U.S. Department of the Interior
U.S. Geological Survey

Chapter D

A Digital Resource Model of the Middle Pennsylvanian Upper Freeport Coal Bed, Allegheny Group, Northern Appalachian Basin Coal Region

By Leslie F. Ruppert, Susan J. Tewalt, Rachel N. Wallack, Linda J. Bragg, David K. Brezinski, Richard W. Carlton, David T. Butler, and Fred J. Calef, III

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1625–C

Prepared in cooperation with the
Maryland Geological Survey
Ohio Division of Geological Survey
Pennsylvania Bureau of Topographic and Geologic Survey
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

CONTENTS

FIGURES

TABLES

CHAPTER D—A DIGITAL RESOURCE MODEL OF THE MIDDLE PENNSYLVANIAN UPPER FREEPORT COAL BED, ALLEGHENY GROUP, NORTHERN APPALACHIAN BASIN COAL REGION

By Leslie F. Ruppert,[1] Susan J. Tewalt,[1] Rachel N. Wallack,[2] Linda J. Bragg,[1] David K. Brezinski,[3] Richard W. Carlton,[4] David T. Butler,[5] and Fred J. Calef, III[6]

ABSTRACT

The Middle Pennsylvanian Upper Freeport coal bed is a significant resource in the northern Appalachian Basin coal region. In 1998, the Upper Freeport coal bed was ranked fourteenth among producing coal beds in the United States and third in the northern Appalachian Basin coal region. The resource model for the Upper Freeport coal bed is based on comprehensive stratigraphic and geochemical digital databases and geographic information system (GIS) coverages of the coal bed. The resource model indicates that the Upper Freeport coal bed originally contained 34 billion short tons of coal, and currently, less than 31 billion short tons remain. However, most of the remaining coal does not meet year 2000 emission requirements which mandate that emissions do not exceed 1.2 pounds of sulfur dioxide (SO_2) per million British thermal units (Btu) (0.6 pounds of sulfur per million Btu). Remaining coal resources are generally thinner, deeper, and more costly to mine than coal that has already been mined.

[1]U.S. Geological Survey, MS 956, Reston, VA, 20192.

[2]Current address: Intertox, Inc., 2819 Elliott Avenue, Seattle, WA 98121.

[3]Maryland Geological Survey, 2300 St. Paul Street, Baltimore, MD 21218.

[4]Ohio Division of Geological Survey, retired

[5]Current address: MTA, Inc./Earth Tech, Inc., 5575 DTC Parkway, Suite 200, Englewood, CO 80111.

[6]CH2M Hill, 625 Herndon Parkway, Herndon, VA 20170

INTRODUCTION

The Middle Pennsylvanian Upper Freeport coal bed (fig. 1) is located in the northern Appalachian Basin coal region (fig. 2) and has been extensively mined for nearly 200 years in both underground and surface operations. As of 1998, it remained the third most productive coal bed in the northern Appalachian Basin coal region and the fourteenth largest producing coal bed in the United States (Freme and Hong, [1999]). Throughout most of the region, the Upper Freeport coal bed is a medium-volatile steam and coking coal with medium to high ash yield and sulfur content. In contrast to the more areally consistent Lower Kittanning and Pittsburgh coal beds, minable coal deposits identified as belonging to the Upper Freeport coal bed exist in irregularly shaped pods that rarely exceed 15 mi in lateral extent.

The Upper Freeport coal-bed assessment area covers more than 14,000 mi^2 and parts or all of 55 counties in Pennsylvania, West Virginia, Ohio, and Maryland (fig. 3). The coal bed extends from Clearfield County, Pa., in the

This chapter, although in a U.S. Geological Survey Professional Paper, is available only on CD-ROM and is not available separately.

This chapter should be cited as:

Ruppert, L.F., Tewalt, S.J., Wallack, R.N., Bragg, L.J., Brezinski, D.K., Carlton, R.W., Butler, D.T., and Calef, F.J., III, 2001, Chapter D—A digital resource model of the Middle Pennsylvanian Upper Freeport coal bed, Allegheny Group, northern Appalachian Basin coal region, *in* Northern and Central Appalachian Basin Coal Regions Assessment Team, 2000 resource assessment of selected coal beds and zones in the northern and central Appalachian Basin coal regions: U.S. Geological Survey Professional Paper 1625–C, CD-ROM, version 1.0.

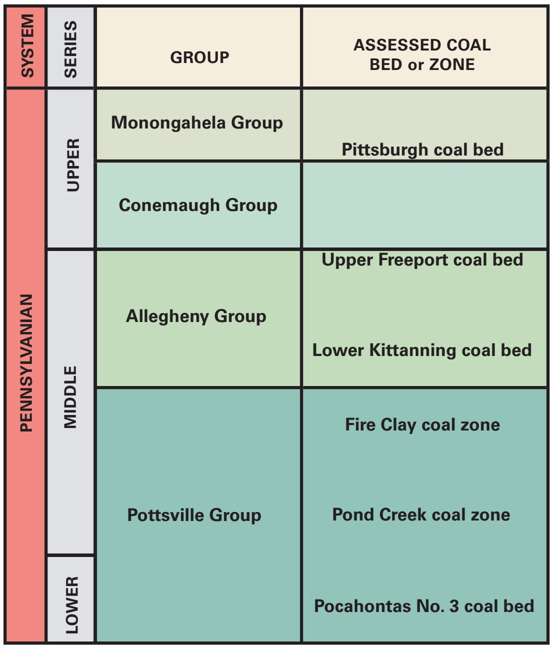


Figure 1. Generalized stratigraphic chart showing relative positions of the six top-producing coal beds or zones assessed in this study. The Lower Kittanning coal bed was assessed for areal extent and geochemistry only. All six coal beds are Pennsylvanian in age.

east to Lawrence County, Ohio, in the west. The northernmost occurrence of the Upper Freeport coal bed is Elk County, Pa., and the southernmost occurrence is Lawrence County, Ohio. The coal bed may extend further to the south into southern West Virginia and eastern Kentucky but stratigraphic correlations are highly uncertain and do not warrant extrapolation south of the areas shown on figure 3 at this time.

There are numerous publications, dissertations, theses, open-file reports, and maps that include information on the Upper Freeport coal bed (see Appendix 1). None of these publications encompass the scope of the present regional, bed-specific assessment. Because of the variable character of different Upper Freeport pods or deposits, only a few citations are appropriate in this overview. Among these are several benchmark geologic studies that were conducted in cooperation with the coal industry during the late 1970's and early 1980's (Pedlow, 1977; Clark, 1979; Hohos, 1979; Sholes and others, 1979; Cecil and others, 1981; Skema and others, 1982).

The coal resource assessment of the Upper Freeport coal bed was conducted by the U.S. Geological Survey (USGS) in cooperation with the Pennsylvania Bureau of Topographic and Geologic Survey (PAGS), the West Virginia Geological and Economic Survey (WVGES), the Ohio Division of Geological Survey (OGS), and the Maryland Geological Survey (MGS).

ACKNOWLEDGMENTS

We would like to thank John Tully for compiling and preparing the Upper Freeport coal bed extent and mine area map. Debra Lane and Eric Morrissey provided much needed help with the graphics. We thank Elizabeth Scroggs for compiling past resource estimates and Leroy Bryant for digitizing maps. Nick Fedorko, Bascombe M. Blake, Jr., James Pancake, and Dawn Moore (West Virginia Geological and Economic Survey), and Viktoras Skema, Clifford Dodge, and James Shaulis (Pennsylvania Bureau of Topographic and Geologic Survey) contributed ideas, data, and expertise to this assessment and their help is greatly appreciated. We also thank David Glick (The Pennsylvania State University), Douglas Crowell (Ohio Division of Geological Survey), and William Grady (West Virginia Geological and Economic Survey) for geochemical data. In addition, we give special thanks to William Bragonier (East Fairfield Coal Co., North Lima, Ohio) for sharing his extensive knowledge of the geology of the Upper Freeport coal bed. Robert Hook (independent contractor) is especially thanked for sharing his extensive knowledge of the geology and mining history of the Upper Freeport coal bed; his help was invaluable. C. Blaine Cecil (USGS) and Paul Lyons (USGS, retired) are thanked for their early and thorough reviews of maps. C. Blaine Cecil and Brenda Pierce (USGS) also provided helpful reviews of this manuscript.

GEOLOGY

GEOLOGY OF THE ALLEGHENY GROUP

The Upper Freeport coal bed was described first from exposures along the Allegheny River near the town of Freeport, in Armstrong County, Pa. (Rogers, 1858). The top of the Upper Freeport coal bed is used throughout the northern Appalachian Plateaus as the stratigraphic contact between the Middle Pennsylvanian Allegheny Group and the overlying Upper Pennsylvanian Conemaugh Group (fig. 4). The contact is inferred where the coal bed is thin or absent. The coal-rich Allegheny Group, termed the Lower Productive Measures or Lower Coal Measures by early workers (Rogers, 1858), overlies the Pottsville Group, which is mostly Middle Pennsylvanian in age in western Pennsylvania (fig. 4).

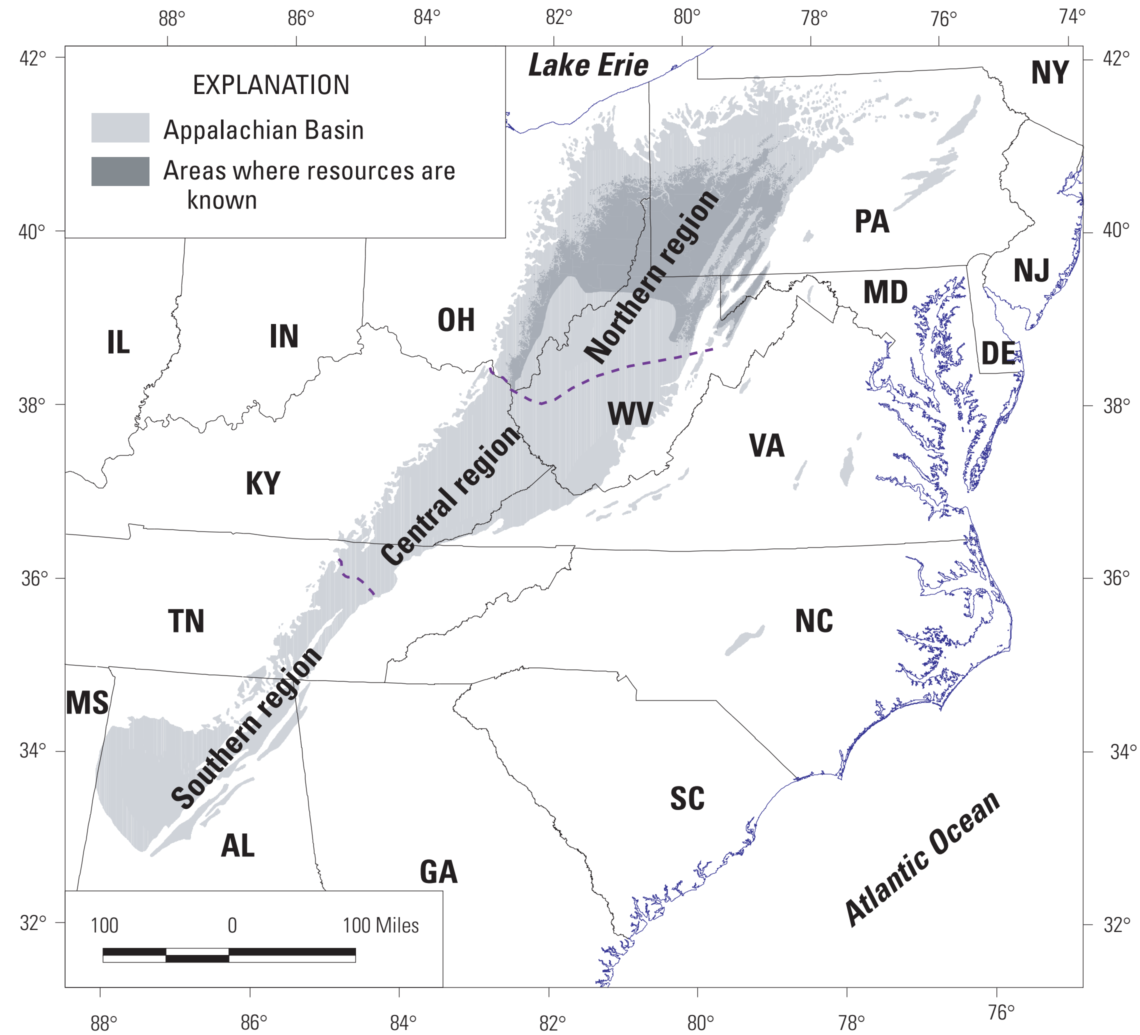


Figure 2. Map showing location of the northern, central, and southern coal regions in the Appalachian Basin. In 1998, over 50 coal beds from these two regions produced about 40 percent of the Nation's coal (Energy Information Administration, 1998).

In the study area, the Allegheny Group ranges from approximately 200 to 300 ft in thickness. The rocks are terrestrial to marine in origin and consist of claystone, siltstone, sandstone, conglomerate, coal, ironstone, and freshwater to marine limestone units. The units were deposited mainly by northeastwardly prograding depositional systems within a foreland basin adjacent to the Allegheny fold and thrust belt during Middle Pennsylvanian time (Ferm, 1970, 1974; Donaldson, 1974; Donaldson and Shumaker, 1981). Seven principal coal beds (which are, in ascending stratigraphic order, the Brookville, Clarion, Lower Kittanning, Middle Kittanning, Upper Kittanning, Lower Freeport and Upper Freeport coal beds and (or) their approximate stratigraphic equivalents (fig. 4)) are mined in the Allegheny Group in the study area of this report. The five latter coal beds tend to be regionally extensive. In contrast, none of the coal beds of the overlying Conemaugh Group are of regional economic significance. The paucity of economic coals led earlier workers to refer to the Conemaugh Group as the Lower Barren Measures (Rogers, 1858).

White (1925), and later Cecil and others (1985) and Cecil (1990), suggested that the absence of economic coal overlying the Allegheny Group may have been climatically controlled. Cecil (1990) postulated that thick and areally extensive peat deposition occurs in tropical climates where sediment and dissolved solid loads in rivers and streams are low. These conditions, which were prevalent in the Appalachian Basin in the Early Pennsylvanian and early Middle Pennsylvanian (fig. 5), resulted in abundant low-sulfur coal beds. The Upper Freeport coal bed, which con-

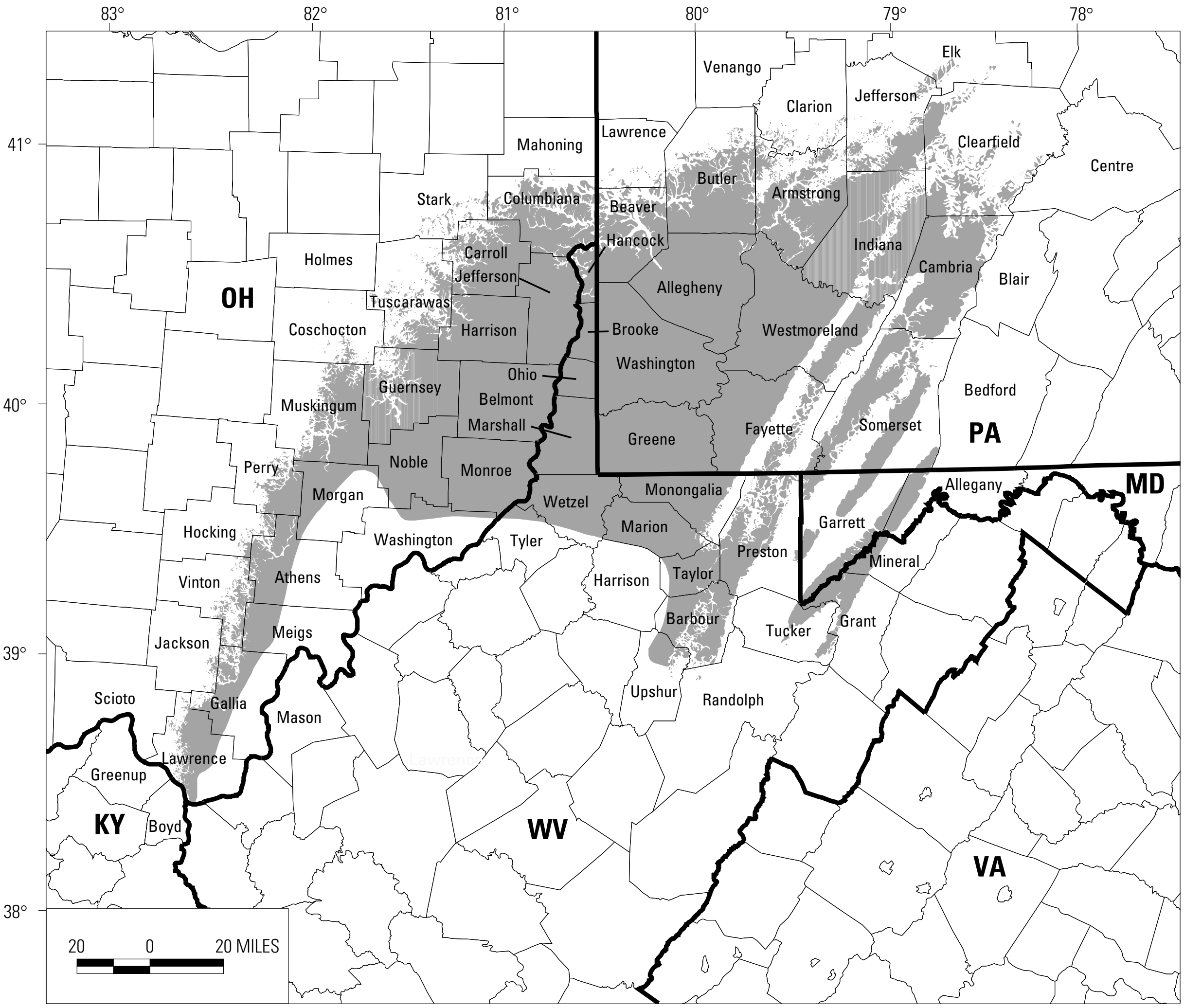


Figure 3. Map showing extent of the Upper Freeport coal bed (shaded). The Upper Freeport coal bed covers more than 14,000 mi^2 and parts or all of 55 counties in Pennsylvania, West Virginia, Ohio, and Maryland. The coal bed may extend southward into eastern Kentucky but correlations are highly uncertain and were not extrapolated south of the areas shown here.

tains moderate sulfur (mean value of 2.24±1.02 weight percent, as-received basis), formed during the transition to a drier but humid, more seasonal climate in the late Middle and Late Pennsylvanian. Coal formed in more seasonal climates tends to have statistically higher ash yield and sulfur content than coal that formed in more ever-wet tropical climates (Cecil and others, 1985).

GEOLOGY OF THE UPPER FREEPORT COAL BED

The Upper Freeport coal bed consists of multiple minable coal bodies that are distinctly pod shaped in cross section and are separated by broad areas where the coal is very thin or absent (fig. 6). Even within individual pods of thick coal there are areas of little or no coal where contemporaneous channels prevented peat accumulation or subsequent fluvial channels scoured or completely removed the peat. The Upper Freeport coal pods are irregular in outline and measure from 2 to 20 mi^2 in areal extent. In an unpublished dissertation based upon confidential industry data, Pedlow (1977) described thick coal in western Pennsylvania as peat islands; subsequent reports that utilized these data (Knapik, 1981; Ferm and Staub, 1984) disclosed that the coal was the Upper Freeport.

