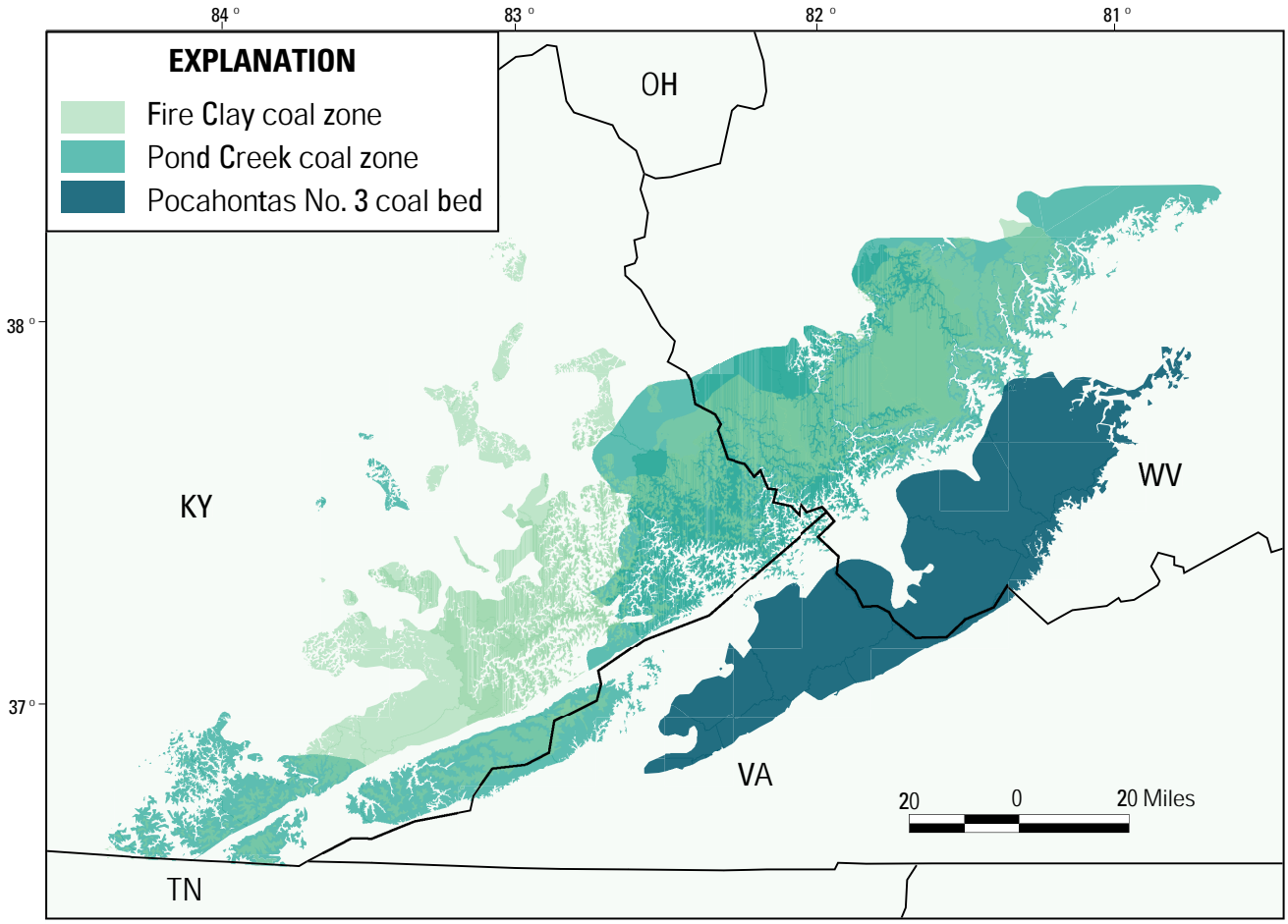


Figure 6. Map showing the three assessed coal beds in the central Appalachian Basin coal region. The stratigraphically youngest Fire Clay coal zone overlies the Pond Creek coal zone in eastern Kentucky, southwestern Virginia, and southern West Virginia. The stratigraphically older Pocahontas No. 3 coal bed extends through southwestern Virginia and southern West Virginia.

ASSESSMENT METHODOLOGY

Coal production was the primary criteria for determining which coal beds and coal zones were assessed within the northern and central Appalachian Basin coal regions. Secondary criteria included the availability of geologic maps and coal stratigraphic data for the correlation of coal beds within and between States. The Pittsburgh, Upper Freeport, and Lower Kittanning coal beds (figs. 4 and 5) were chosen for assessment because they account for 80 percent of the bituminous coal production in the northern Appalachian Basin coal region (Freme and Hong, [1999]). The central Appalachian Basin coal region constitutes about 27 percent of U.S. coal production and about 63 percent of the Appalachian bituminous coal production (Freme and Hong, [1999]). Within the central Appalachian region, the Fire Clay and Pond Creek coal zones and the Pocahontas No. 3 coal bed (figs. 4 and 6) were chosen for assessment because these coals account for about 18 percent of central Appalachian Basin coal production, and because maps and coal thickness data were available. Other top-producing central Appalachian coal zones were not modeled in the current USGS assessment because detailed coal-bed maps and verified coal thickness data were not available; they are, from youngest to oldest, the No. 5 Block coal zone of the Allegheny Group; and the Stockton and Coalburg coal zone, the Winifrede/Hazard coal zone, the Williamson/Amburgy coal zone, the Campbell Creek/Upper Elkhorn No. 3 coal zone, and the Upper Elkhorn Nos. 1 and 2/Powellton coal zone of the Pottsville Group (fig. 7). However, stratigraphic correlations and depositional and production history for each coal zone are discussed in detail in Chapter I (this report).