Thick deposits of Upper Freeport coal consist of multiple coal facies (fig. 7), or megascopically recognizable subunits or benches, that are separated generally by thin part-

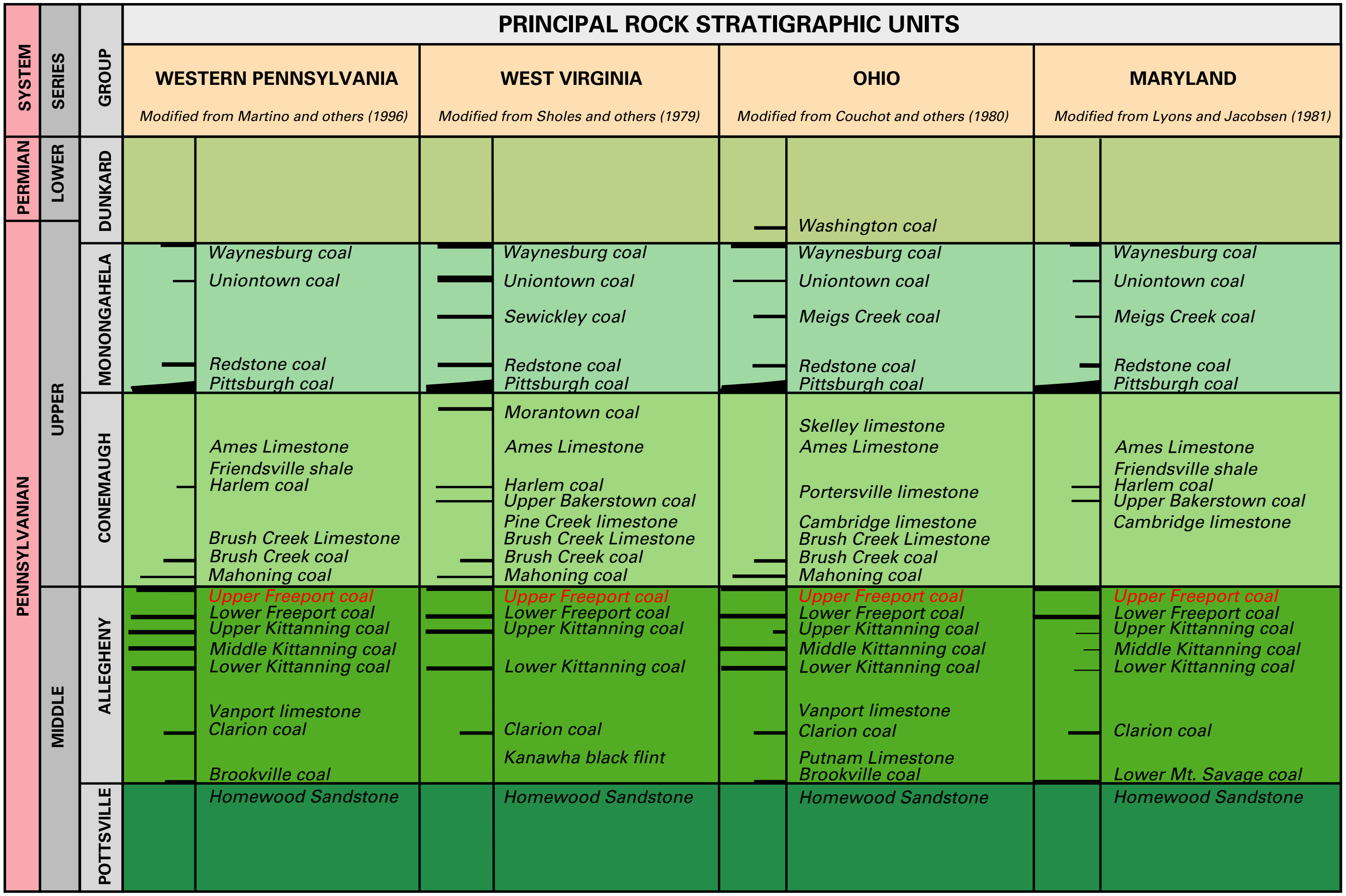


Figure 4. Stratigraphic chart showing the position of the Upper Freeport coal bed (highlighted in red). Coal beds are shown by thick, black lines. The Upper Freeport coal bed is stratigraphically at the boundary between the Middle Pennsylvanian Allegheny and Upper Pennsylvanian Conemaugh Groups throughout most of the Appalachian foreland basin in Pennsylvania, West Virginia, Ohio, and Maryland. The top of the Allegheny Group is defined as the top of the Upper Freeport coal bed in all four States, and as a result, the coal has been projected as the group boundary in many areas where it is thin or even absent. (All names are informal unless the rank term's first letter is capitalized. Rank terms (such as Group, Formation, or Member) were chosen to ensure uniformity in entering data into the stratigraphic database. Uses of these terms do not constitute formal changes in the status of a stratigraphic unit name.)

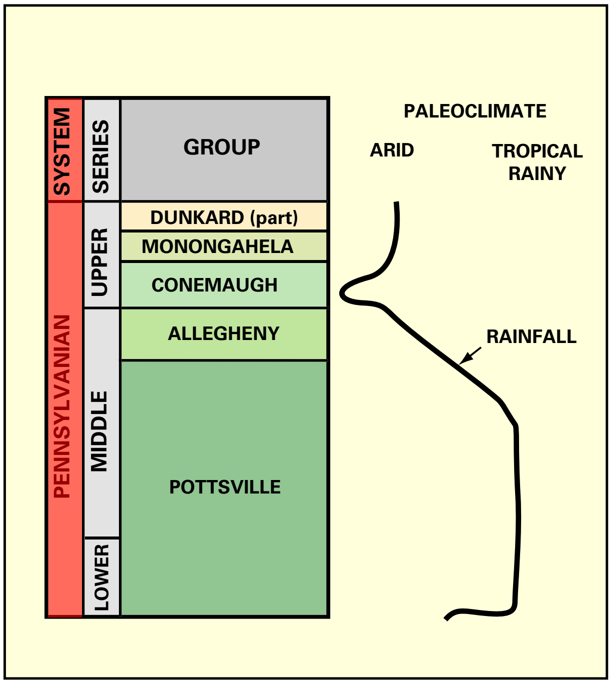


Figure 5. Chart showing paleoclimatic conditions during the Pennsylvanian. Paleoclimatic conditions are thought to control the distribution of thick and laterally extensive minable coals in the Appalachian Basin coal regions. Based on the distribution of siliciclastic and chemical rocks, Cecil and others (1985) and Cecil (1990) have suggested that climatic conditions in the Early and lower Middle Pennsylvanian changed from ever-wet to seasonally wet and drier in the upper Middle Pennsylvanian. The Upper Freeport coal bed was deposited in the transitional, but drier, upper Middle Pennsylvanian (modified from Cecil, 1990).

ings of carbonaceous claystone. The upper parting (fig. 7) is regionally persistent in the northern Appalachian Basin coal region and is thought to represent an extensive flooding event. Peat accumulation continued in some areas where there was protection from active sedimentation. This allowed thick, minable pods of coal to form, which are now recognized as the upper coal facies. The coal generally becomes dull in luster upwards and, where not scoured by clastic deposits, is overlain by several inches of bone coal.

Nearly all thick deposits of Upper Freeport coal are overlain closely or directly by sandstone deposits (fig. 8), a factor that hinders both underground and surface mining. Channels within these sandstone deposits may scour downward and remove part or all of the coal bed. These features are known by many mining terms (faults, roof rolls, washouts, cutouts). Because these features can be of very limited extent, they often cannot be detected or defined by exploration drilling. In underground mines, the roof may become incompetent when mudstones between the top of the coal and the base of the overlying sandstone have undergone compactional stress. Additional roof-control problems may occur in areas where channel deposits are present close to the top of the coal. Basal channel conglomerate, channel-bank slumps, and channel-fill mudstone are among the channel-related deposits that are difficult, if not impossible, to support.

Variation in Upper Freeport coal quality corresponds to coal-bed geometry (Pedlow, 1977; Cecil and others, 1981). Both sulfur content and ash yields are elevated in the bottom and top parts of the seam and increase abruptly throughout the seam toward the margins of the peat islands. Within the Upper Freeport pods, coal quality also diminishes sharply in areas adjacent to coal-seam discontinuities that are related to contemporaneous or subsequent channels (Kertis, 1984; Ruppert and others, 1991).

The distribution of thick Upper Freeport coal deposits may have been influenced by deep-seated structures that influenced topography during the Middle Pennsylvanian (Root and Hoskins, 1977; also see Chapter B, this report). Similar tectonic features and their relation to coal occurrences and coal quality have been documented in the central and southern Appalachian Basin coal regions (Weisenfluh and Ferm, 1984; Staub, 1985; Ferm and Weisenfluh, 1989; Staub and others, 1991). In the northern Appalachian Basin coal region, structural influence is most evident in Ohio, where several major transcurrent features coincide with lithofacies changes in the Upper Freeport coal bed interval and other parts of the Allegheny and Conemaugh Groups (Root, 1992, 1996). Subsequent folding in Pennsylvania, West Virginia, and Maryland may mute the expression of similar structural patterns in these regions.

Several modern analogues have been offered as models for the development of the Upper Freeport coal bed (Pedlow, 1977; Clark, 1979; Hohos, 1979; Cecil and others, 1981; Kertis, 1984) but thus far, no single analogue has provided the combination of tectonic, climatic, and depositional regimes that adequately characterize the upper Allegheny Group of the northern Appalachian Basin coal region.

MINING HISTORY

The Upper Freeport coal bed was first mined commercially in the northern Appalachian Plateaus during the middle 19th century in scattered small underground mines for local use. By the turn of the century, the Upper Freeport coal bed was mined at numerous locations in drift, slope, or shaft mines, mostly to serve the burgeoning coke and steel industry. Company towns (fig. 9) spread quickly and attracted skilled British miners and, later, immigrants from other European nations. In the late 19th and early 20th century, most of the towns were located on rail lines. In Ohio, comparatively little Upper Freeport coal was used in coke manufacturing because of impurities; rather, it was used mainly

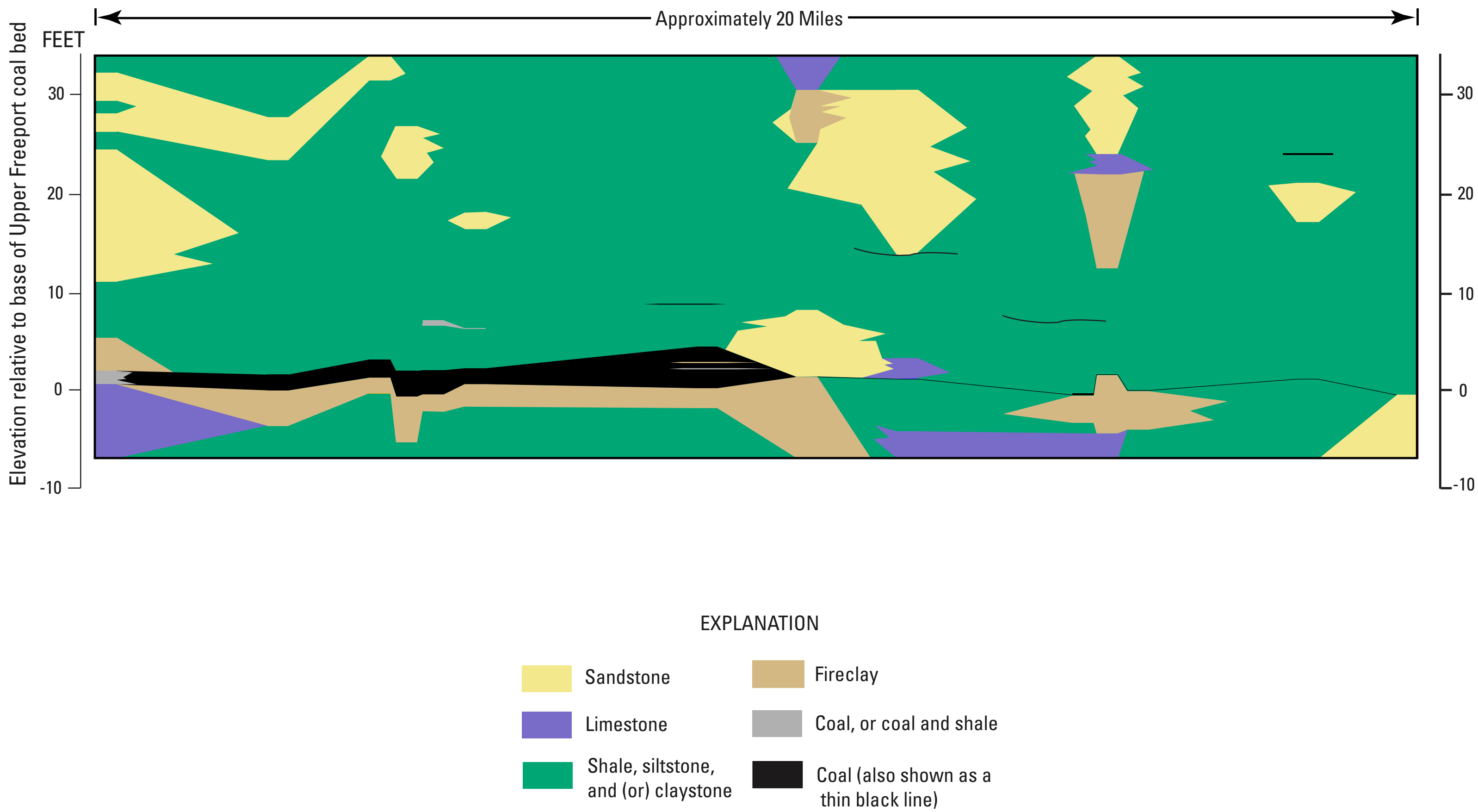


Figure 6. Generalized cross section of the Upper Freeport coal bed in Pennsylvania. Throughout the areal extent of the Upper Freeport coal bed, minable blocks, which tend to be podlike in shape, are often separated by areas where the coal was never deposited or was removed by erosion from channels or compaction from overlying sediment. Vertical exaggeration X828.

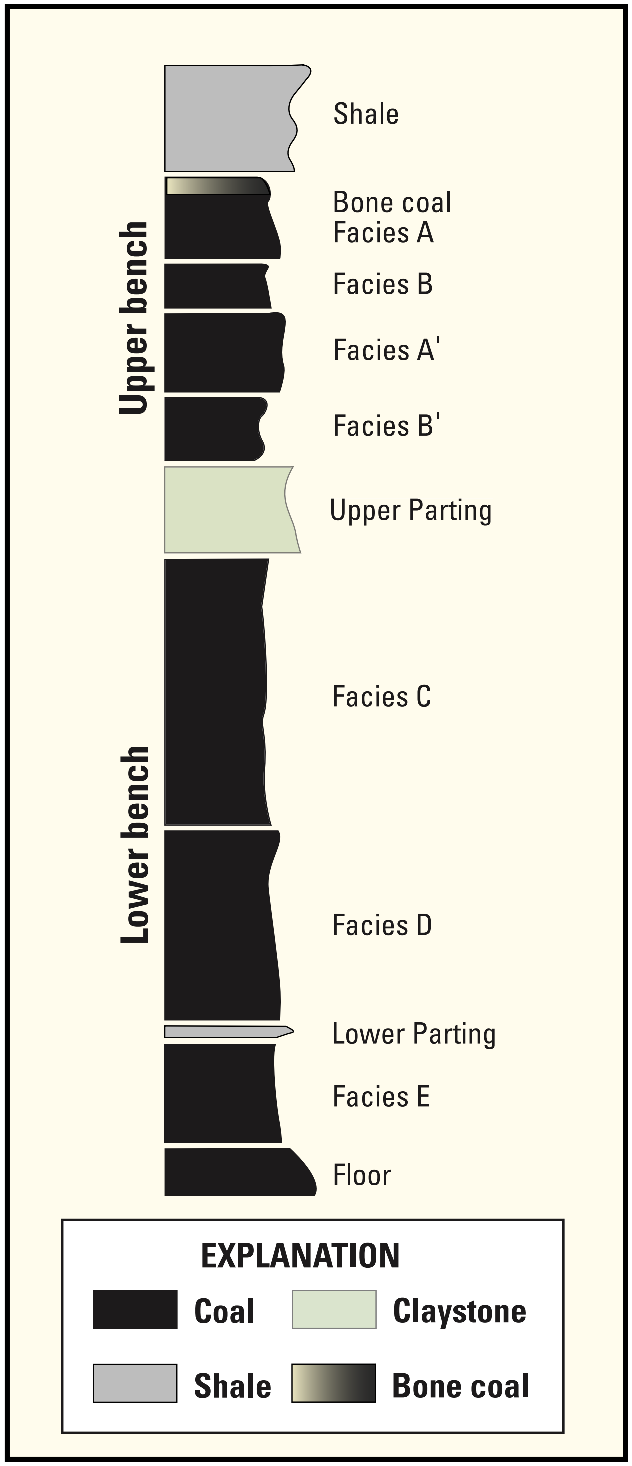


Figure 7. Stratigraphic column showing coal-bed facies. These megascopically recognizable subunits within the coal reflect changing environmental conditions within the Upper Freeport paleoswamp. The Upper Freeport coal formed on a rooted and weathered soil and was initially fed by ground water (lower bench). Drowning of the peat swamp, as indicated by the persistent parting at the top of the lower bench, ended peat deposition except in areas protected from siliciclastic input. Where peat deposition resumed, additional facies of thick coal formed the top bench of coal.

Figure 8. Photograph of the Upper Freeport coal bed in Pennsylvania. Person is pointing to the upper contact of the coal bed. Note the overlying sandstone. (Photograph courtesy of James Shaulis, Pennsylvania Bureau of Topographic and Geologic Survey.)

Figure 9. Photograph showing a company town. Increased demand for coal, beginning in the early 20th century, attracted skilled workers to mine coal. Company towns, such as the one pictured here in Hocking Valley, Ohio, grew up throughout the Appalachian Basin coal fields. (Photograph courtesy of Douglas Crowell, Ohio Division of Geological Survey, 1995; reprinted with permission from the Ohio Historical Society.)

as a fuel by the railroads and the ceramic industry. The early 1900's saw the rise of several major coal companies that bought or otherwise consolidated vast numbers of small operators in the northern Appalachian Basin coal region. These large companies fostered increased mechanization of underground mining (fig. 10), a trend that started in the 1920's and that continues to this day. Mechanization increased production, required a smaller labor force, and resulted in lower costs.

Today's active underground mines in the Upper Freeport coal bed produce approximately 10.5 million short tons of coal annually (Energy Information Administration, 1999) with fewer workers than in the past. The Mettiki mine in Garrett County, Md., mines about 2.7 million short tons of coal annually and over 11,000 short tons daily (Keystone, Coal Industry Manual, 1998) with longwall mining methods. However, most of the underground mines are room-and-pillar and utilize both conventional and continuous mining techniques (fig. 11).

In general, Upper Freeport coal production decreased in the latter part of the 20th century (fig. 12; Appendix 2). In 1997, about one quarter (4.2 million short tons) of Upper Freeport coal was produced from surface mines (Energy Information Administration, 1998). In the last 20 years, the number of surface mines has decreased because of costs related to heightened environmental regulations, greater overburden-to-coal ratios impacting profitability, and market changes. With the exception of 1994 and 1995, Upper Freeport coal production is decreasing overall in Pennsylvania (Appendix 3), remaining somewhat steady in West Virginia (Appendix 4), and increasing slightly in Ohio (Appendix 5) and Maryland (Appendix 6). Upper Freeport production data, by top-producing counties in each State, are shown in figures 13 to 16.

COALBED METHANE

There are two coalbed methane (CBM) plays in the northern Appalachian Basin coal region: the Northern Appalachian Syncline Play and the Northern Appalachian Anticline Play (fig. 17; also see Chapter B, this report). Although the Upper Freeport extends into both plays, only a few wells in Indiana and Greene Counties, Pa., produce limited quantities of CBM. Because the few exploratory wells that have been drilled in the deeper parts of the Appalachian Basin did not identify thick

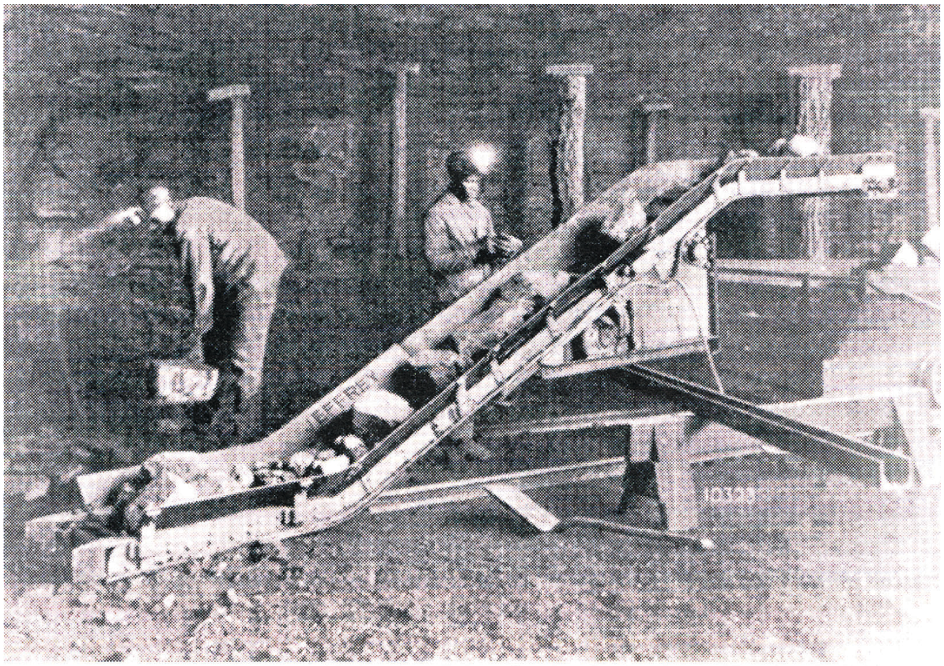


Figure 10. Photograph showing coal miners loading coal by hand onto a conveyor in 1918. In the 19th century, most of the mining was done by hand. Mechanization increased rapidly throughout the early 20th century and led to increased coal production. (Photograph courtesy of Douglas Crowell, Ohio Division of Geological Survey, 1995; originally from The Coal Trade Bulletin, 1918, v. 39, no. 11, p. 47.)

Figure 11. Photograph showing a continuous mining machine in an Upper Freeport coal bed mine, Homer City region, Indiana County, Pa. Continuous miners were introduced in the late 1940's and are currently used to produce over 50 percent of the underground coal tonnage mined in the Appalachian Basin (Reid and Richardson, 1995). (Photograph courtesy of Ronald Stanton, USGS.)

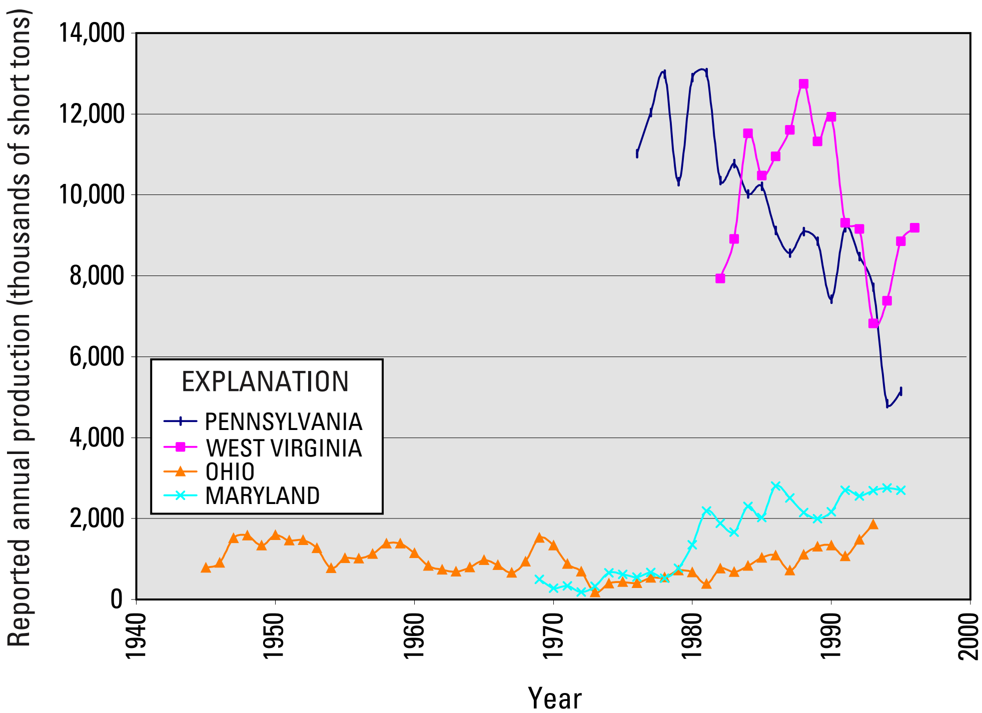


Figure 12. Graph showing recent reported annual production (in thousands of short tons) from the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland, assembled from State agencies. In general, Upper Freeport coal-bed production is declining. Sources: Ohio Division of Labor Statistics (1945–1946, 1947–1965, 1966–1981, 1982–1993), Maryland Bureau of Mines (1969–1995), Commonwealth of Pennsylvania (1975–1995), Gayle H. McColloch (West Virginia Geological and Economic Survey, unpublished search of West Virginia Office of Miner's Health, Safety, and Training—Safety Information System (MHST-SIS) database, 1997).

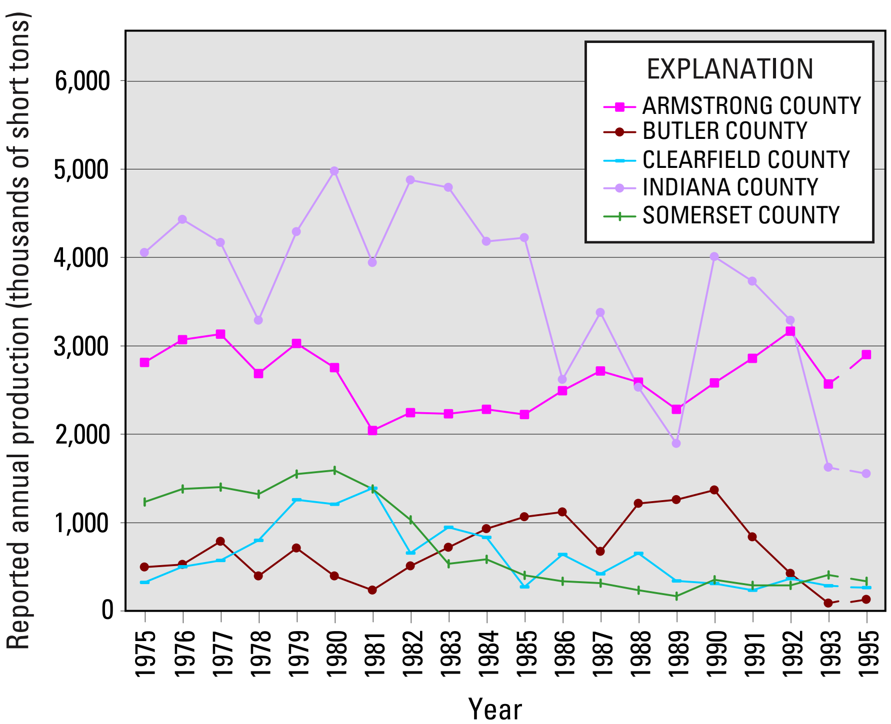


Figure 13. Graph showing recent reported annual production (in thousands of short tons) from the Upper Freeport coal bed in the five top-producing counties in Pennsylvania from 1975 to 1995. No data for 1994. Source: Commonwealth of Pennsylvania (1975–1995).

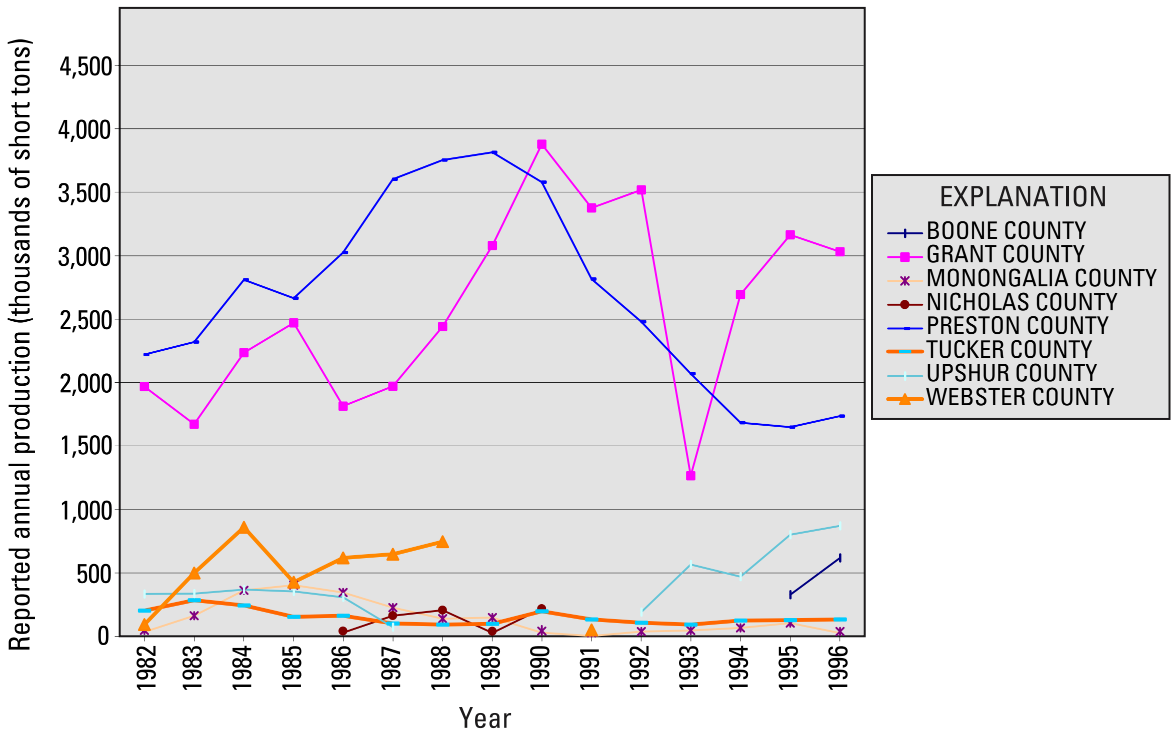


Figure 14. Graph showing recent reported annual production (in thousands of short tons) from the Upper Freeport coal bed in the eight top-producing counties in West Virginia from 1982 to 1996. Source: Gayle H. McColloch (West Virginia Geological and Economic Survey, unpublished search of West Virginia Office of Miner's Health, Safety, and Training—Safety Information System (MHST-SIS) database, 1997).

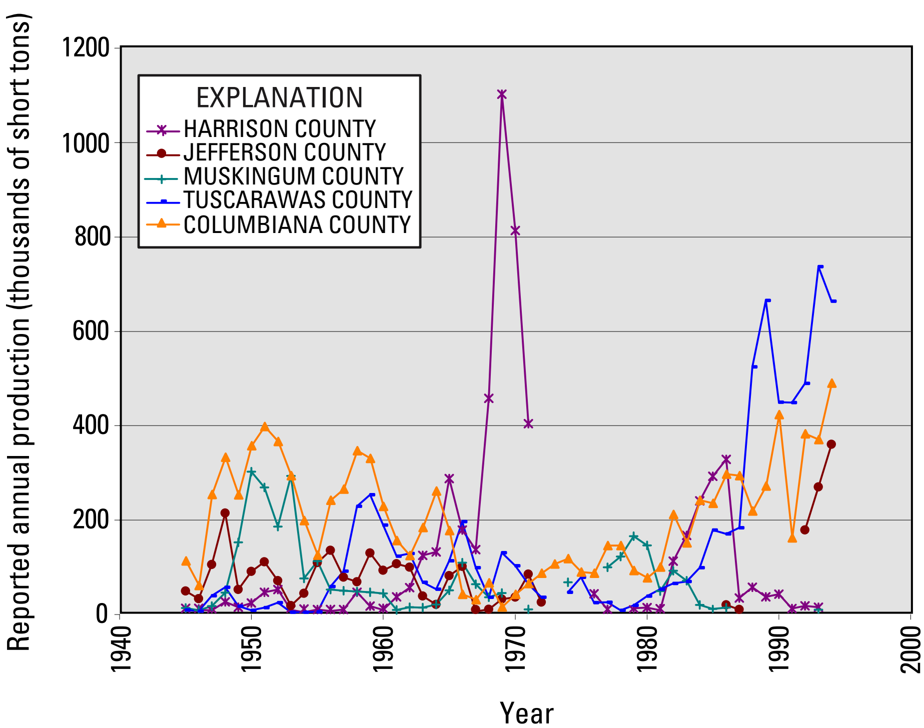


Figure 15. Graph showing recent reported annual production (in thousands of short tons) from the Upper Freeport coal bed in the five top-producing counties in Ohio from 1945 to 1994. Tuscarawas and Columbiana Counties have been the top producers throughout the 1990's. Sources: Ohio Division of Labor Statistics (1945–1946, 1947–1965, 1966–1981, 1982–1994).

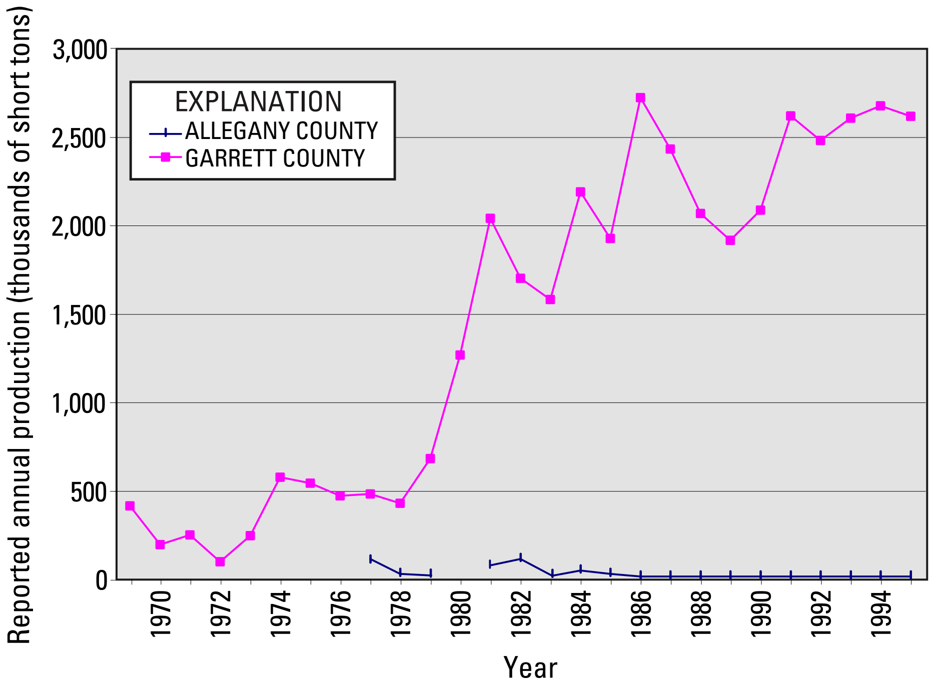


Figure 16. Graph showing recent reported annual production (in thousands of short tons) from the Upper Freeport coal bed in Maryland, by county, from 1969 to 1995. The Mittiki longwall underground mine, Garrett County, opened in 1985 and is now almost solely responsible for Upper Freeport coal production in the State. Source: Maryland Bureau of Mines (1969–1995).

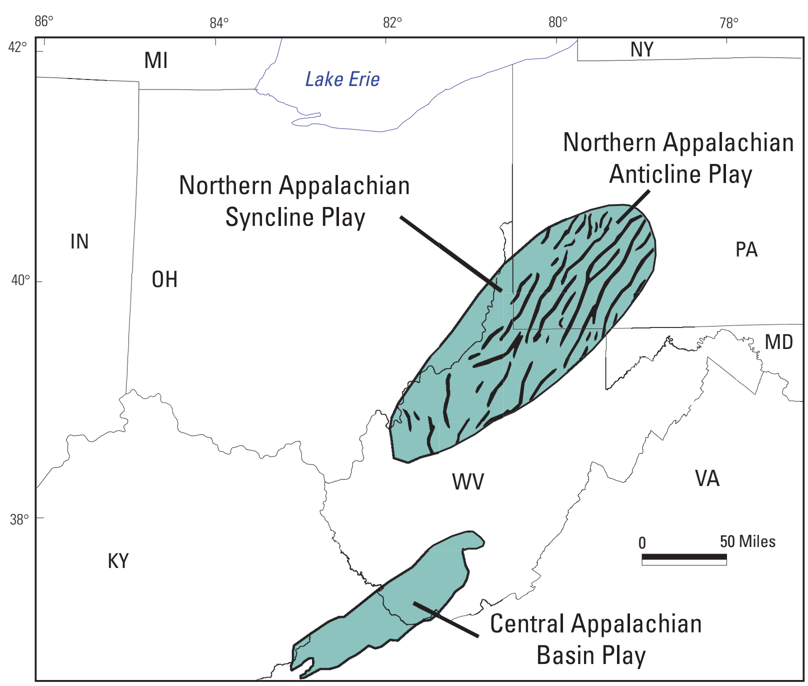


Figure 17. Map of part of the Appalachian Basin coal region showing location of coalbed methane plays. The Upper Freeport coal bed extends over two coalbed methane plays in the northern Appalachian Basin coal region, the Northern Appalachian Anticline Play (black lines) and the Northern Appalachian Syncline Play (dark blue). Wells in Indiana and Greene Counties, Pa., have produced limited quantities of coal-bed methane. Modified from Rice (1995).

Upper Freeport coal deposits, the potential for further production is minimal.

ASSESSMENT METHODOLOGY

DATABASES

Two databases, a stratigraphic database and a geochemical database, were the primary tools used to assess the Upper Freeport coal bed. The stratigraphic database, which was used to construct cross sections and structure-contour and isopach maps, contains approximately 12,400 drill-hole, mine, and outcrop descriptions; 1,421 of these records contain coal elevation data only. Approximately two-thirds of the records in the stratigraphic database (fig. 18) are publicly available and can be downloaded in ASCII format from Appendix 7.

The Upper Freeport coal bed geochemical database consists of data for 3,781 analyses (Appendix 8) from in-ground, mine, run-of-mine, tipple, and delivered samples, reported on an as-received whole-coal basis. The database was derived from a variety of sources including the USGS, the U.S. Bureau of Mines, The Pennsylvania State University, other Federal and State agencies (see Appendix 10), and company confidential data. About three-fourths of the 3,781 analyses in the geochemical database are located by latitude and longitude coordinates; about one-sixth of the analyses are publicly available and are shown in figure 19. Locations of the others are considered to be reliable and accurate to at least a county scale. Two-hundred and fifty-nine records contain analyses of as many as 86 different trace elements; the remaining records contain analyses of ash yield, sulfur content, and gross calorific value (Btu/lb). Because many of the Upper Freeport coal bed samples were collected as subsamples from discrete benches or facies, they were aggregated to obtain representative analyses of the entire coal bed chemistry at any one location for the purposes of this study. Additional information on data source, handling, averaging, and formatting is given in Appendix 9. The public geochemical records, metadata, and references shown in Appendixes 8, 9, and 10 can be downloaded in ASCII format.

GEOGRAPHIC INFORMATION SYSTEM (GIS)

The map that shows the areal extent and mined areas of the Upper Freeport coal bed (fig. 20) was completed by collecting and digitally converting, transforming, and combining data from 191 geologic and coal-outcrop paper maps that ranged in scale from 1:24,000 to 1:500,000 (Appendix 11). One-hundred 1:24,000-scale maps were digitized and joined to provide continuous coverage of the Upper Freeport coal bed in Ohio. Seventy-nine 1:24,000-scale maps likewise were compiled for West Virginia. Maps of varying scales from ten county reports were digitized to cover most of the Upper Freeport outcrop in Pennsylvania; for Beaver, Clearfield, Elk, and Lawrence Counties, the Allegheny-Conemaugh contact was digitized from the 1:500,000-scale geologic map of Pennsylvania (Berg and others, 1980). Finally, USGS working maps at 1:24,000 scale and a 1:100,000-scale map of Garrett and Allegany Counties, Md., were digitized to complete the areal extent of the Upper Freeport coal bed. Map references are included in Appendix 11 and are arranged by State, scale, and author.

In the central part of the basin where subsurface data are limited, a thickness boundary of 14 inches (1.17 ft) was generated from the stratigraphic database to truncate the assessment area. The southern boundaries of Lawrence County, Ohio, and Upshur County, W. Va., were used to terminate the extent of the Upper Freeport coal bed for this assessment because correlations are highly tentative south of these counties. The resulting areal extent map (fig. 20) was used to delimit subsequent structure-contour, overburden-thickness, and isopach GIS coverages.

The completeness and accuracy of mined areas shown for the Upper Freeport coal bed (fig. 20) varies based upon whether and when mine data were compiled (Appendix 11). For Ohio, the extent of underground mines was derived from a series of 1:24,000-scale maps that have been compiled by the Ohio Division of Geological Survey; the extent of surface mining was estimated from disturbed areas shown on 1:24,000-scale topographic maps and from Ohio Division of Mines and Reclamation permit maps. Where available, county reports by the Pennsylvania Bureau of Topographic and Geologic Survey were used to define surface and underground mining areas in most of western Pennsylvania. The West Virginia Geological and Economic Survey plotted maps of mines in West Virginia on 1:24,000-scale open-file maps through the middle 1980's. These maps were digitized and included in the mined-area coverage. In all three states, the compilation of mine maps is incomplete and the currentness of the mine maps is dependent on the date of the mine source and the availablility of mine maps (Appendix 11).

Mine map compilation is not complete for Garrett County, Md., and mine maps were not compiled for Allegany County, Md., and Beaver, Clearfield, Elk, and Lawrence Counties, Pa. (fig. 3). Additional work by the State geological surveys and the USGS will correct this omission in the future.