More than 1,000 published and unpublished maps at scales ranging from 1:24,000 to 1:500,000 were digitized and combined in a geographic information system (GIS) to

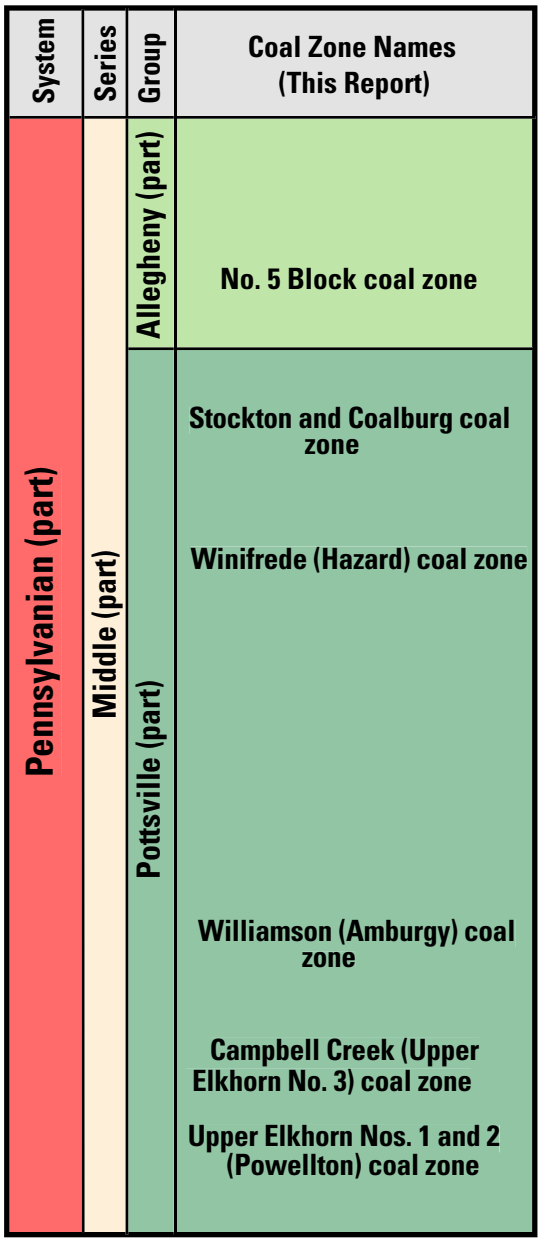


Figure 7. Generalized stratigraphic column showing the Middle Pennsylvanian Allegheny Group and Pottsville Group coal zones that were not assessed. These coal zones are important coal producers in the central Appalachian Basin coal region, but were not fully assessed because correlated coal thickness data were not available.

create a database that describes the areal extent and mined areas for each of the assessed coal beds and zones. In addition, comprehensive geochemical databases were created for each assessed coal bed or coal zone, and are available in ASCII format in the Appendixes in Chapters C through H. Bed-specific stratigraphic databases (available in ASCII format in the Appendixes in Chapters C, D, and F through H) were created from all available sources. Detailed methodology sections, appendixes, and geochemical metadata are included in each chapter (Chapters C through H). Generally, the databases were managed and stored using a relational database manager. Processes were developed to create coal-bed thickness, elevation, overburden thickness, and geochemical maps (coverages). Coal-bed and overburden thicknesses were classified according to Wood and others (1983). The coverages were combined and original and remaining resources were calculated in a GIS for the Pittsburgh, Upper Freeport, Fire Clay, Pond Creek, and Pocahontas No. 3 coal beds or zones. (Because correlated, verified stratigraphic databases for the Lower Kittanning coal bed are not complete and areal extent and mined-area maps are not available over the extent of the coal bed, resources have not been calculated for this coal bed.) Coal resource tonnage values for the Upper Freeport coal bed and the Fire Clay and Pond Creek coal zones were separated into two categories: (1) identified (resources calculated for areas within 3 mi of a coal-thickness measurement point), and (2) hypothetical (resources calculated for areas farther than 3 mi from a coal-thickness measurement) using criteria developed in Wood and others (1983) because all the stratigraphic records were not verified back to the original records held by USGS and State geological surveys. Identified resources for the Pittsburgh and Pocahontas No. 3 coal beds were subdivided into three categories: (1) measured (resources calculated for areas within 0.25 mi of a coal-thickness measurement point), (2) indicated (resources calculated for areas within 0.25 to 0.75 mi of a coal-thickness measurement point), and (3) inferred (resources calculated for areas within 0.75 to 3 mi of a coal-thickness measurement point) because all of the stratigraphic records were verified against the original records.