Structure contours on the top of the Upper Freeport coal bed (fig. 21) were generated by contouring a grid created from elevations taken from the stratigraphic database and

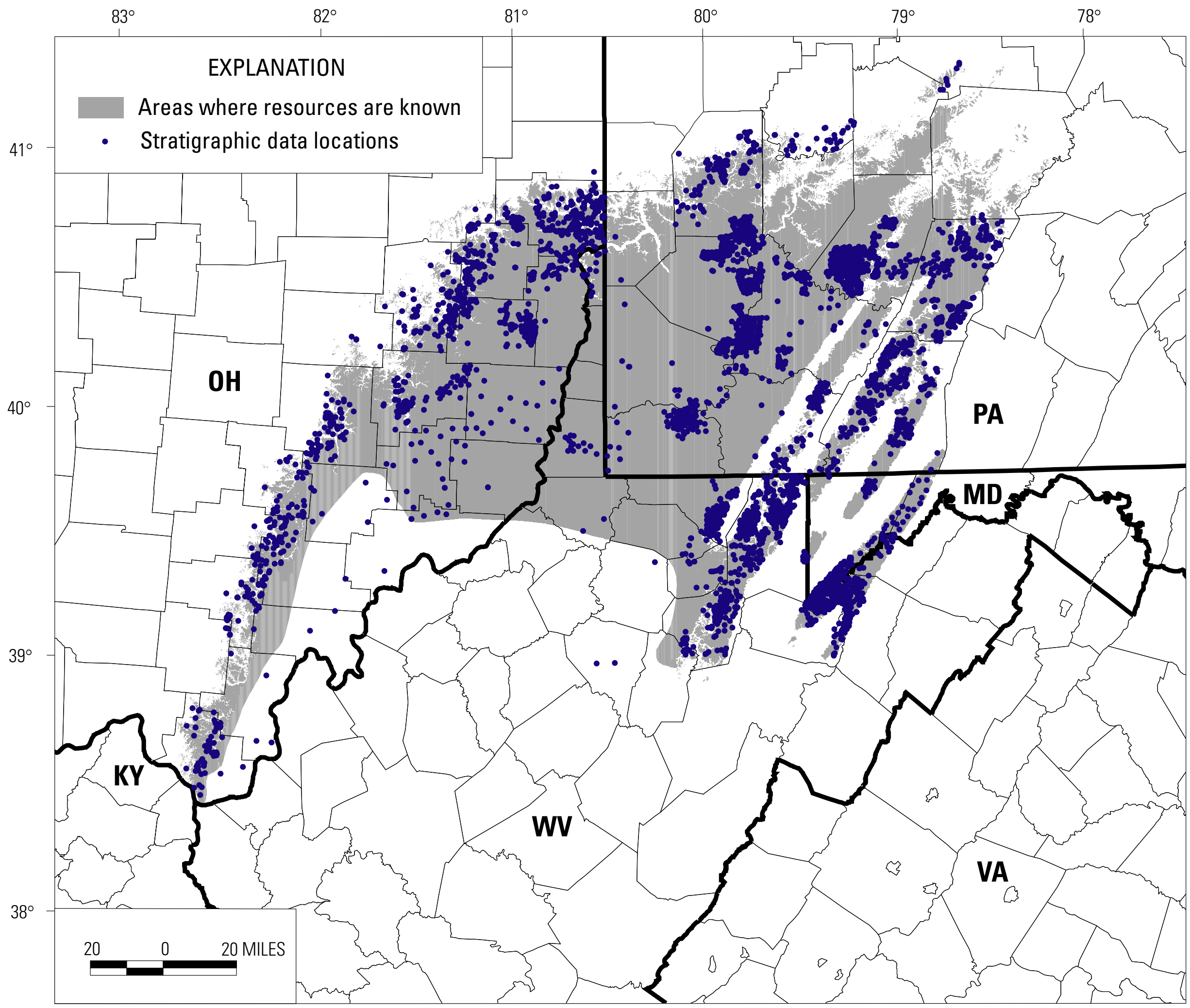


Figure 18. Map showing point locations of stratigraphic records that are publicly available and were used to model the coal resources of the Upper Freeport coal bed. Point identifier or record name, latitude, longitude, coal elevation, and coal thickness for all records can be downloaded from Appendix 7 in ASCII format. See figure 3 for county names.

digitized lines from published structure-contour maps of the Upper Freeport coal bed. In Greene County, Pa., where few control points exist, approximate elevations were derived by subtracting the total thickness of the Conemaugh Group (approximately 400 ft) from the top of the Pittsburgh coal bed (see Chapter C, this report). Lower Freeport and Lower Kittanning structure-contour maps in Armstrong, Cambria, Clarion, Elk, Indiana, Jefferson, and Westmoreland Counties, Pa., were projected (elevations raised) to the Upper Freeport horizon and used as input. Although the structure contours were generated at 100-ft intervals, only-200 ft contours are shown for the sake of clarity. Approximately 12,000 elevations were used to generate the map. Elevations for the Upper Freeport coal bed range from 500 ft below sea level in Greene County, Pa., and Wetzel, Monongalia, and Marion Counties, W. Va., to 3,900 ft above sea level in Tucker County, W. Va. (fig. 3).

Overburden thickness (fig. 22) was calculated by subtracting the structure-contour grid on the top of the Upper Freeport coal bed from a topographic grid made from 1:250,000- and 1:100,000-scale digital elevation models. The contour intervals used for overburden thickness were 0 to 200 ft, >200 to 500 ft, >500 to 1,000 ft, and >1,000 to 2,000 ft and are based upon criteria from Wood and others (1983). Although the deepest category is classified as up to 2,000 to 3,000 ft, the greatest overburden thickness is approximately 2,000 ft in Wetzel County, W. Va.

Thickness contours, or isopach lines, of the Upper Freeport coal bed were generated from 11,950 stratigraphic records (fig. 23). Thickness values for the Upper Freeport

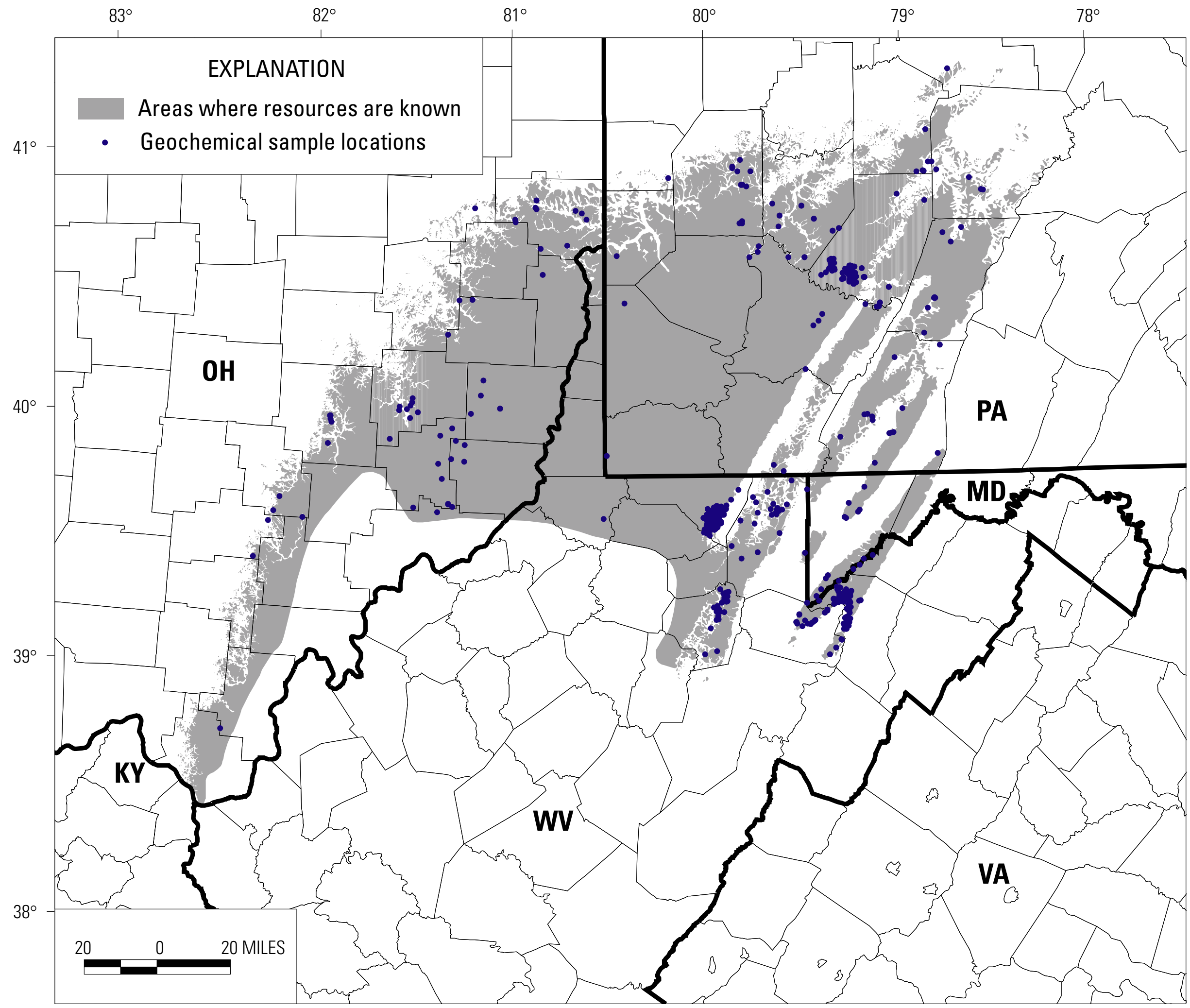


Figure 19. Map showing point locations of geochemical samples of the Upper Freeport coal bed for which records are publicly available and located by latitude and longitude. All of the geochemical data can be downloaded in ASCII format from Appendix 8. Appendix 9 contains geochemical metadata, and Appendix 10 contains references for the geochemical data and analyses. See figure 3 for county names.

were exported as an ASCII x,y,z file from the stratigraphic database. Identified partings and bone coal greater than 0.38 inches in thickness were excluded based upon the criteria of Wood and others (1983) and are not included in the summation of coal thickness. Thickness values were gridded and contoured into 14-inch, or 1.17-ft, intervals (fig. 23).

RESOURCE MODELING AND METHODOLOGY

Original and remaining resources were calculated for the Upper Freeport coal bed from the thickness and overburden coverages described above. USGS reliability category coverages of identified resources (calculated for areas within 3 mi of a coal-thickness measurement point) and hypothetical resources (calculated for areas farther than 3 mi from a coal-thickness measurement) (Wood and others, 1983) were generated in order to assess areas around all available coal-thickness points and then were combined in a single coverage for resource calculations.

In order to retain all criteria required for resource calculations (Wood and others, 1983), contour-line coverages for coal-bed and overburden thicknesses were combined with coverages of mined areas, reliability, and county lines (USGS, 1:100,000 digital line graphs). Resources were calculated by multiplying the area of each polygon by the average coal thickness within the polygon and a tonnage factor for bituminous coal of 0.445 short tons/ft-m^2 (the weight of bituminous coal per unit volume). The resulting calculations

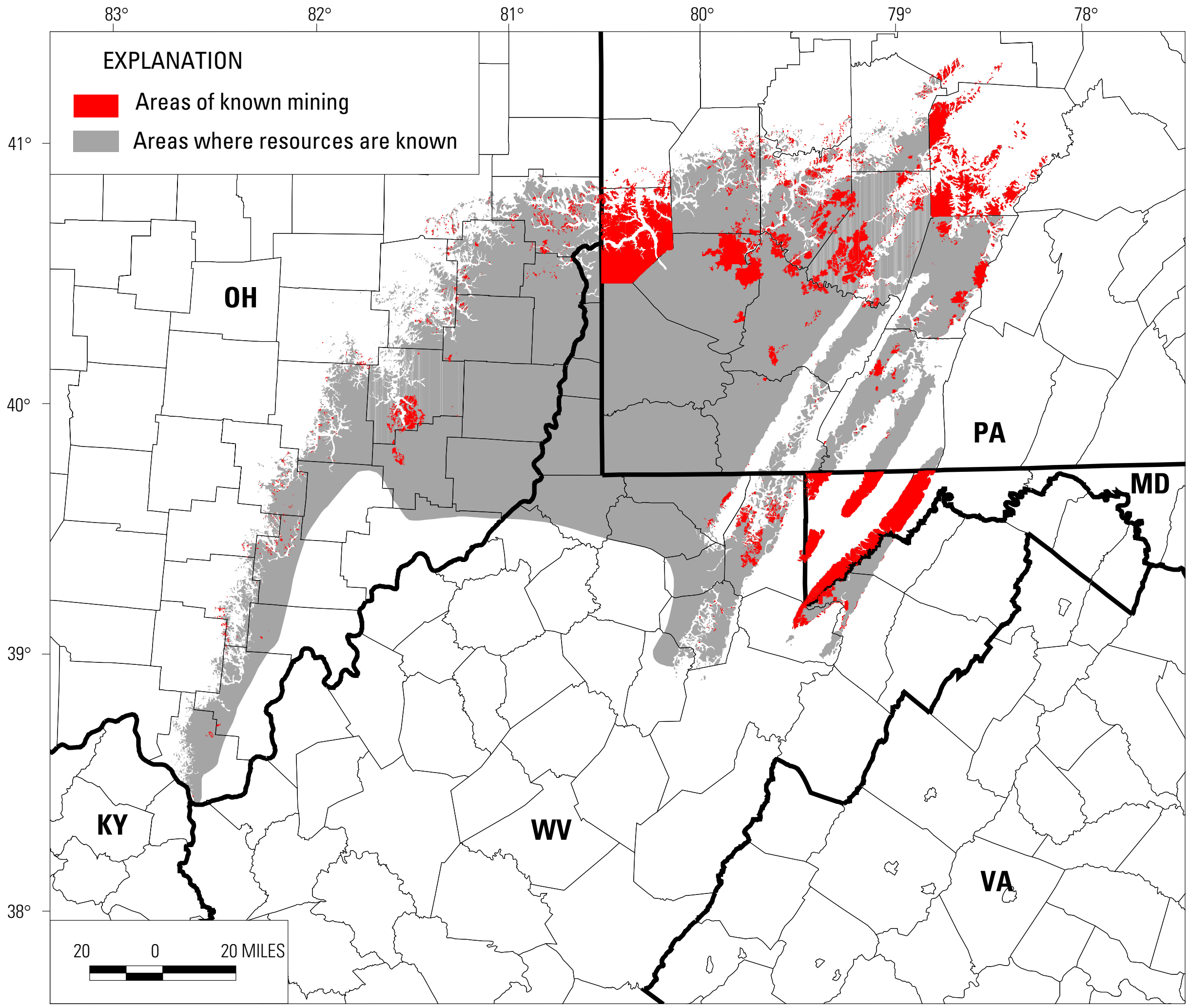


Figure 20. Map showing areal extent of the Upper Freeport coal bed where resources are known (dark gray) and mined areas (red). The coal bed cannot be confidently mapped south of Upshur County, W. Va., and Lawrence County, Ohio. In the central part of the basin where data are sparse, a line representing coal thickness of 14 inches (1.17 ft) was generated from the stratigraphic database to truncate the assessment area. Currentness of mined areas is dependent on the date of the mine source and the availability of mine maps (Appendix 11). Mine map compilation is not complete for Garrett County, Md., and mine maps were not compiled for Allegany County, Md., and Beaver, Clearfield, Elk, and Lawrence Counties, Pa. See figure 3 for county names.

were exported to a spreadsheet for the summation of original and remaining resources for each county by reliability, coal-thickness, and overburden-thickness categories.

The total original and remaining resources are shown by county in table 1. Appendixes 12 and 13 contain resources for overburden, reliability, and coal-bed thickness categories, by county. In table 1, the remaining resources in Allegany and Garrett Counties, Md., and in Beaver, Clearfield, Elk, and Lawrence Counties, Pa., are shown in bold type and preceded by a "<" because mine map compilation is incomplete or missing. Therefore, the grand total remaining resource, calculated at 31 billion short tons, is also shown in bold type and preceded by a "<" sign. In some counties, the hypothetical resources (Wood and others, 1983) are >60 percent of the total county resource; these county names and totals are shown in bold and italicized type.

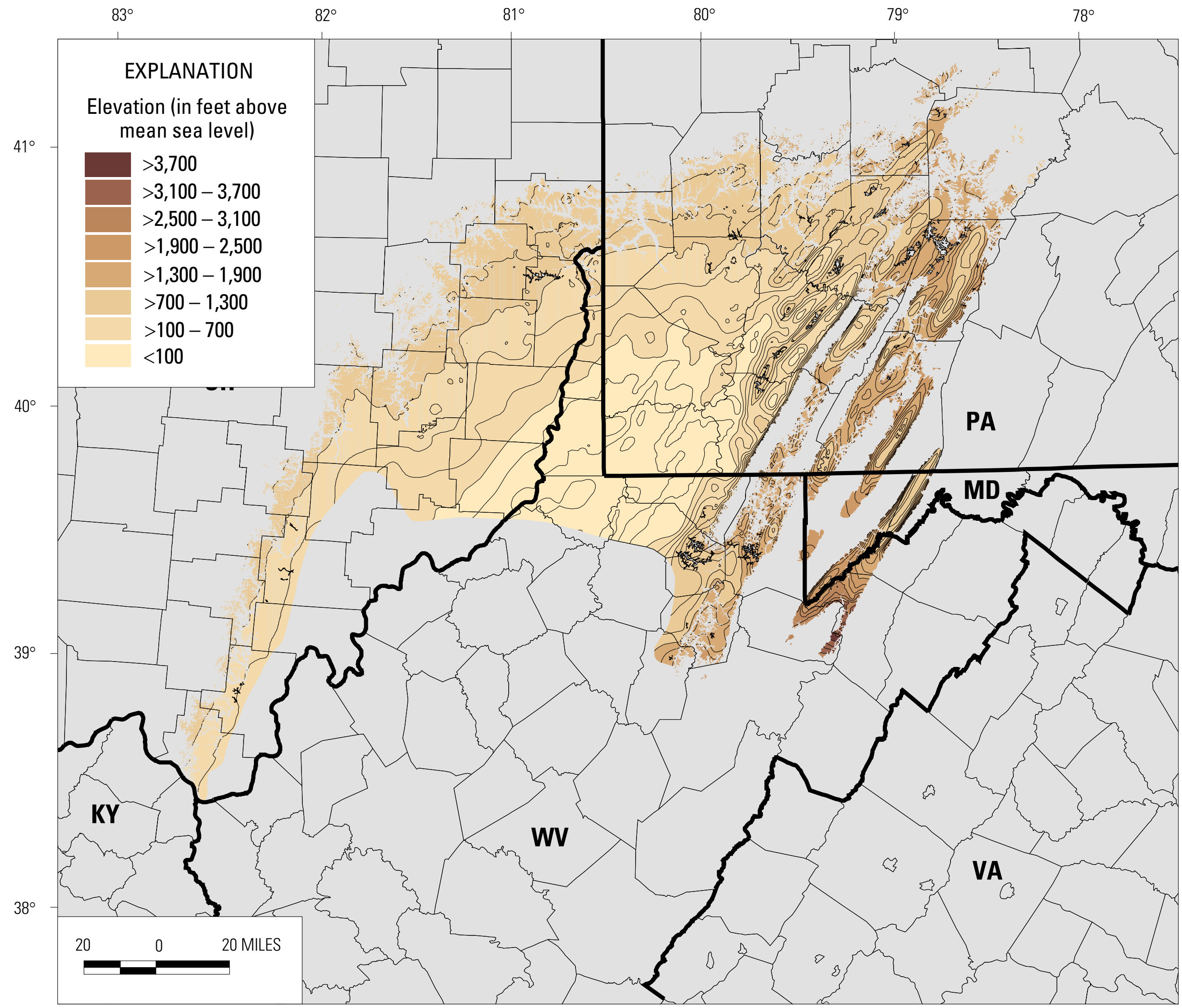
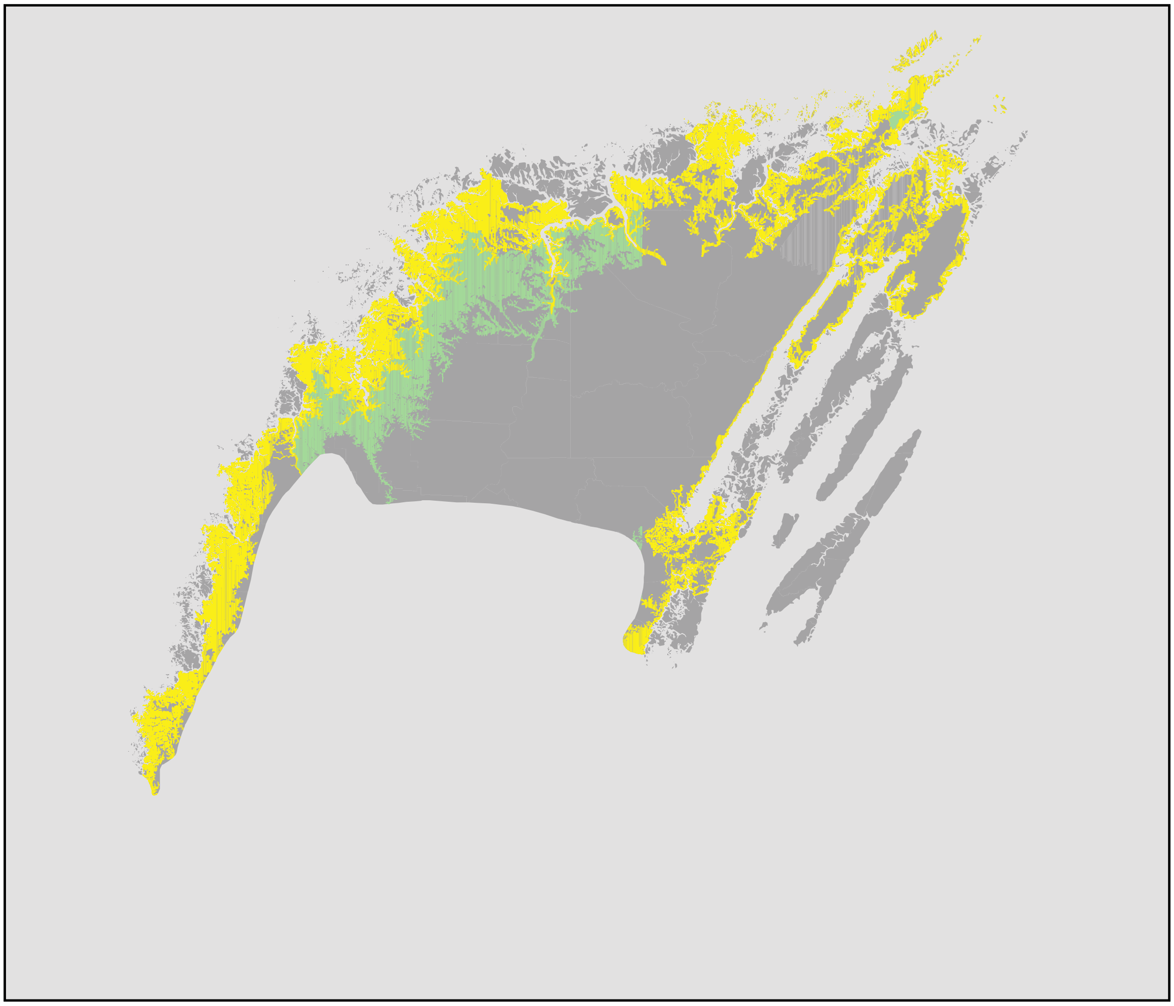


Figure 21. Structure-contour map of the Upper Freeport coal bed. The contours are presented on the top of the coal bed at 200-ft intervals; however, for visual acuity, most contours were colored in 600-ft intervals. Approximately 12,000 elevation measurements were used to generate the map. See figure 3 for county names.

PREVIOUS RESOURCE STUDIES

The State geological surveys have published resource estimates for the Upper Freeport coal bed dating back to the beginning of the 20th century. Some of the coal identified and assessed as Upper Freeport coal in the past has been recorrelated in this study, resulting in improved and refined resource estimates. Estimates of resources from this study, with one exception, compare well with past studies in areas where the assessments overlap.

In Pennsylvania, Reese and Sisler (1928) estimated original resources to be about 16 billion short tons, whereas the USGS estimate totals 15.7 billion short tons, a difference of less than 2 percent. The West Virginia Geological and Economic Survey, in a series of county reports (Grimsley, 1907; Hennen and White, 1909, 1912; Hennen and others, 1913; Krebs and Teets, 1913; Hennen and Reger, 1914; Reger and White, 1916; Hennen and Gawthrop, 1917; Reger and Teets, 1918; Reger and others, 1923; Reger and Tucker, 1924) identified total Upper Freeport resources in 16 counties to be about 3.7 billion short tons. In the 12 counties that were also studied in this USGS resource assessment, the USGS estimate is within 0.1 billion short tons. The Ohio Division of Geological



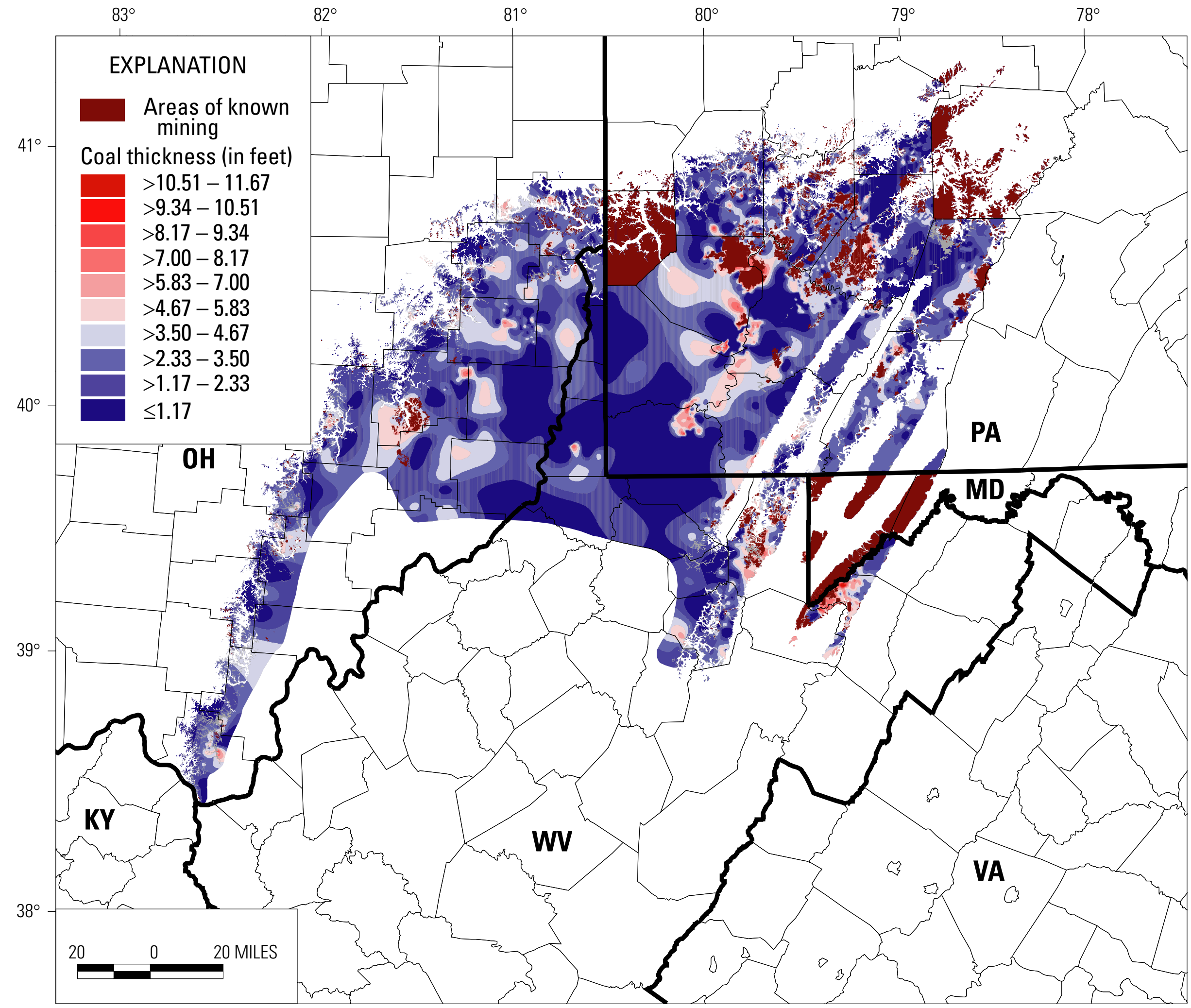


Figure 23. Map showing thickness contours, or isopach lines, for the Upper Freeport coal bed. The thickness isopachs, presented in 14-inch (or 1.17-ft) intervals, were generated from 11,950 stratigraphic records. The isopach map clearly shows the thick pods of Upper Freeport coal bounded laterally by thin coal. See figure 3 for county names.

Table 1. Original and remaining resources by State and county for the Upper Freeport coal bed, rounded to millions of short tons.

[In some counties, the hypothetical resources (Wood and others, 1983) are >60 percent of the total county resource; these county names and totals are shown in bold and italicized type. Remaining resources preceded by "<" and shown in bold type are uncertain because mine map compilations are not complete; therefore, values are less than shown.]

State/County	Original	Remaining
PENNSYLVANIA		
Allegheny	***3,000***	***2,200***
Armstrong	***1,100***	***750***
Beaver	***340***	***<340***
Blair	14	2.6
Butler	980	910
Cambria	1,100	880
Centre	***0.23***	***0.23***
Clarion	60	40
Clearfield	***390***	***<380***
Elk	3.8	**<3.8**
Fayette	1,300	1,300
Greene	460	460
Indiana	1,600	1,100
Jefferson	170	150
Lawrence	5.1	**<5.1**
Somerset	1,300	1,300
Washington	***1,700***	***1,700***
Westmoreland	2,400	2,100
Pennsylvania Total	16,000	***<14,000***
WEST VIRGINIA		
Barbour	580	570
Brooke	***76***	***76***
Grant	620	510
Hancock	130	130
Harrison	***0.037***	***0.037***
Marion	***400***	***400***
Marshall	***400***	***400***
Mineral	130	120
Monongalia	370	340
Ohio	***240***	***240***
Preston	1,000	750
Randolph	***2.0***	***2.0***
Taylor	190	190
Tucker	260	160
Upshur	160	160
Wetzel	***430***	***430***
West Virginia Total	5,000	4,500
OHIO		
Athens	490	480
Belmont	820	820
Carroll	840	830
Columbiana	950	860
Coshocton	1.2	1.2
Gallia	***470***	***470***
Guernsey	1,400	1,200
Harrison	1,200	1,200
Hocking	59	54
Holmes	***0.018***	***0.018***
Jackson	***36***	***32***
Jefferson	***1,200***	***1,200***
Lawrence	350	350
Meigs	***290***	***290***
Monroe	***1,000***	***1,000***
Morgan	***460***	***460***
Muskingum	790	780
Noble	1,100	1,100
Perry	220	210
Stark	***41***	***35***
Tuscarawas	270	260
Vinton	99	96
Washington	230	230
Ohio Total	12,000	12,000
MARYLAND		
Allegany	200	***<200***
Garrett	710	***<610***
Maryland Total	910	***<810***
Grand Total	34,000	***<31,000***

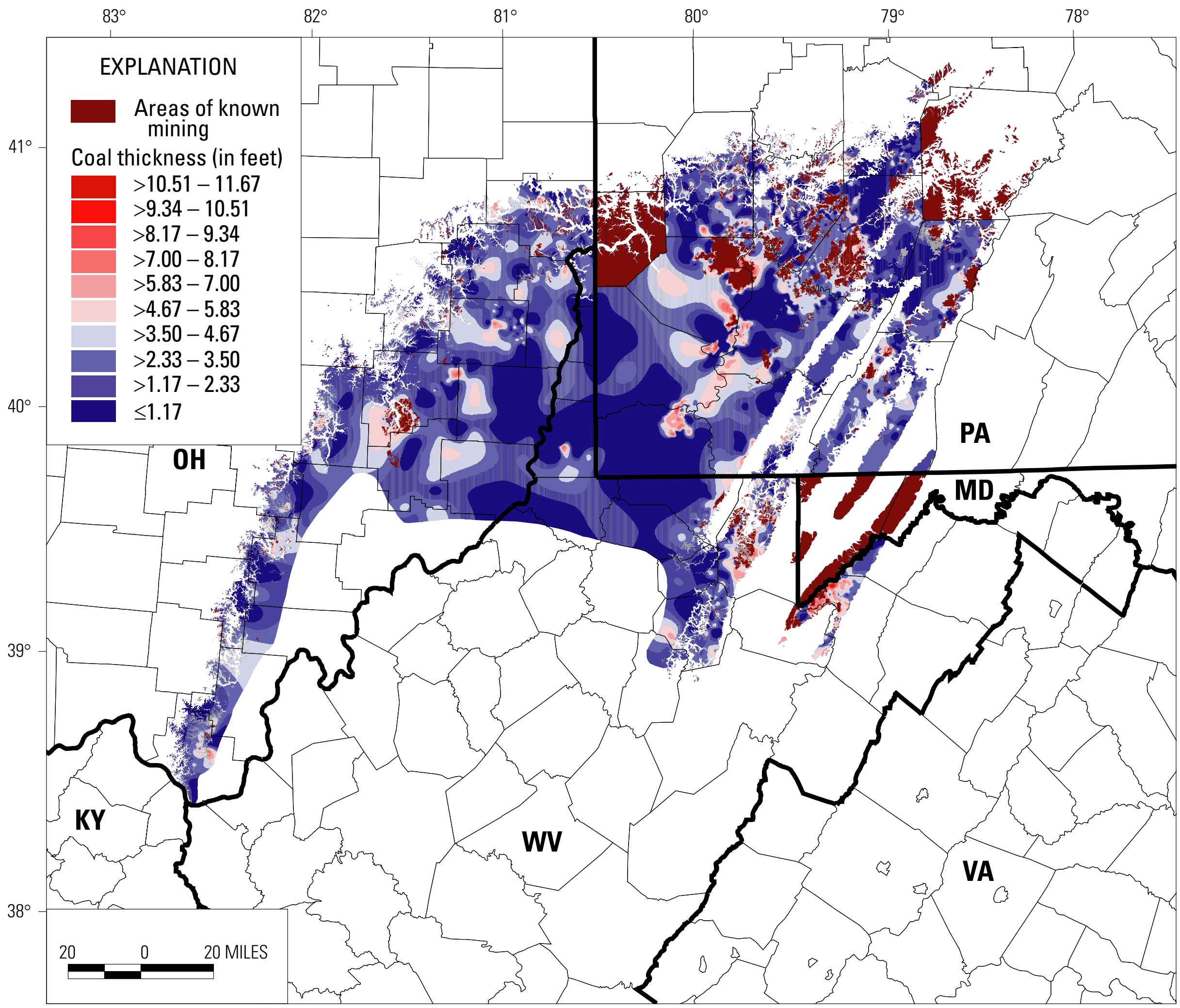


Figure 24. Map showing mined areas overlying the thickness map of the Upper Freeport coal bed. Note that many of the thick coal bodies have been mined. Relatively large bodies still remain and are roughly centered in Jefferson, Harrison, Belmont, Monroe, Noble, and Carroll Counties, Ohio; and Allegheny, Washington, Fayette, and Westmoreland Counties, Pa. See figure 3 for county names.

Survey has just completed an assessment of the Upper Freeport coal bed and estimated an original resource of 10.7 billion short tons (James McDonald, Ohio Division of Geological Survey, written commun., 1999) which is 13 percent lower than the resource estimate reported in this study. The difference is thought to be the result of utilizing different stratigraphic databases.

RESULTS AND DISCUSSION

The depositional surface of the Upper Freeport coal bed was extensive (approximately 14,000 mi^2), but thick (>3.5 ft) Upper Freeport coal pods are separated from one another by large areas of thin or absent coal (fig. 23). Although most of the thick pods are 5 to 15 mi^2 in area, some are as small as 2 and as large as 20 mi^2. By area, about 43 percent of the original Upper Freeport coal resource was >2.33 ft thick and 23 percent was >3.5 ft thick. Only about 1 percent was >7.0 ft thick. The thickest and largest Upper Freeport coal bodies (>7.0 ft) were located in Allegheny County, Pa., and Tucker and Grant Counties, W. Va. (fig. 3); they are essentially mined out (fig. 24). Relatively large bodies remain that range in thickness from 3.5 to 7.0 ft, approximately centered in Jefferson, Harrison, Belmont, Monroe, and Guernsey Counties, Ohio; and Allegheny, Washington, Fayette, and Westmoreland Counties, Pa. Overburden thickness (fig. 22) for these coal bodies ranges from >250 to >2,000 ft. The deeper bodies probably will not be mined given current economic conditions and technological restrictions.

Both contemporaneous and postdepositional sedimentation controlled the distribution of thick minable bodies of

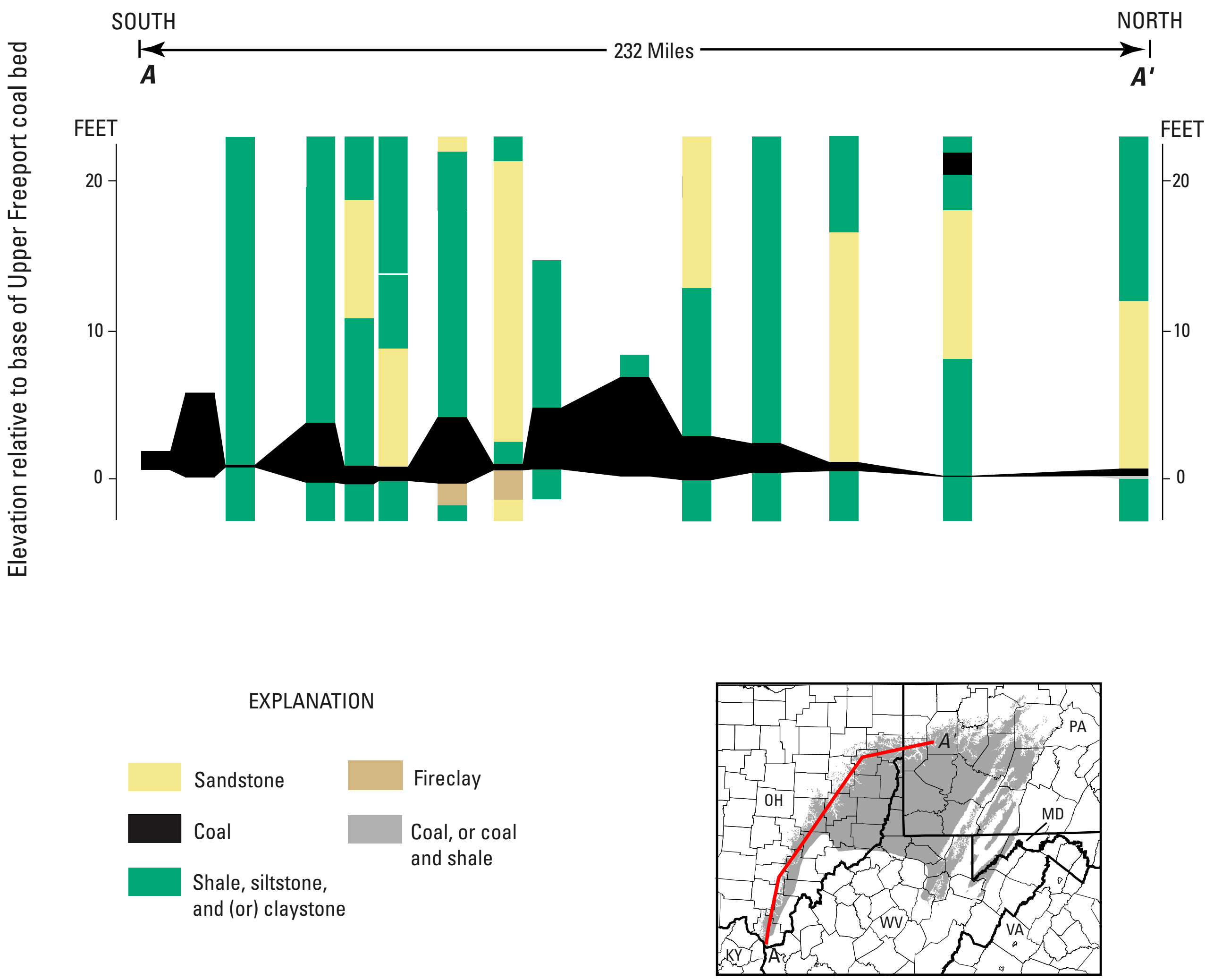


Figure 25. Generalized cross section (*A-A´*) of the Upper Freeport coal bed trending south to north-northeast from Lawrence County, Ohio, to Butler County, Pa. This section shows pods of thick coal bounded by shale and sandstone. Columns represent individual coal cores along the line of section. Vertical exaggeration X16,585.

Upper Freeport coal. Thick bodies are commonly bounded by sandstone, shale, siltstone and claystone (figs. 25, 26), indicating that peat deposition or preservation was delimited by active fluvial or deltaic processes. The coal is sometimes bounded by freshwater limestone (fig. 27) and underlain by flint clay or fireclay, which indicates fluctuations in the water table during peat formation. In addition, the Upper Freeport coal was, in part, scoured and eroded or thinned by channels that were later filled in with mud or sand (fig. 25).