All the digital GIS coverages used to assess the coal beds and coal zones are located on Disc 2 of this CD set. The digital files are available for viewing in three formats. The first format is via the internet at http://geode.usgs.gov. The internet portal, GeoDE (Geologic Data Explorer), was created to provide access to USGS maps, data, and ancillary information. The portal is a map-oriented application, and all data files are available for complex queries based on user-defined criteria. Coal-resource-assessment data files can be integrated with selected coverages of Federal land ownership, major transportation systems, land-use, biological habitats, and with digital elevation models and satellite imagery; custom maps can be downloaded as image files to

use in other applications. Alternatively, users with ESRI ArcView or ArcInfo[2] software can download export files of coal-bed extents, mined areas, structure contours, coal thicknesses, overburden thicknesses, and stratigraphy and geochemistry data locations of the Pittsburgh, Upper Freeport, Fire Clay, Pond Creek, and Pocahontas No. 3 coal beds or zones. Export files for the Lower Kittanning coal bed are limited to coal-bed extent and geochemical data locations. ArcView shape (.SHP) files of States, counties, urban areas, mines, fossil-fuel powerplants, nuclear powerplants, Federally managed lands, roads, railroads, and hydrology in the northern and central Appalachian Basin coal regions also are included. For users without direct internet access or ESRI software, ESRI ArcView Data Publisher is installed on Disc 2 and can be used to access generalized, county-based files of the bed-specific coal extent, elevation ranges, thickness ranges, overburden thickness ranges, ash yield, sulfur and sulfur-dioxide content, gross calorific value, arsenic and mercury concentrations, and stratigraphy and geochemistry data points. These files are derivatives of the files used to assess the Pittsburgh, Upper Freeport, Lower Kittanning, Fire Clay, Pond Creek, and Pocahontas No. 3 coal beds or zones. These files are provided because the generalization significantly decreases the data file size and allows for relatively rapid access to coal-resource-assessment data.

GEOLOGY AND MINING HISTORY OF THE NORTHERN AND CENTRAL APPALACHIAN BASIN COAL REGIONS (CHAPTER B)

Coal-bearing strata in the northern and central Appalachian Basin occupy a region commonly referred to as the Appalachian Plateaus Physiographic Province. This province is, in general, an intricately dissected upland of concordant sharp ridges and V-shaped valleys. Economically important coal beds were deposited primarily during Pennsylvanian time in a southeastward-thickening foreland basin. Coal and associated rocks form a clastic wedge that thickens from north to south, from Pennsylvania into southeast West Virginia and southwestern Virginia.

Formal stratigraphic names of Pennsylvanian coal and strata tend to differ from State to State in the Appalachian Basin (see Rice and others, 1994). In this report, we use nomenclature for the major stratigraphic subdivisions first established for these rocks in southwest Pennsylvania. In this report, the Pennsylvanian strata are divided into four groups; they are, from oldest to youngest, the Pottsville, Allegheny, Conemaugh, and Monongahela Groups (fig. 4).

Bituminous coal of the northern and central Appalachian Basin coal regions was mined locally until the middle of the 19th century when rail lines and canals were built throughout the eastern U.S. Available and inexpensive transportation led to an explosive growth in coal production. Between 1850 and 1900, total northern and central Appalachian Basin coal production increased tenfold from 12.2 to 1,456 million short tons; by 1950, coal production increased a further tenfold to 14,847 million short tons (Milici, 1999; also see Appendix 1, this chapter). By 1996, over 32 billion short tons of bituminous coal had been produced in the two regions (Milici, 1999; also see Appendix 1, this chapter).

Coal production continues to increase in the region, mostly from the central Appalachian Basin coal region, because the thickest and highest quality northern Appalachian Basin coal is mined out and coal from the northern Appalachian Basin coal region does not meet environmental regulations that limit emissions of sulfur from coal-fired power plants. Phase II requirements of the Clean Air Act Amendments of 1990 (Public Law 101-549), which took effect in 2000, limit sulfur dioxide emissions from coal-fired power plants to a maximum of 1.2 pounds of sulfur dioxide (SO_2) per million British thermal units (Btu) or 0.6 pounds of sulfur per million Btu. These factors, along with a national trend toward the consolidation of coal mining and transportation industries (Attanasi, 1998), have created an increased demand for low-sulfur coal. The central Appalachian and Powder River Basins are the primary sources of low-sulfur coal. Virtually none of the coal from the Illinois Basin and northern Appalachian Basin meets the sulfur dioxide standards (fig. 8). However, coal from the Appalachian and Illinois Basins contains higher calorific values and produces more heat per ton than the lower rank subbituminous Powder River Basin coal. Coal from the Appalachian and Illinois Basins will continue to be mined because electric utility companies can burn the highest calorific value coal and meet air quality standards by coal blending; installing flue-gas desulfurization units; retiring older, less efficient units; or purchasing emission allowances from companies that emit less sulfur than the maximum allowed by Phase II regulations.

[2]ArcView and ArcInfo are products of ESRI, 380 New York Street, Redlands, CA 92373-8100, USA.

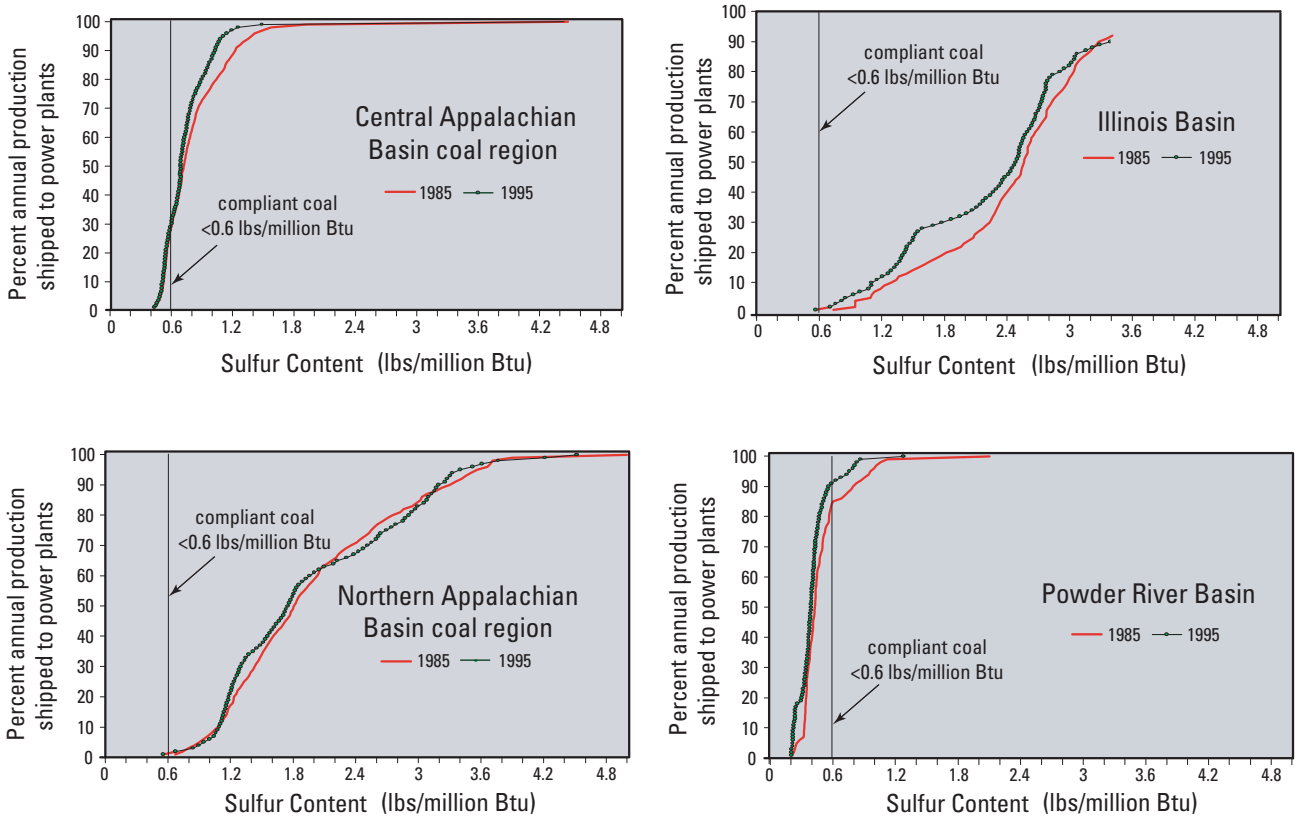
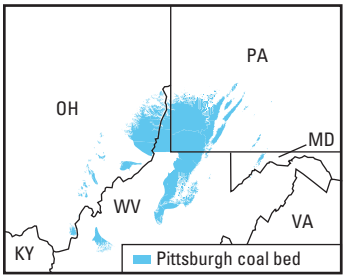


Figure 8. Graphs showing cumulative distribution of U.S. coals shipped to power plants between 1985 and 1995, by sulfur content per million Btu. Phase II of the Clean Air Act Amendments of 1990 (Public Law 101-549) mandates maximum sulfur emissions of 1.2 lbs of sulfur dioxide per million Btu, which equates to 0.6 lbs of sulfur per million Btu. About 30 percent of central Appalachian Basin coal and 90 percent of Powder River Basin coal meets compliance standards limiting sulfur dioxide emissions to 0.6 pounds of sulfur per million Btu. Coal from the northern Appalachian Basin coal region and the Illinois Basin does not meet the standards. Modified from Attanasi (1998).

ASSESSMENT RESULTS

NORTHERN APPALACHIAN BASIN COAL REGION

PITTSBURGH COAL BED (CHAPTER C)



The Pittsburgh coal bed of the Upper Pennsylvanian, Monongahela Group (fig. 4) and its lateral non-coal equivalents (horizons) extend over 11,000 mi^2. The coal alone covers over 5,000 mi^2 in Ohio, Pennsylvania, West Virginia, and Maryland. The Pittsburgh is a high-rank, high-volatile A bituminous coal that is used for both metallurgical and steam purposes. In over 220 years of mining, the Pittsburgh coal bed has produced more coal than any other coal bed in the Nation. Currently, it is the Nation's second largest producer and the top producer in the Appalachian Basin (Energy Information Administration, 2000).