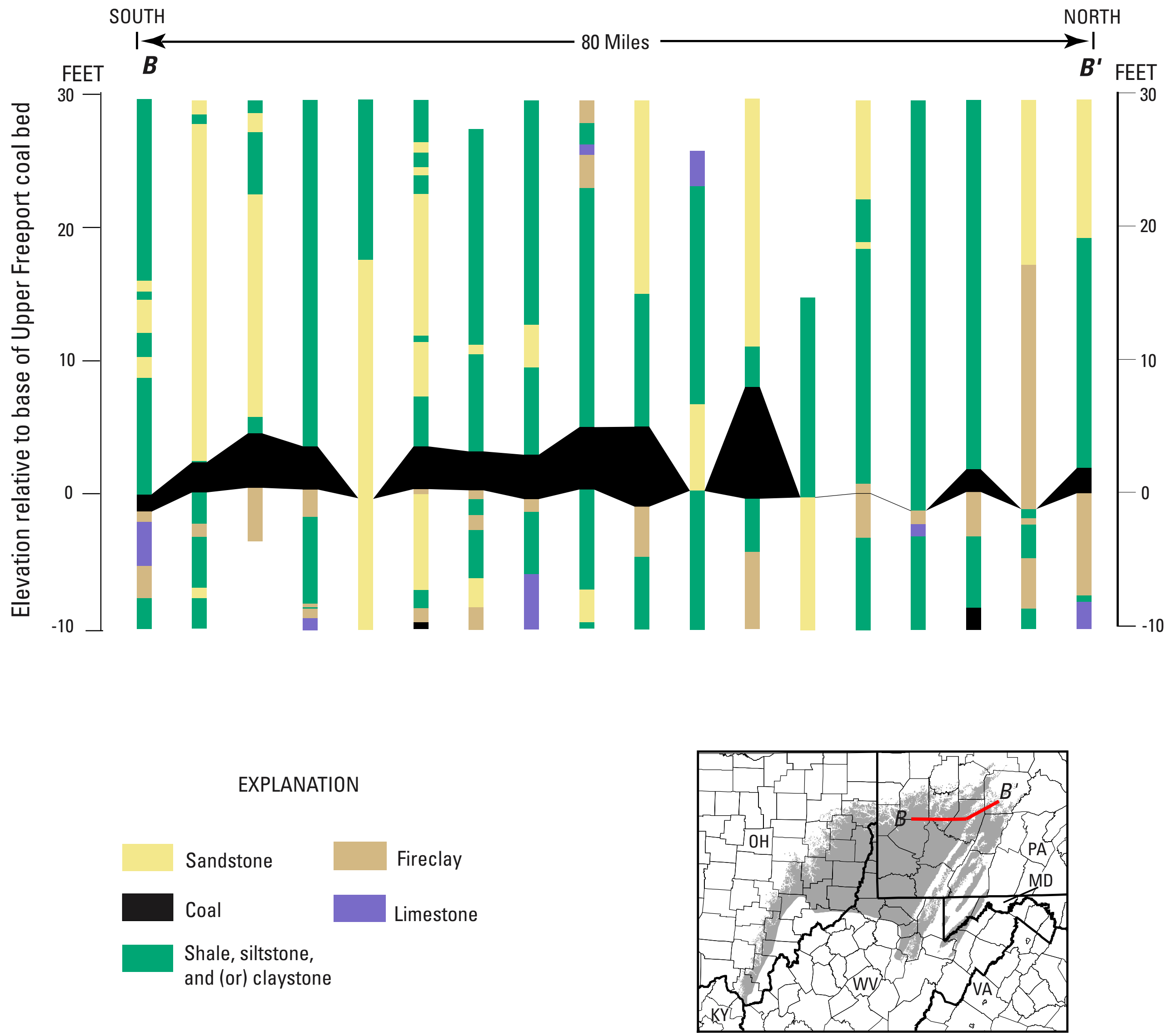


Figure 26. Generalized cross section (*B-B′*) of the Upper Freeport coal trending west to east, from Clearfield County east and northeast to Butler County, Pa. The sandstone separating two of the thicker pods of coal may have been penecontemporaneous with peat deposition. Columns represent individual coal cores along the line of section. Vertical exaggeration X6,054.

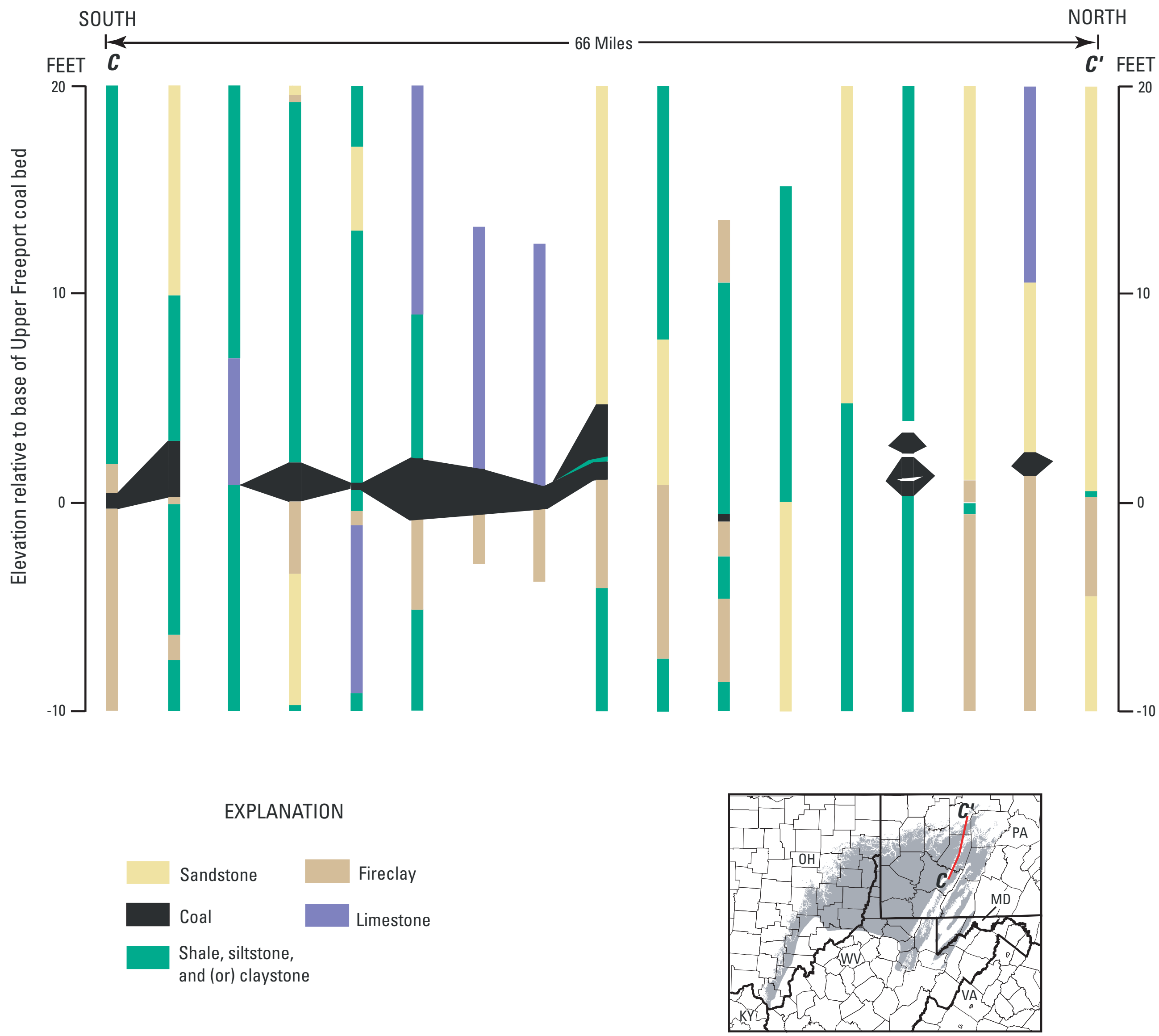


Figure 27. Generalized cross section (*C-C′*) of the Upper Freeport coal bed trending south to north from Westmoreland to Jefferson County, Pa. This section shows the coal adjacent to freshwater limestone and overlying fireclay. The occurrence of coal, freshwater limestone, and fireclay together indicates that the water table fluctuated. Columns represent individual coal cores along the line of section. Vertical exaggeration X7,467.

The close proximity or juxtaposition of sandstone and coal (figs. 28, 29) may seriously affect the minability of the Upper Freeport coal bed. Ruppert and others (1991) have shown that Upper Freeport coal quality is affected by the proximity to sandstone channels. Kertis (1984) has shown that the presence of sandstone overlying and dissecting thick Upper Freeport coal bodies can cause roof stability problems and water and coalbed methane traps, all of which may effectively eliminate blocks of Upper Freeport coal from being mined.

GEOCHEMISTRY

Most of the sample localities in the geochemical database are located along the edges of the extent of the Upper Freeport coal bed and in areas that have been mined (figs. 19, 20); therefore, they may not be representative of the entire Upper Freeport coal resource. Samples having ash yields (fig. 30) greater than 33.33 percent on an as-received whole-coal basis are not defined as coal (Wood and others, 1983) and were removed from the database.

Of the 3,781 analyses in the geochemical database, only those that are publicly available and located by latitude and longitude (Appendix 8) are shown in maps labeled A in figures 30 to 32, 34, and 36 to 48. All data, both public and proprietary, are represented by the county average maps labeled B on the same figures and were used to generate the statistical parameters in tables 2 to 18. All analyses are on an as-received whole-coal basis. Ash yield, sulfur content, and sulfur-dioxide (SO_2) content data are classified into categories of low (>0 to ≤8 weight percent ash; >0 to ≤1 weight percent sulfur; >0 to ≤1.2 pounds SO_2 per million Btu), medium (>8 to ≤15 weight percent ash; >1 to <3 weight percent sulfur; >1.2 to ≤2.5 pounds SO_2 per million Btu), and high (>15 weight percent ash; ≥3 weight percent sulfur; >2.5 pounds SO_2 per million Btu). Ash yield and sulfur content are classified according to Wood and others (1983). Sulfur-dioxide content is classified based on criteria specified by past and present Clean Air Acts. Ash yield, sulfur content, and sulfur-dioxide content are presented as both data points (Map A, figs. 30–32), and as county means (Map B, figs. 30–32). Gross calorific value, total moisture content, and trace element contents, reported in figures 34 and 36 to 48, are classified into five data categories, or quintiles, each representing 20 percent of the data values. Because the 20 percent intervals are based on different sets of data (point data (Appendix 8) versus county means (tables 2–18)), the ranges of the 20 percent intervals will be different for each data set and each chemical parameter.

Maps of ash yields (weight percent, as-received whole-coal basis) (fig. 30A, B) do not show distinct trends on a regional scale, probably because the Upper Freeport coal bed is composed of individual pods that developed in separate and correlative peat mires. However, ash yields tend to be higher (>8 to ≤15 weight percent category) in the southern half of the Upper Freeport coal bed extent. This is most clearly seen in fig. 30B. Overall, the Upper Freeport is classified as a medium-ash coal bed (mean value for 3,434 samples is 12.31±3.98 weight percent); however, there is a large regional variation observed when examining ash yield statistics broken down by State (table 2). Mean ash yields range from 11.28±3.52 weight percent in West Virginia to 14.53±5.46 weight percent in Maryland.

Sulfur contents (weight percent, as-received whole-coal basis), much like ash yields, tend to be higher in the southern half of the Upper Freeport coal bed (fig. 31). Overall, the Upper Freeport is a medium-sulfur coal (fig. 31; table 3) with a mean sulfur content of 2.24±1.02 weight percent. On a State scale, sulfur contents range from a mean of 2.01±1.13 weight percent in West Virginia to 2.90±1.54 weight percent in Maryland.

The electric power industry is Federally mandated to comply with the Clean Air Act Amendments of 1990 (Public Law 101-549), which legislate the amount of sulfur dioxide (SO_2) that can be released into the environment. Beginning in the year 2000, the compliance level was reduced from 2.4 lbs SO_2 per million Btu to 1.2 lbs SO_2 per million Btu, which equates to 0.6 pounds of sulfur per million Btu. Although a few Upper Freeport coal samples (fig. 32A; table 4) meet pre-2000 emission standards, examination of data means (table 4) and county mean maps (fig. 32B) clearly shows that, overall, the Upper Freeport coal as mined is noncompliant. Examination of coal delivered to power plants shows that virtually none of the Upper Freeport coal meets the 2000 standard (fig. 33), even though much of it is washed or cleaned to remove mineral matter and pyrite, one of the primary sources of sulfur in coal. However, usage continues because of long-term contracts. For now, electric utility companies can meet air quality standards by coal blending; installation of 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 in the Clean Air Act Amendments of 1990 (Attanasi, 1998).

Upper Freeport coal bed gross calorific values appear to decrease from east to west (fig. 34). The mean gross calorific value for the Upper Freeport coal bed is 12,950±730 Btu/lb and ranges from 13,300±660 Btu/lb in West Virginia to 12,280±660 Btu/lb in Ohio (fig. 34; table 5). The decrease in gross calorific values reflects rank changes from low-volatile bituminous through medium-volatile bituminous to high-volatile C bituminous observed from east to west (fig. 34) that resulted from regional metamorphism that occurred during Permian tectonism (Puglio, 1983).

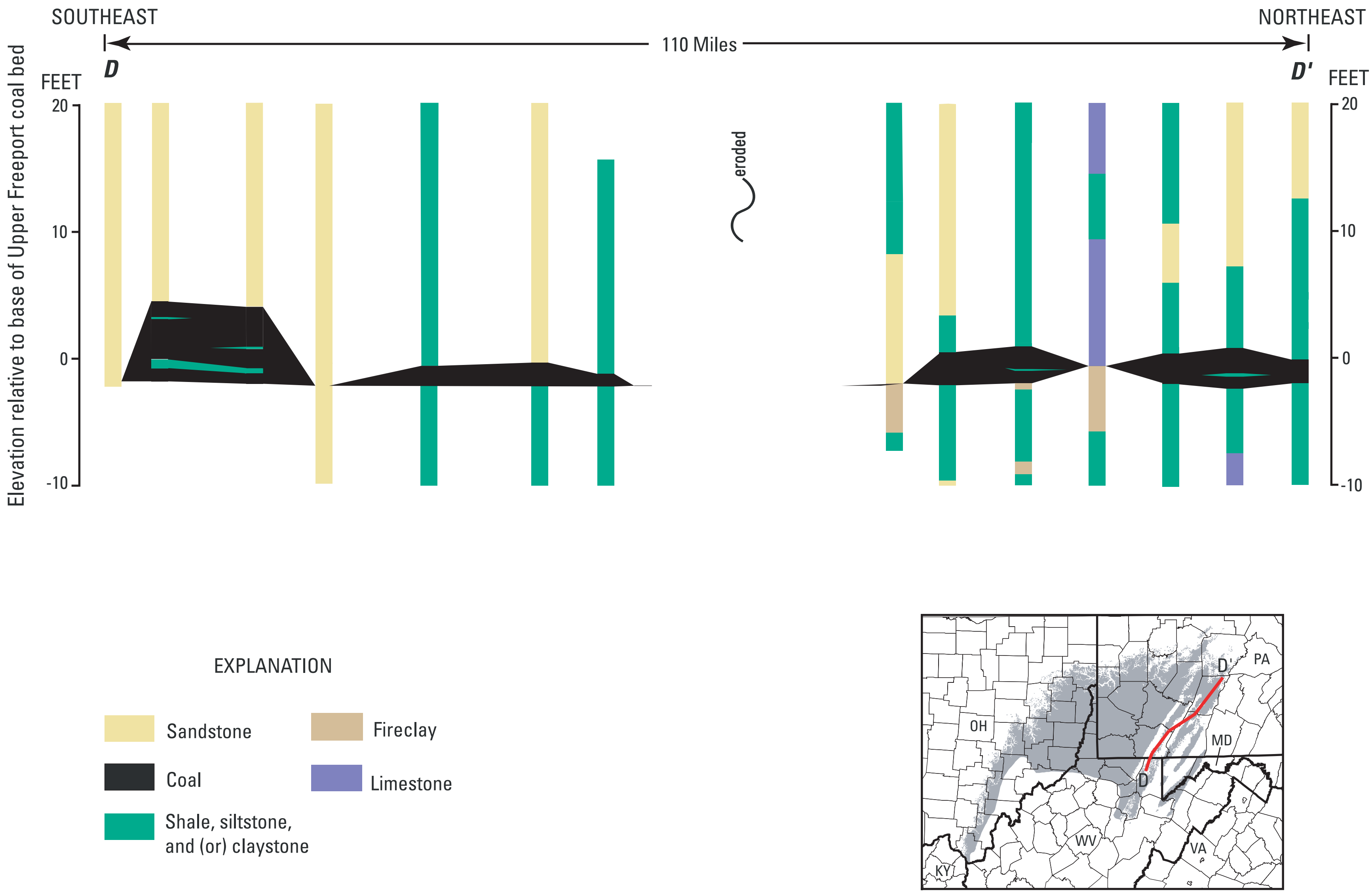


Figure 28. Generalized cross section (*D-D′*) of the Upper Freeport coal bed trending southwest to northeast from Preston County, W. Va., to Cambria County, Pa. The Upper Freeport coal is not of minable thickness over much of its depositional surface. Columns represent individual coal cores along the line of section. Vertical exaggeration X6,279.

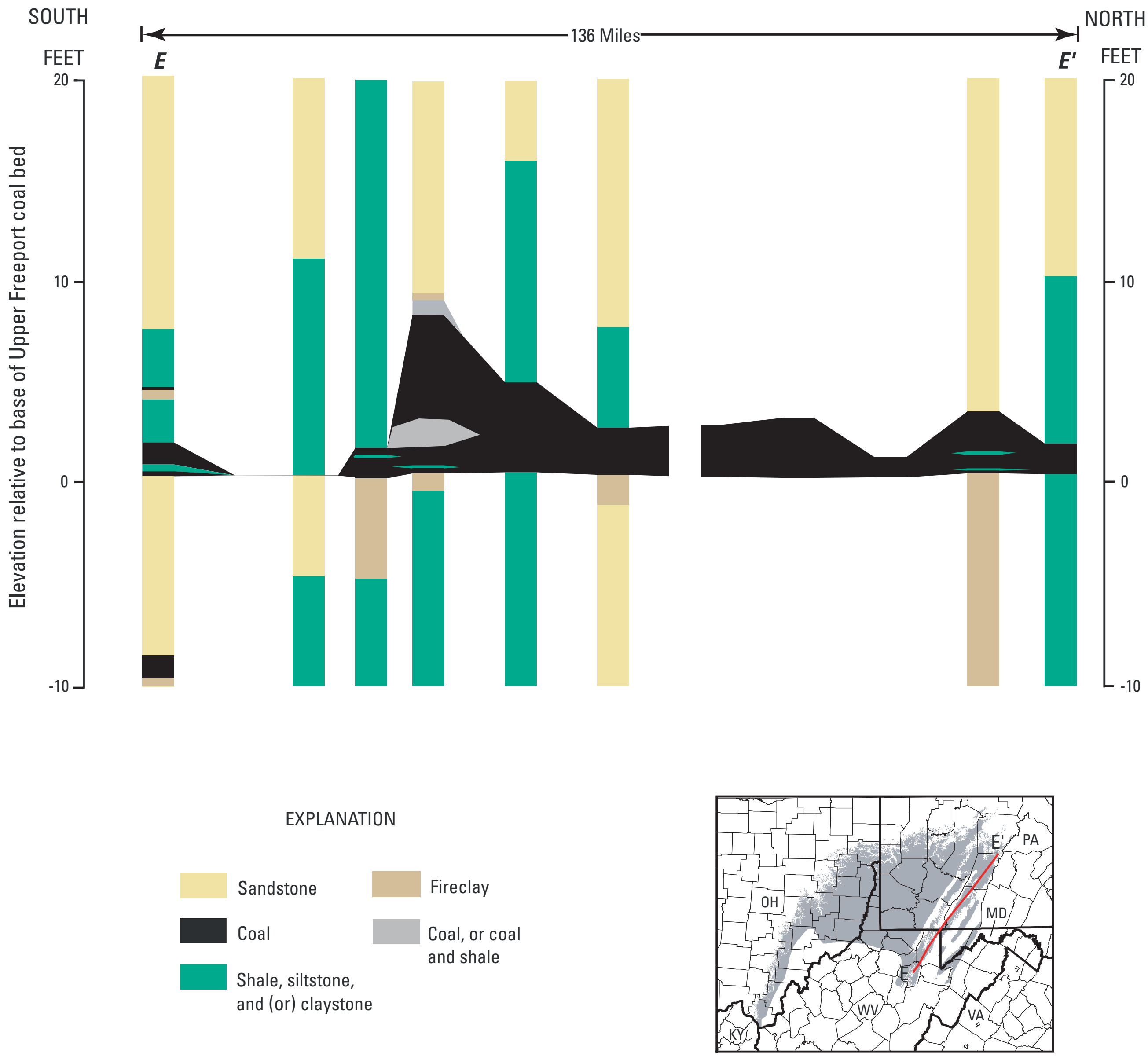


Figure 29. Generalized cross section (*E-E′*) of the Upper Feeport coal bed trending south to north-northeast from Barbour County, W. Va., to Cambria County, Pa. Columns represent individual coal cores along the line of section. Vertical exaggeration X10,312.