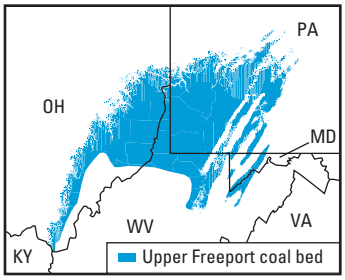
Geochemical analyses show that, overall, the Pittsburgh is a medium-ash and medium-sulfur coal bed (9.02±2.90 and 2.80±1.13 weight percent, respectively, as-received basis). Both parameters show large regional variations: ash yield and sulfur contents tend to increase from east to west. With a calculated mean sulfur dioxide (SO_2) content of 4.34±1.81 lbs of sulfur dioxide per million Btu, the Pittsburgh coal bed does not meet 2000 emission standards (Clean Air Act Amendments of 1990, Public Law 101-549),

Table 1. Original and remaining resources by State for the Pittsburgh, Upper Freeport, Fire Clay, Pond Creek, and Pocahontas No. 3 coal beds or zones, rounded to millions of short tons and two significant figures.

COAL BED/ZONE	State	Original	Remaining
Pittsburgh	Pennsylvania	15,000	5,000
	West Virginia	13,000	7,800
	Ohio	5,900	3,200
	Maryland	260	0
	Grand Total	**34,000**	**16,000**
Upper Freeport	Pennsylvania	16,000	14,000
	West Virginia	5,000	4,500
	Ohio	12,000	12,000
	Maryland	910	<810
	Grand Total	**34,000**	**<31,000**
Fire Clay	Kentucky	4,200	3,200
	Virginia	55	49
	West Virginia	2,100	1,800
	Grand Total	**6,300**	**5,100**
Pond Creek	Kentucky	4,600	3,300
	Virginia	570	370
	West Virginia	5,600	5,000
	Grand Total	**11,000**	**8,700**
Pocahontas No. 3	Virginia	2,900	2,500
	West Virginia	4,300	2,600
	Grand Total	**7,200**	**5,100**

but usage continues because the coal has such a high mean calorific value (13,130±680 Btu/lb, as-received basis). Mean arsenic and mercury concentrations (12 parts per million (ppm) and 0.14 ppm, respectively, as-received whole-coal basis) are lower than the Appalachian Basin means of 35 and 0.21 ppm, respectively (Finkelman and others, 1994).

The original resource of the Pittsburgh coal bed was estimated at 34 billion short tons (table 1). About 16 billion short tons remain (5 billion short tons in Pennsylvania, 7.8 billion short tons in West Virginia, and 3.2 billion short tons in Ohio; Maryland is essentially mined out). Of that, an estimated 860 million short tons of Pittsburgh coal underlie Federally owned land surfaces, all of which are located in Ohio (Tewalt, 2001). Most of the remaining coal is thinner (4–7 ft versus >7 ft), deeper (500–2,000 ft versus 0–500 ft), and higher in ash yield and sulfur content than the coal that has already been mined. However, there are blocks of extensive thick (6–8 ft) coal in southwestern Pennsylvania and the northern panhandle of West Virginia that could be mined. Much of the remaining Pittsburgh coal to the south of Marion County, W. Va., and west through much of Ohio is high in ash yield and sulfur, and is not likely to be extensively mined in the near future given current economic and environmental conditions.



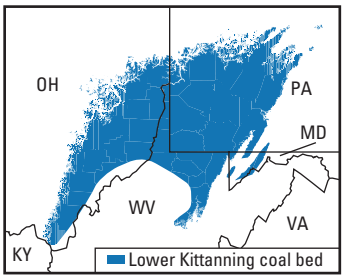
UPPER FREEPORT COAL BED (CHAPTER D)

The Upper Freeport coal bed of the Middle Pennsylvanian Allegheny Group (fig. 4) covers more than 14,000 mi^2 in Ohio, Pennsylvania, West Virginia, and Maryland. The coal bed has been extensively mined for nearly 200 years in both underground and surface operations. Although production is beginning to decline, the Upper Freeport remains the third most productive coal bed in the northern Appalachian Basin coal region and the fourteenth largest producing coal bed in the United States (Energy Information Aministration, 2000).

Overall, the Upper Freeport is classified as a medium-ash (12.31±3.98 weight percent, as-received basis) and medium-sulfur (2.24±1.02 weight percent, as-received basis) coal bed but, as mined, Upper Freeport coal fails to

meet the 2000 emission standards without blending or scrubbing. The calorific value is high (12,950±730 Btu/lb, as-received basis) and rank ranges from low-volatile bituminous in the eastern part of the basin to high-volatile C bituminous in the western part of the basin. Mean arsenic and mercury concentrations are 34±25 ppm and 0.30±0.17 ppm, respectively (as-received whole-coal basis).

The original total resource of the Upper Freeport coal bed was estimated to be 34 billion short tons, of which less than 31 billion short tons remain (table 1). Of that, 5,500 million short tons of Upper Freeport coal underlie Federally owned land surfaces (4,400 million short tons in Ohio, 701 million short tons in Pennsylvania, 310 million short tons in West Virginia, and 44 million short tons in Maryland) (Tewalt, 2001). Pods of thick coal remain, but they are under deep overburden cover (>1,000–2,000 ft) and are unlikely to be mined given current economic and technological conditions. Relatively shallow beds remain in Pennsylvania and Ohio, and such resources can be mined and combusted in power plants that blend coal or are equipped with flue-gas desulfurization units.



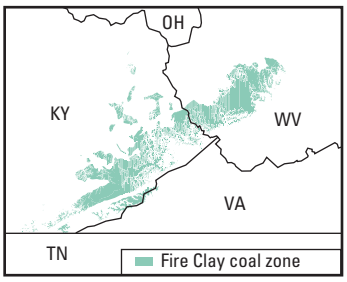
LOWER KITTANNING COAL BED (CHAPTER E)

The Lower Kittanning coal bed of the Middle Pennsylvanian Allegheny Group (fig. 4) and its non-coal equivalents extend over 18,800 mi^2 in western Pennsylvania and adjacent parts of Ohio, West Virginia, and Maryland. Although the Lower Kittanning has been correlated with the No. 5 Block coal zone (see fig. 7) in southern West Virginia and eastern Kentucky, this correlation is poorly understood and therefore the No. 5 Block is not included in the assessment. The apparent rank of the Lower Kittanning coal bed ranges from low-volatile bituminous in the east to high-volatile C bituminous in the southwest. This coal bed is the sixth most productive coal bed in the Appalachian Basin. The coal is used for coking as well as electric power generation.

In general, the Lower Kittanning is a medium-ash (11.98±4.69 weight percent, as-received basis) and medium- to high-sulfur (2.90±1.55 weight percent, as-received basis) coal, although there is large variation in sulfur content by State (1.73±0.86 weight percent in West Virginia to 3.73±1.55 weight percent in Ohio, all on an as-received basis). The mean calorific value is high (12,890±940 Btu/lb, as-received basis), and mean arsenic and mercury concentrations (19±20 ppm and 0.22±0.18 ppm, respectively, as-received basis) are close to the means for Appalachian Basin coal (Finkelman and others, 1994).

Resources for the Lower Kittanning coal bed were not estimated in this assessment because mine maps are not yet compiled, and correlated verified stratigraphic data were not available. However, past resource studies (see Chapter E, this report) indicate that the original resource of the Lower Kittanning coal bed is estimated to be 26.6 billion short tons (9.9 billion short tons in Ohio, 12.2 billion short tons in Pennsylvania, and 4.5 billion short tons in West Virginia).

CENTRAL APPALACHIAN BASIN COAL REGION



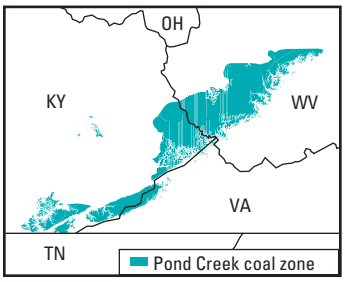
FIRE CLAY COAL ZONE (CHAPTER F)

The Fire Clay coal zone of the Middle Pennsylvanian Pottsville Group is equivalent to the Hazard No. 4 coal bed in Kentucky, the Phillips coal bed in Virginia, and the Fire Clay coal bed in West Virginia. Unlike the Pittsburgh, Upper Freeport, and Pocahontas No. 3 coal beds, the Fire Clay is a zone consisting of multiple benches of coal and associated rock material that are of variable thickness and extent. To calculate Fire Clay coal zone resources, stratigraphic records of only those coal benches most likely to be mined were used to estimate resources. Thin coal benches (<14 in or 1.17 ft thick) and coal benches that were separated from other benches by thick rock partings (>50 percent of the overlying or underlying coal thickness) are not likely to be mined and, therefore, were not included in the estimates.

The Fire Clay coal zone is distributed throughout approximately 5,500 mi^2 in Kentucky, West Virginia, and Virginia. The coal zone contains a volcanic ash or tonstein parting that serves as a regional stratigraphic marker. Overall, the coal is high-volatile A bituminous in rank and is used for steam generation. The great majority of the Fire Clay coal zone mined to date has been from underground mines. Surface mining (contour stripping and mountain-top removal) has been limited because of the deeply dissected terrain of the region.

The Fire Clay coal is classified as a medium-ash (10.62±4.53 weight percent, as-received basis) and low-sulfur (0.99±0.46 weight percent, as-received basis) coal. The mean calorific value for the Fire Clay coal is 12,910±780 Btu/lb (as-received basis). As mined, the coal does not meet 2000 emission standards, but it is blended with lower sulfur coal or scrubbed. Mean arsenic and mercury concentrations are 11±13 and 0.12±0.089 ppm, respectively (as-received whole-coal basis).

Of the 6.3 billion original short tons of Fire Clay coal, 5.1 billion short tons remain (table 1). Most of the remaining coal is in Leslie and Knott Counties, Ky., and Boone County, W. Va. Of the remaining resource, 1,100 million short tons of Fire Clay coal underlie Federally owned land surfaces (42 million short tons in Virginia, and 1,060 short tons in Kentucky) (Tewalt, 2001). Because much of the remaining 5.1 billion short tons of Fire Clay coal is below drainage and is in thinner beds than those previously mined, future mining will be more difficult and costly. However, because the Fire Clay is low in sulfur and high in calorific value, it is expected to continue to be a major producer in the central Appalachian Basin coal region, particularly in Kentucky, for the next decade.