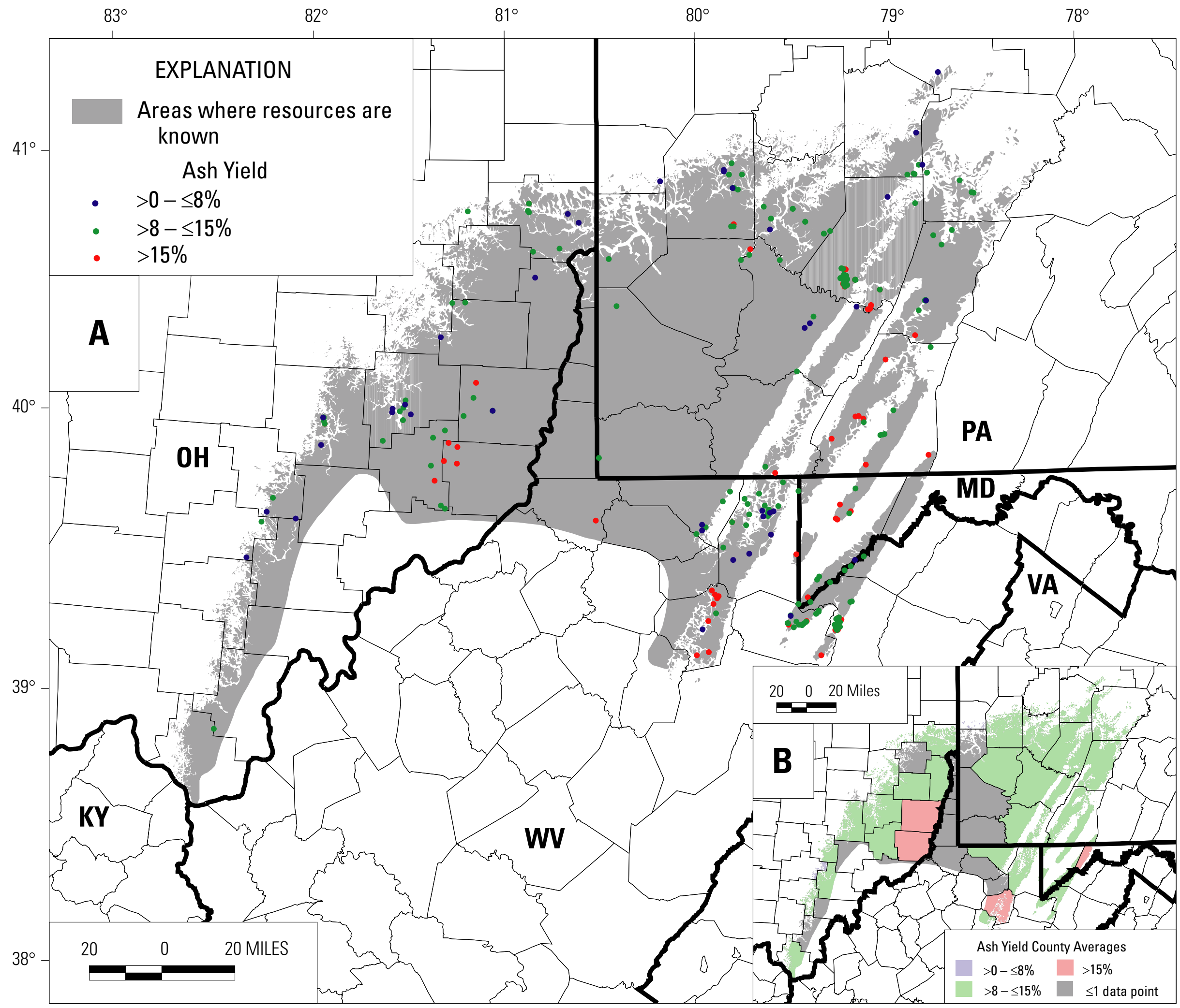


Figure 30. Maps showing ash yield (weight percent, as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows ash yields of the 278 geochemical samples for which records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for ash yields using all 3,434 records in the geochemical database, including those that are located only to a county level; ash yields range from 0.28 to 33.32 weight percent with a mean value of 12.31±3.98 weight percent (table 2). Ash yields are classified into low (>0 to ≤8 percent), medium (>8 to ≤15 percent), and high (>15 percent) categories as specified by Wood and others (1983). In Barbour County, W. Va., where the Upper Freeport coal is thin, and in Monroe and Belmont Counties, Ohio, where two of the thick pods (>3.5–7 0 ft) remain, the ash-yield tends to be highest (table 2). See figure 3 for county names.

Table 2. Ash yield (weight percent; American Society for Testing and Materials method) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	12.31	0.28	33.32	3.98	3,434
PA	na	12.40	0.28	33.32	3.98	3,002
WV	na	11.28	5.18	27.60	3.52	228
OH	na	11.63	3.60	27.70	4.01	175
MD	na	14.53	7.17	25.40	5.46	29
PA	Allegheny	11.78	4.78	21.74	3.94	35
PA	Armstrong	12.32	0.28	30.01	3.63	1,002
PA	Beaver	nd	10.31	10.31	nd	1
PA	Butler	13.33	6.25	32.62	5.52	84
PA	Cambria	9.89	6.63	15.13	1.91	56
PA	Clarion	9.63	6.58	12.29	1.91	7
PA	Clearfield	11.12	6.72	22.20	2.59	78
PA	Elk	8.65	6.18	11.12	3.49	2
PA	Fayette	14.27	6.74	33.32	6.93	13
PA	Greene	nd	9.70	9.70	nd	1
PA	Indiana	12.66	3.60	32.65	4.07	1,275
PA	Jefferson	12.48	0.80	28.00	4.64	122
PA	Lawrence	7.01	5.57	8.50	1.47	3
PA	Somerset	12.15	6.31	23.80	3.61	65
PA	Washington	nd	13.12	13.12	nd	1
PA	Westmoreland	12.31	6.35	27.40	4.21	257
WV	Barbour	17.33	6.70	27.60	5.93	12
WV	Grant	13.51	8.68	22.54	3.11	30
WV	Mineral	9.79	6.80	11.78	1.75	12
WV	Monongalia	10.27	5.65	14.55	3.35	13
WV	Preston	10.99	5.18	18.76	2.47	116
WV	Tucker	9.62	5.18	19.98	3.45	39
WV	Upshur	8.36	7.19	9.60	0.92	5
WV	Wetzel	nd	16.20	16.20	nd	1
OH	Athens	11.52	6.40	17.80	4.02	9
OH	Belmont	16.91	10.40	27.70	7.38	5
OH	Carroll	nd	19.70	19.70	nd	1
OH	Columbiana	10.94	5.60	18.80	3.55	25
OH	Gallia	nd	12.40	12.40	nd	1
OH	Guernsey	11.51	3.60	24.03	3.88	47
OH	Harrison	11.93	6.70	15.95	2.85	17
OH	Hocking	7.95	5.60	10.30	3.32	2
OH	Holmes	6.59	4.67	8.56	1.62	4
OH	Jackson	nd	13.90	13.90	nd	1
OH	Jefferson	12.18	6.65	17.70	4.46	5
OH	Lawrence	10.17	7.05	13.18	1.93	10
OH	Monroe	17.92	16.88	20.40	1.66	4
OH	Muskingum	12.30	5.22	21.20	4.18	18
OH	Noble	13.48	9.60	20.79	3.73	11
OH	Perry	8.33	7.30	9.60	1.07	4
OH	Stark	12.58	11.25	14.87	1.99	3
OH	Tuscarawas	9.31	5.60	14.65	3.32	5
OH	Vinton	8.84	6.05	10.57	2.44	3
MD	Allegany	15.07	9.58	24.35	5.80	6
MD	Garrett	14.39	7.17	25.40	5.50	23

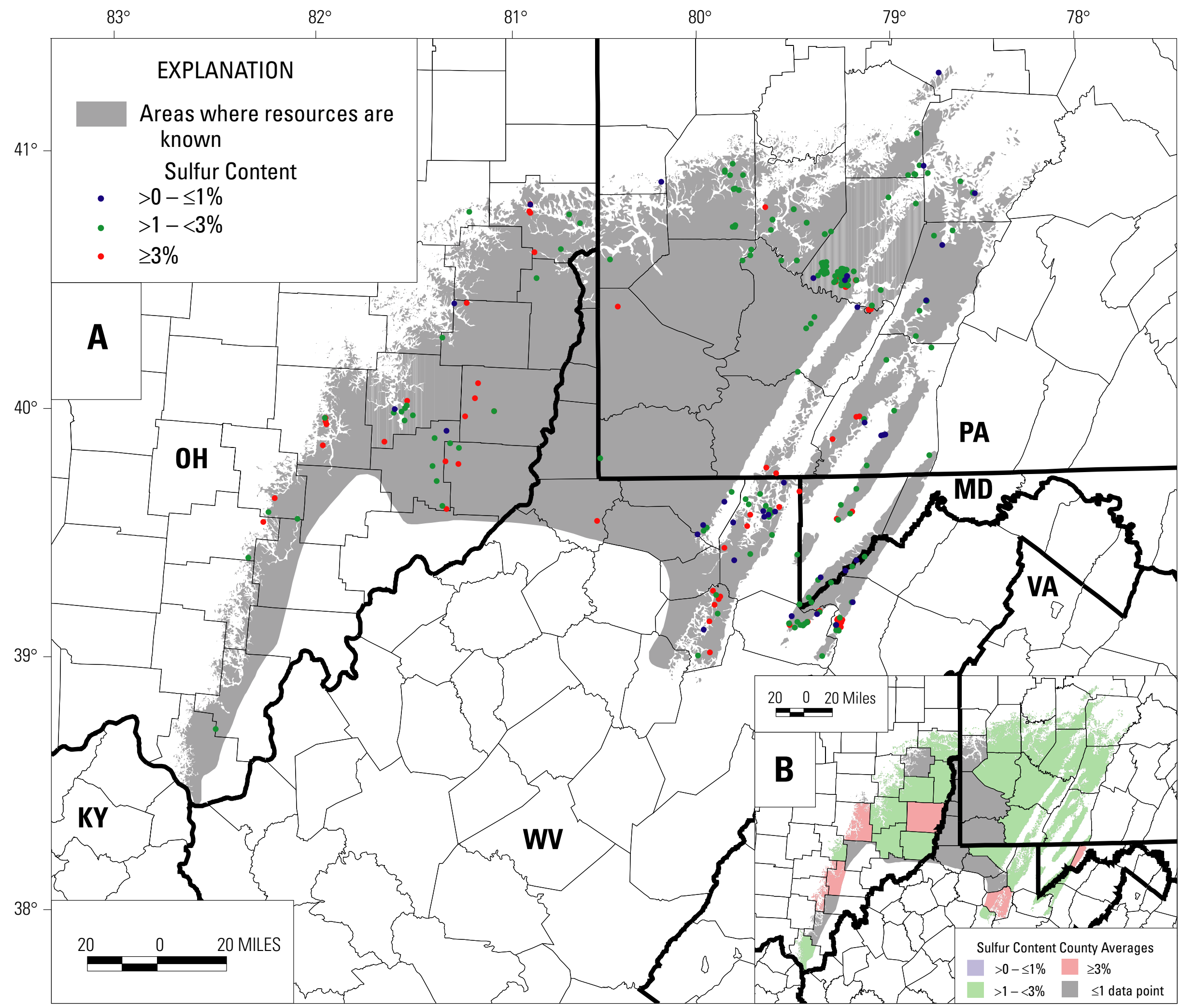


Figure 31. Maps showing sulfur content (weight percent, as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows sulfur contents of the 318 geochemical samples for which records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for sulfur contents using all 3,482 records in the geochemical database, including those that are located to only a county level; sulfur contents range from 0.38 to 5.85 weight percent with a mean value of 2.24±1.02 weight percent (table 3). Sulfur contents are classified into low (>0 to ≤1 percent), medium (>1 to <3 percent), and high (≥3 percent) categories as specified by Wood and others (1983). As with ash yield, sulfur content tends to be higher in the southern half of the Upper Freeport coal bed. See figure 3 for county names.

Table 3. Sulfur content (weight percent; American Society for Testing and Materials method) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	2.24	0.38	5.85	1.02	3,482
PA	na	2.21	0.38	5.82	0.98	3,049
WV	na	2.01	0.49	5.40	1.13	228
OH	na	2.83	0.64	5.85	1.17	177
MD	na	2.90	0.48	5.77	1.54	28
PA	Allegheny	1.71	0.49	2.84	0.61	35
PA	Armstrong	2.33	0.49	5.82	0.93	1,005
PA	Beaver	nd	1.81	1.81	nd	1
PA	Butler	2.18	0.75	4.60	0.91	84
PA	Cambria	1.55	0.68	3.30	0.65	56
PA	Clarion	1.96	1.10	4.24	1.07	7
PA	Clearfield	1.68	0.38	5.70	0.99	78
PA	Elk	1.30	0.59	2.01	1.00	2
PA	Fayette	2.80	1.28	5.10	1.19	13
PA	Greene	nd	2.80	2.80	nd	1
PA	Indiana	2.17	0.45	5.80	1.02	1,319
PA	Jefferson	2.06	0.53	4.56	0.83	122
PA	Lawrence	1.64	0.76	2.16	0.77	3
PA	Somerset	1.76	0.47	5.73	0.97	65
PA	Washington	nd	3.23	3.23	nd	1
PA	Westmoreland	2.52	0.72	5.45	0.91	257
WV	Barbour	3.07	0.85	5.15	1.27	12
WV	Grant	2.92	0.57	5.14	1.35	30
WV	Mineral	1.40	0.53	2.60	0.76	12
WV	Monongalia	1.11	0.61	2.05	0.42	13
WV	Preston	2.02	0.49	5.40	0.95	116
WV	Tucker	1.43	0.52	4.54	0.94	39
WV	Upshur	1.56	1.45	1.65	0.10	5
WV	Wetzel	nd	4.40	4.40	nd	1
OH	Athens	3.39	2.00	5.55	1.27	9
OH	Belmont	3.57	3.30	4.00	0.29	5
OH	Carroll	nd	3.06	3.06	nd	1
OH	Columbiana	2.47	0.64	4.40	1.06	25
OH	Gallia	nd	1.80	1.80	nd	1
OH	Guernsey	2.65	0.70	5.63	1.23	47
OH	Harrison	2.64	0.94	3.94	0.73	17
OH	Hocking	3.35	1.70	5.00	2.33	2
OH	Holmes	3.63	2.87	4.23	0.66	4
OH	Jackson	nd	3.08	3.08	nd	1
OH	Jefferson	2.88	1.90	4.18	0.87	5
OH	Lawrence	2.63	0.80	5.26	1.50	12
OH	Monroe	2.88	1.61	4.10	1.17	4
OH	Muskingum	3.49	0.65	5.85	1.28	18
OH	Noble	2.81	0.90	4.30	0.94	11
OH	Perry	2.97	1.27	5.80	1.99	4
OH	Stark	2.02	1.70	2.51	0.43	3
OH	Tuscarawas	2.09	1.00	3.00	0.97	5
OH	Vinton	4.07	3.39	4.56	0.60	3
MD	Allegany	3.65	2.58	4.72	0.86	5
MD	Garrett	2.74	0.48	5.77	1.63	23

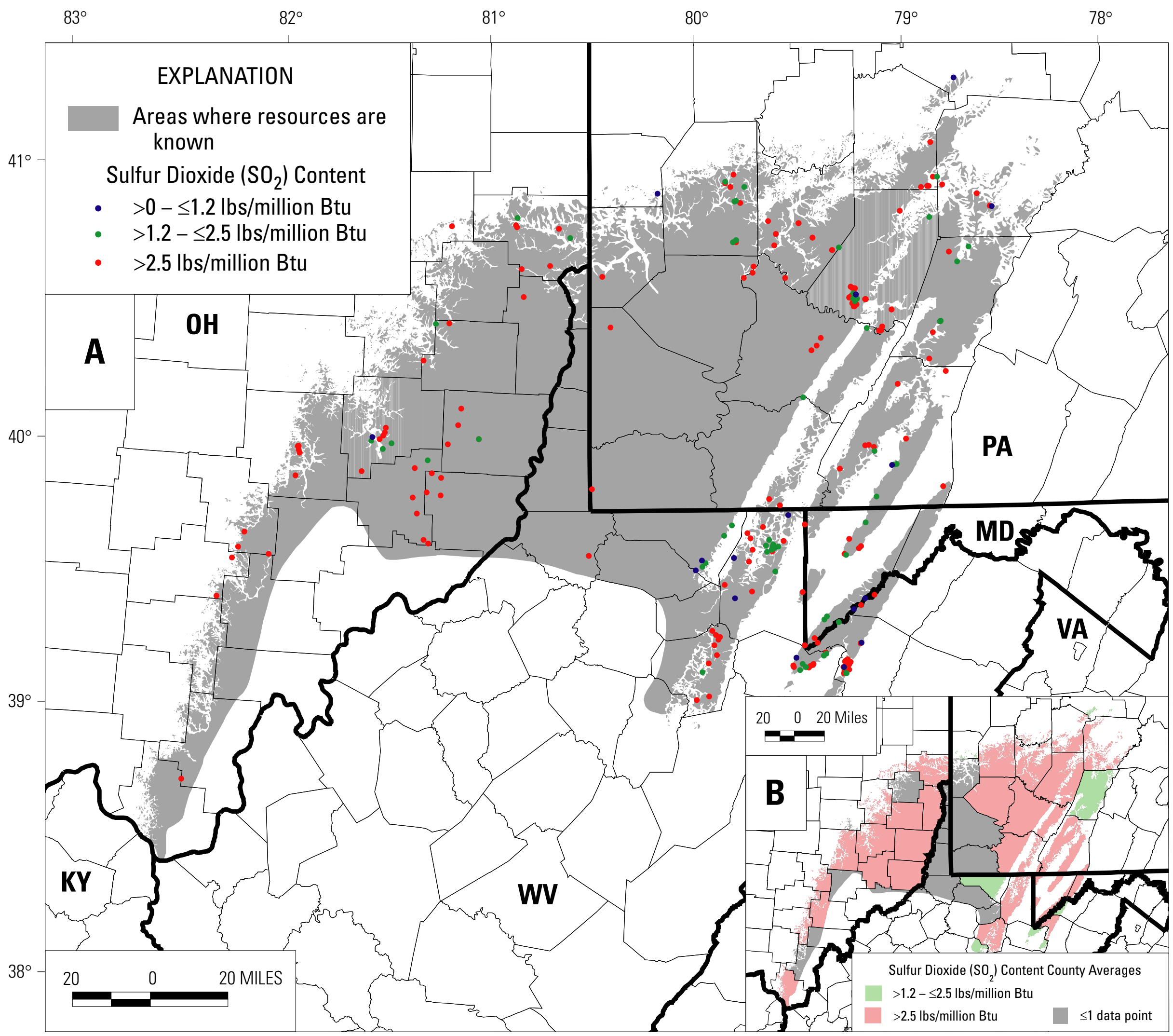


Figure 32. Maps showing sulfur-dioxide (SO_2) content (lbs/million Btu. as-received whole-coal basis) of the Upper Freeport coal in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows SO_2 contents of 278 geochemical samples for which records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for SO_2 contents using all 1,735 records in the geochemical database, including those that are located only to a county level; SO_2 contents range from 0.58 to 10.59 lbs/million Btu with a mean value of 3.46±1.72 (table 4). The values are classified into three categories, low (0 to ≤1.2 lbs/million Btu), medium (>1.2 to ≤2.5 lbs/million Btu), and high (>2.5 lbs/million Btu), and are based on criteria specified in past and present Clean Air Acts. See figure 3 for county names.

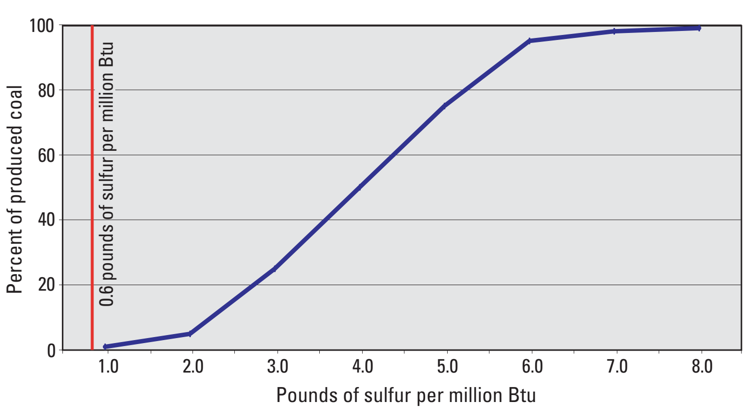


Figure 33. Graph showing sulfur in Upper Freeport coal delivered to power plants from 1989 to 1997. During Phase I of the Clean Air Act Amendments of 1990 (Public Law 101-549), only a fraction of the total Upper Freeport production delivered to power plants was compliant at 1.2 lbs of sulfur per million Btu (1.2 lbs of sulfur is equivalent to 2.4 lbs of sulfur dioxide (SO_2) per million Btu). However, under Phase II, virtually none of the Upper Freeport coal meets emission standards of 0.6 lbs of sulfur per million Btu (which is equivalent to 1.2 lbs of SO_2 per million Btu). Data from Attanasi (1998).