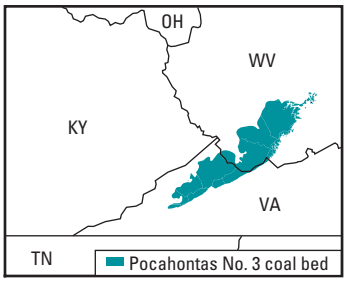


POND CREEK COAL ZONE (CHAPTER G)

The Pond Creek coal zone of the Middle Pennsylvanian Pottsville Group (fig. 4) is equivalant to the Lower Elkhorn coal bed in eastern Kentucky, the Imboden coal bed in southwestern Virginia, and the Eagle coal bed in southern West Virginia. The coal zone extends over 8,700 mi^2, of which almost 3,700 mi^2 were assessed. Coal beds of the Pond Creek coal zone are mined extensively underground and at the surface. The coal is used mainly for electric power generation. However, many coal benches of the Pond Creek are of metallurgical quality and were mined as coking coal in the past.

Although less extensive and generally thinner than other top-producing Appalachian coal beds, Pond Creek coal is highly desirable because of its low ash yield and relatively low sulfur content (7.24±3.98 and 1.05±0.77 weight percent, respectively, as-received basis) and high calorific value (13,540±650 Btu/lb, as-received basis). It is classified as a high-volatile A bituminous coal over most of its extent. With a mean sulfur dioxide (SO_2) value of 1.57±1.17 lbs of sulfur dioxide per million Btu, much of the Pond Creek coal as mined does not meet 2000 emission compliance standards, but coal blending and physical coal-cleaning methods are somewhat effective in reducing the sulfur content of Pond Creek coal that is delivered to power plants. Overall mean arsenic and mercury concentrations for 88 Pond Creek coal samples are 9.9±14 and 0.11±0.10 ppm, respectively (as-received whole-coal basis).

Estimates for the Pond Creek coal zone were calculated on individual coal benches or deposits that are most likely to be mined using criteria described previously in the Fire Clay coal zone section. Of the calculated original resource of 11 billion short tons, about 8.7 billion short tons remain (table 1). Of that, an estimated 570 million short tons of Pond Creek coal underlie Federally owned land surfaces (10 million short tons in West Virginia, 250 million short tons in Virginia, and 310 million short tons in Kentucky) (Tewalt, 2001). Kentucky has depleted more Pond Creek coal (1.3 billion short tons out of an original resource of 4.6 billion short tons) than any other State, and Kentucky's remaining coal is in thinner beds than those previously mined. About 370 million short tons of Pond Creek coal remain in Virginia out of a total original estimated resource of 570 million short tons. West Virginia, which had the largest original amount of the estimated Pond Creek coal resource (5.6 billion short tons), has the largest remaining amount (5.0 billion short tons). Some of the remaining Pond Creek coal in West Virginia is relatively thick and shallow, making it likely to be mined in the future.



POCAHONTAS NO. 3 COAL BED (CHAPTER H)

The Pocahontas No. 3 coal bed of the Lower Pennsylvanian Pottsville Group is in southern West Virginia and western Virginia. The Pocahontas No. 3 coal bed is, in general, a high-rank, low-volatile bituminous coal that was once considered a standard for metallurgical coal. Coal was first produced from the Pocahontas No. 3 coal bed in the early 1880's and the coal bed has produced more high-quality coal than any other in Virginia.

The Pocahontas No. 3 coal bed has a low ash yield and sulfur content (5.75±2.24 and 0.66±0.16 weight percent, respective, as-received basis), and the coal, as

mined, meets 2000 compliance coal standards with a calculated sulfur dioxide (SO_2) value of 0.91±0.22 lbs of sulfur dioxide per million Btu. The mean calorific value for the Pocahontas No. 3 coal bed is 14,490±340 Btu/lb (as-received basis). Mean arsenic and mercury concentrations are 7.1±8.1 ppm and 0.064±0.044 ppm, respectively (as-received whole-coal basis).

The resource model indicates that, of the original 7.2 billion short tons of Pocahontas No. 3 coal, 5.1 billion short tons remain (table 1). Of that, an estimated 350 million short tons underlie Federally owned land surfaces (250 million short tons in West Virginia and 100 million short tons in West Virginia) (Tewalt, 2001). Most of the coal, however, is in the inferred or hypothetical categories and generally is thinner, deeper, and more costly to mine than the coal that has already been mined. Large areas of unmined coal remain at depths of 1,000 to 2,000 ft; an additional area of relatively thick unmined coal remains at depths of 500 to 1,000 ft. Remaining pockets of deep (>1,000 ft) Pocahontas No. 3 coal are in mountainous terrain between areas of extensive mining; this coal currently is being exploited for its coal-bed methane resources.

NON-ASSESSED COAL BEDS (CHAPTER I)

In 1996, six Middle Pennsylvanian, central Appalachian Basin coal region coal zones, the No. 5 Block, Stockton and Coalburg, Winifrede/Hazard, Williamson/Amburgy, Campbell Creek/Upper Elkhorn No. 3, and the Upper Elkhorn Nos. 1 and 2/Powellton (fig. 7), produced about 163 million short tons of coal. Although these coal zones produced about 15 percent of the Nation's coal in 1996, they were not fully assessed and modeled in this report because (1) they are composed of multiple, discontinuous coal benches that are not completely mapped; (2) the stratigraphic and structural relationships between and among the coal benches and associated strata are not fully understood; and (3) they are identified by a plethora of State, regional, and local names. Although these factors prohibited the development of verified and correlated stratigraphic databases critical to a digital geology-based coal-resource assessment model, coal-resource and coal-chemistry parameters for each coal zone were compiled from previous USGS resource estimates and coal production was compiled from State data.

Mean ash yields for the six coal zones ranged from a low of 6.8±3.9 weight percent in Upper Elkhorn Nos. 1 and 2/Powellton coal zone to a high of 11.8±5.5 weight percent for the No. 5 Block coal zone. Mean sulfur contents ranged from 1.0±0.7 weight percent for the Winifrede/Hazard coal zone to 1.8±1.3 weight percent for the Williamson/Amburgy coal zone. Calorific value tends to be related to depth of burial: the No. 5 Block is stratigraphically highest and it averages 12,200 Btu/lb, while the stratigraphically lowest coal zone in this group, the Upper Elkhorn Nos. 1 and 2/Powellton, has a mean of 13,500 Btu/lb. Mean arsenic and mercury concentrations are, for the most part, at or lower than the mean values of 35 and 0.21 ppm, respectively (as-received basis), for all Appalachian coal (Finkelman and others, 1994), although there is significant scatter in the data.

CONCLUSIONS

The USGS, in partnership with the State geological surveys of Pennsylvania, Maryland, Ohio, West Virginia, Kentucky, and Virginia, digitally assessed six top-producing Pennsylvanian coal beds and coal zones in the northern and central Appalachian Basin coal regions. The six coal beds and zones—the Pittsburgh coal bed, Upper Freeport coal bed, Lower Kittanning coal bed, Fire Clay coal zone, Pond Creek coal zone, and Pocahontas No. 3 coal bed (fig. 4)—produce over 15 percent of the Nation's coal (Energy Information Administration, 2000). The total original amounts of available coal resources were calculated for five of the coal beds and zones—the Pittsburgh, Upper Freeport, Fire Clay, Pond Creek, and Pocahontas No. 3 (table 1)—and are estimated at about 93 billion short tons, of which about 66 billion short tons remain. Much of the remaining coal in all five coal beds and zones is thinner (<3.5 ft) and deeper (>1,000 ft) than the coal that has been mined, but economic resources are still available and mining in each coal bed and coal zone will continue throughout this decade and into the next given current market conditions.

Coal quality issues, especially sulfur content, play an increasingly important role in Appalachian Basin coal production trends. The 2000 sulfur-dioxide-emission regulations (Clean Air Act Amendments of 1990, Public Law 101-549), which mandate maximum emissions of 1.2 lbs of sulfur dioxide (SO_2) per million Btu, favor production of central Appalachian Basin coal region coal beds and coal zones over northern Appalachian Basin coal region coal beds, because the northern region coal beds (Pittsburgh, Upper Freeport, and Lower Kittanning) tend to be higher in ash and sulfur than the central region coal beds and zones (Fire Clay, Pond Creek, and Pocahontas No. 3). The Upper Freeport coal bed contains the highest mean ash yield (12.31 weight percent, as-received basis) and the Lower Kittanning coal bed contains the highest mean sulfur content (2.90 weight percent, as-received basis), while the Pocahontas No. 3 coal bed contains the lowest ash yield and sulfur content (5.75 and 0.66 weight percent, as-received basis, respectively). In addition, at the end of 2000, the U.S. Environmental Protection Agency will decide if mercury emissions from coal-burning power plants will be regulated.

In general, mercury contents tend to be higher in northern Appalachian Basin coal beds (for example, a mean of 0.30 ppm for the Upper Freeport coal bed) than in central Appalachian Basin coal beds and zones (for example, a mean of 0.064 ppm for the Pocahontas No. 3 coal bed).

The Nation is dependent on, and will remain dependent on, coal-powered electric power plants for the majority of our electricity for at least the next few decades. Coal-quality issues will continue to drive coal production from the plentiful, high-ash and high-sulfur, northern Appalachian Basin coal to the low-ash and low-sulfur central Appalachian Basin coal and northern Rocky Mountains coal in the next decade.

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APPENDIX 1

BITUMINOUS COAL PRODUCTION IN THE APPALACHIAN BASIN—PAST, PRESENT, AND FUTURE

By Robert C. Milici

This appendix is a re-release of U.S. Geological Survey Miscellaneous Field Studies Map MF–2330, and consists of four oversized map sheets. It is also available on the web at http://pubs.usgs.gov/mf-maps/mf-2330/.

CLICK HERE TO GO TO SHEET 1

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