Table 4. Sulfur-dioxide (SO_2) content (lbs/million Btu) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	3.46	0.58	10.59	1.72	1,735
PA	na	3.33	0.58	10.59	1.55	1,315
WV	na	3.15	0.73	8.40	1.84	216
OH	na	4.65	0.99	9.79	2.01	176
MD	na	4.57	0.71	10.16	2.64	28
PA	Allegheny	2.67	0.69	4.69	1.00	34
PA	Armstrong	3.59	0.81	9.82	1.56	473
PA	Beaver	nd	2.89	2.89	nd	1
PA	Butler	3.33	1.66	7.02	1.48	44
PA	Cambria	2.27	0.96	4.87	0.96	54
PA	Clarion	3.29	2.08	6.69	1.94	5
PA	Clearfield	2.50	0.58	8.60	1.57	65
PA	Elk	1.94	0.86	3.02	1.53	2
PA	Fayette	4.75	1.86	10.59	2.43	12
PA	Greene	nd	4.10	4.10	nd	1
PA	Indiana	3.41	0.77	9.61	1.55	375
PA	Jefferson	3.25	0.88	7.50	1.36	88
PA	Lawrence	2.45	1.17	3.15	1.11	3
PA	Somerset	2.76	0.71	9.67	1.64	63
PA	Washington	nd	5.10	5.10	nd	1
PA	Westmoreland	3.48	1.24	7.26	1.27	94
WV	Barbour	5.07	1.23	8.39	2.20	12
WV	Grant	4.53	0.87	8.34	2.16	30
WV	Mineral	1.96	0.80	3.76	1.11	10
WV	Monongalia	1.69	0.86	3.22	0.67	12
WV	Preston	3.10	0.81	8.40	1.49	114
WV	Tucker	2.22	0.73	7.83	1.60	35
WV	Upshur	2.29	2.15	2.43	0.20	2
WV	Wetzel	nd	7.08	7.08	nd	1
OH	Athens	5.56	3.17	9.01	2.11	9
OH	Belmont	6.06	5.19	6.67	0.58	5
OH	Carroll	nd	4.69	4.69	nd	1
OH	Columbiana	3.98	0.99	7.89	1.85	25
OH	Gallia	nd	3.14	3.14	nd	1
OH	Guernsey	4.31	1.08	9.13	2.05	46
OH	Harrison	4.23	1.50	5.69	1.16	17
OH	Hocking	5.70	2.83	8.57	4.06	2
OH	Holmes	6.15	4.92	7.71	1.30	4
OH	Jackson	nd	5.07	5.07	nd	1
OH	Jefferson	4.49	2.83	6.57	1.36	5
OH	Lawrence	4.53	1.35	9.19	2.65	12
OH	Monroe	4.92	2.74	6.99	1.94	4
OH	Muskingum	5.89	1.04	9.52	2.24	18
OH	Noble	4.47	1.42	6.76	1.45	11
OH	Perry	4.93	2.02	9.79	3.41	4
OH	Stark	3.22	2.92	3.82	0.52	3
OH	Tuscarawas	3.40	1.69	4.77	1.52	5
OH	Vinton	6.97	5.57	8.00	1.26	3
MD	Allegany	5.59	3.77	7.86	1.61	5
MD	Garrett	4.35	0.71	10.16	2.79	23

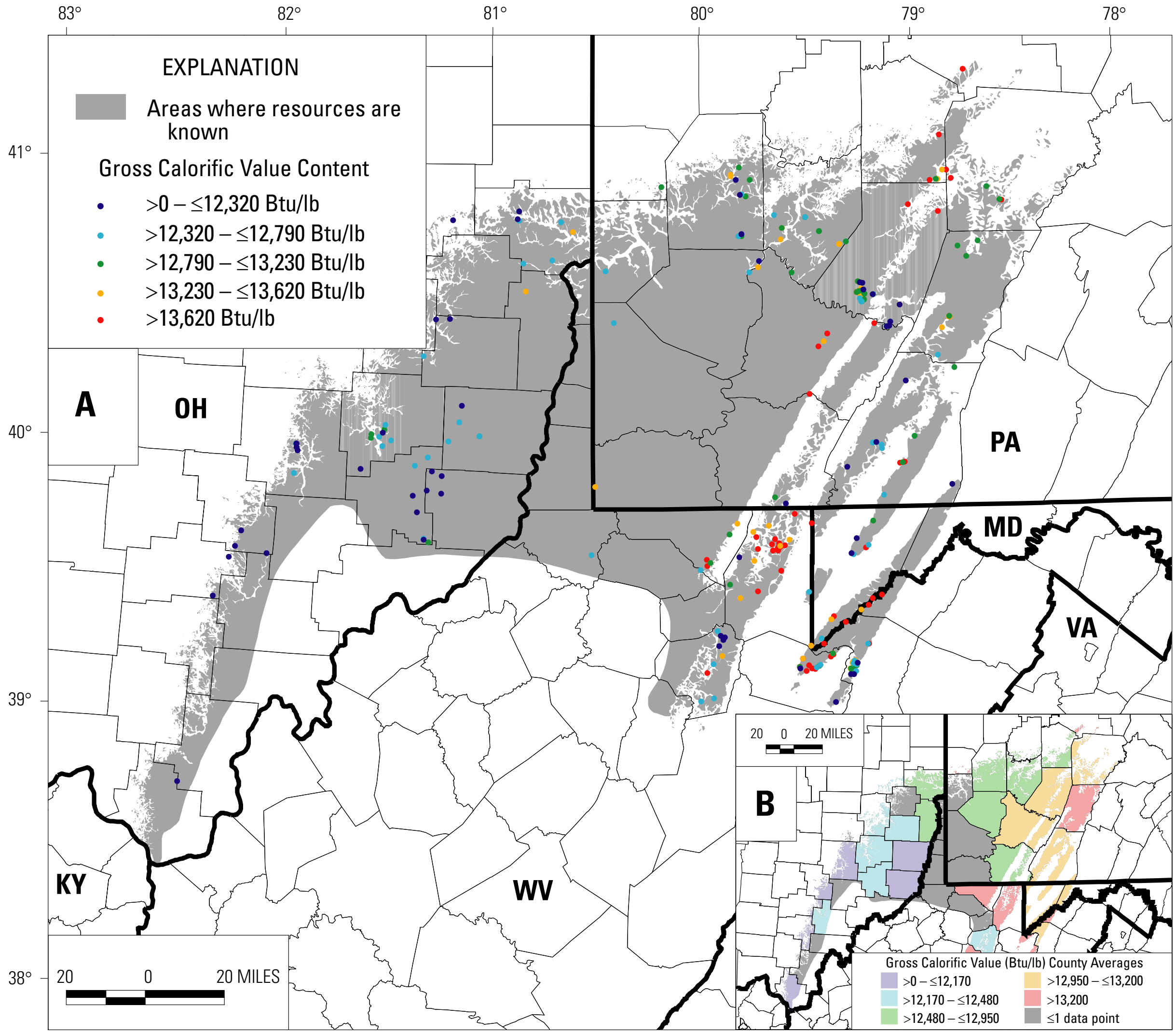


Figure 34. Maps showing gross calorific value (Btu/lb, as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows gross calorific values of 279 geochemical samples for which records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for gross calorific values using all 1,736 records in the geochemical database; gross calorific values range from 9,630 to 15,090 Btu/lb with a mean value of 12,950±730 Btu/lb (table 5). The values are classified into five categories, each representing 20 percent of the data values. Gross calorific values clearly increase from the west to the east. See figure 3 for county names.

Table 5. Gross calorific value (Btu/lb; American Society for Testing and Materials method) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	12,950	9,630	15,090	730	1,736
PA	na	12,980	9,630	14,340	690	1,315
WV	na	13,300	10,880	15,090	660	216
OH	na	12,280	10,490	13,840	660	177
MD	na	13,000	11,220	14,060	840	28
PA	Allegheny	12,860	11,260	14,060	740	34
PA	Armstrong	12,810	10,210	13,970	630	473
PA	Beaver	nd	12,530	12,530	nd	1
PA	Butler	12,810	10,950	13,720	720	44
PA	Cambria	13,460	12,190	14,230	490	54
PA	Clarion	12,770	12,550	12,900	150	5
PA	Clearfield	13,250	11,070	14,150	490	65
PA	Elk	13,500	13,290	13,700	290	2
PA	Fayette	12,640	9,630	13,900	1,180	12
PA	Greene	nd	13,410	13,410	nd	1
PA	Indiana	13,010	10,230	14,290	730	375
PA	Jefferson	12,950	11,120	14,340	760	88
PA	Lawrence	13,300	13,020	13,720	370	3
PA	Somerset	13,130	10,940	14,140	690	63
PA	Washington	nd	12,560	12,560	nd	1
PA	Westmoreland	13,410	11,390	14,200	560	94
WV	Barbour	12,280	10,880	13,840	820	12
WV	Grant	13,030	11,930	14,190	620	30
WV	Mineral	13,960	13,320	14,440	330	10
WV	Monongalia	13,430	12,650	14,200	570	12
WV	Preston	13,260	11,920	14,500	490	114
WV	Tucker	13,760	11,610	15,090	700	35
WV	Upshur	13,580	13,570	13,580	10	2
WV	Wetzel	nd	12,430	12,430	nd	1
OH	Athens	12,240	11,470	12,630	370	9
OH	Belmont	11,820	10,490	12,710	1,010	5
OH	Carroll	nd	13,030	13,030	nd	1
OH	Columbiana	12,610	10,840	13,800	760	25
OH	Gallia	nd	11,470	11,470	nd	1
OH	Guernsey	12,380	10,740	13,010	530	46
OH	Harrison	12,480	11,310	13,840	740	17
OH	Hocking	11,840	11,660	12,020	250	2
OH	Holmes	11,860	10,980	12,540	690	4
OH	Jackson	nd	12,150	12,150	nd	1
OH	Jefferson	12,850	11,710	13,450	690	5
OH	Lawrence	11,700	10,980	12,260	350	12
OH	Monroe	11,670	11,250	11,930	290	4
OH	Muskingum	11,970	10,500	13,060	690	18
OH	Noble	12,480	11,300	13,250	540	12
OH	Perry	12,170	11,850	12,540	300	4
OH	Stark	12,460	11,650	13,100	740	3
OH	Tuscarawas	12,220	11,840	12,610	370	5
OH	Vinton	11,720	11,390	12,180	410	3
MD	Allegany	13,200	12,000	13,870	730	5
MD	Garrett	12,960	11,220	14,060	870	23

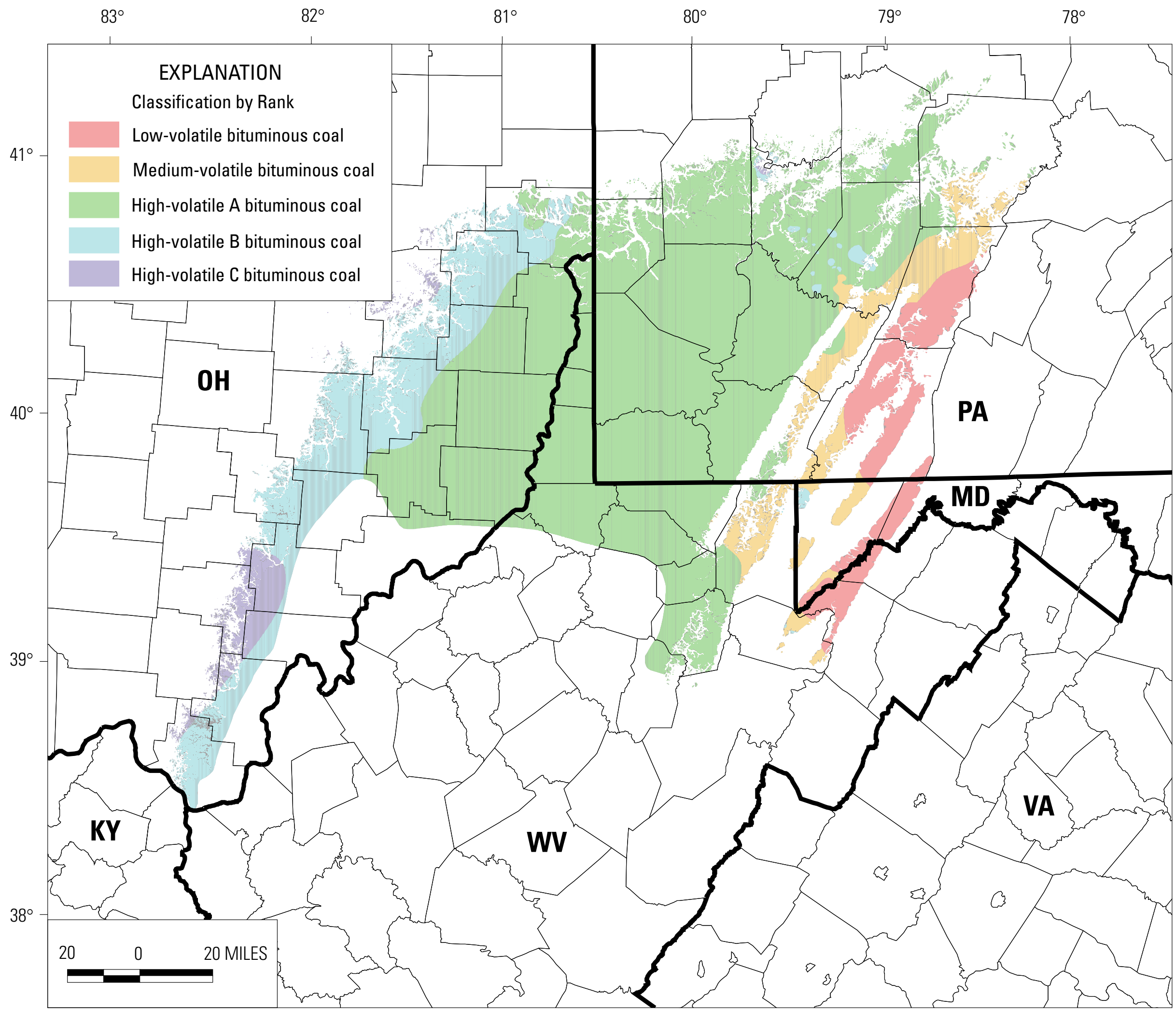


Figure 35. Map showing apparent rank of the Upper Freeport coal bed based on 394 analyses. The coal tends to decrease in rank from low-volatile bituminous in the east to high-volatile C bituminous in the west. It is important to note that some of the regularity of the rank trend is due to the absence of data in the central and deep parts of the basin. Small, bullseye-shaped pods of high-volatile B coal (Indiana County, Pa.) and high-volatile C coal (Armstrong County, Pa.) are observed. Methodology for rank determinations is based on the percentage of fixed carbon in the sample. When dry, mineral-matter-free (dmmf) fixed carbon is greater than 69 percent, rank is determined on dmmf fixed carbon; when dmmf fixed carbon is less than 69 percent, rank is determined from moist, mineral-matter-free gross calorific values (American Society for Testing and Materials, 1996). See figure 3 for county names.

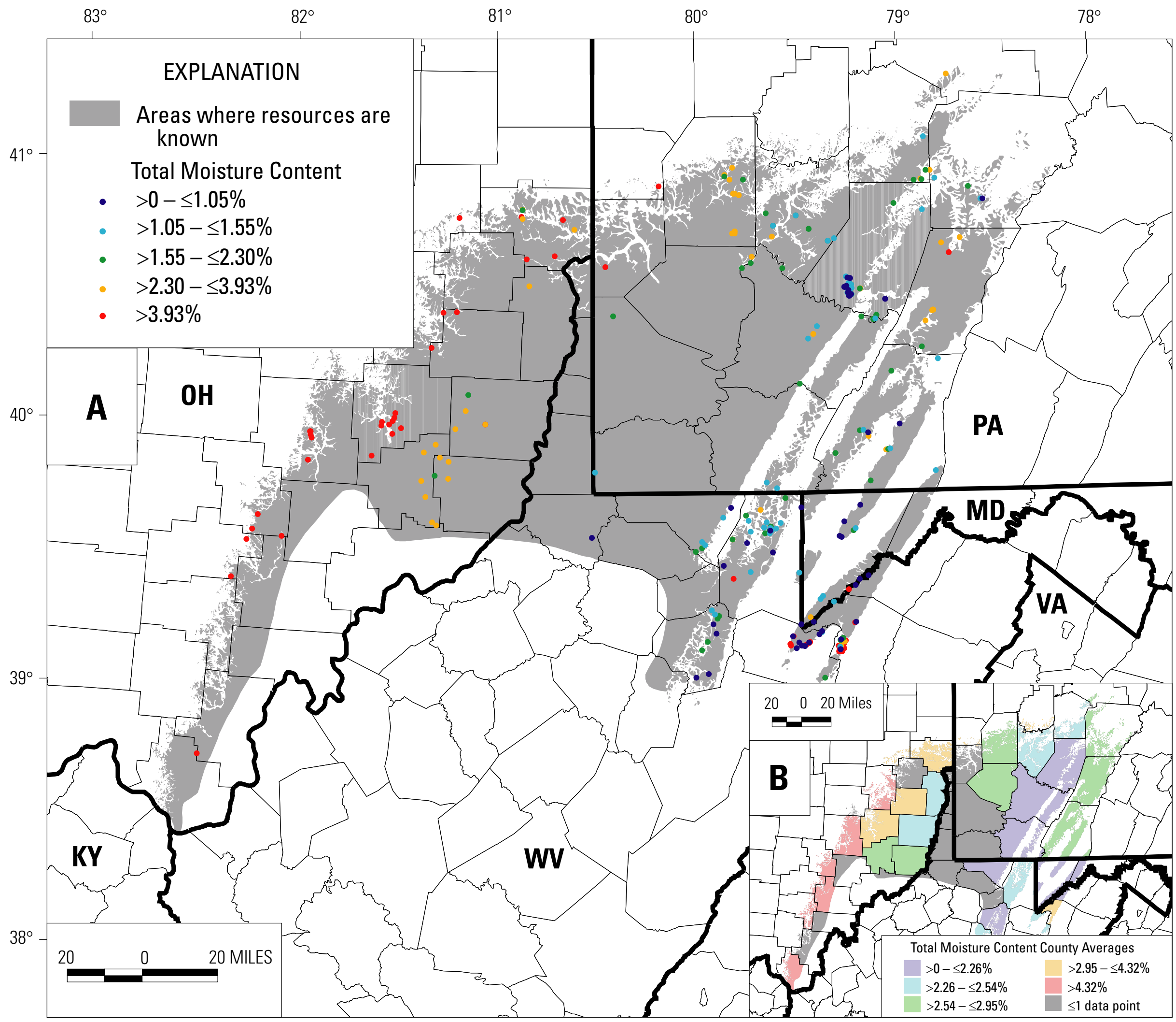


Figure 36. Maps showing total moisture content (weight percent, as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. ASTM (American Society for Testing and Materials) moisture was replaced by equilibrium moisture values where available for the Upper Freeport coal bed. Map A shows total moisture contents of 278 geochemical samples for which records are publicly available and are located by latitude and longitude (Appendix 8). Map B shows county averages for total moisture content using all 2,015 records in the geochemical database, including those that are located only to a county level; total moisture contents range from 0.05 to 10.37 weight percent with a mean value of 2.63±1.60 (table 6). The values are classified into five categories, each representing 20 percent of the data values. The Upper Freeport coal bed is a bituminous coal and the moisture content is relatively low. See figure 3 for county names.

Table 6. Total moisture content (weight percent) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[ASTM (American Society for Testing and Materials) moisture was replaced by equilibrium moisture values where available. Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	2.63	0.05	10.37	1.60	2,015
PA	na	2.45	0.05	10.37	1.33	1,582
WV	na	2.43	0.20	7.74	1.40	228
OH	na	4.66	0.54	10.30	2.53	176
MD	na	1.60	0.60	4.40	0.92	29
PA	Allegheny	2.79	1.60	5.50	1.02	35
PA	Armstrong	2.54	0.10	10.37	1.42	620
PA	Beaver	nd	5.56	5.56	nd	1
PA	Butler	2.60	0.98	5.90	0.91	61
PA	Cambria	2.95	1.04	6.20	1.14	56
PA	Clarion	4.32	3.60	5.56	0.72	7
PA	Clearfield	2.89	0.64	6.13	1.13	70
PA	Elk	2.70	2.40	3.00	0.42	2
PA	Fayette	2.12	0.99	3.70	0.80	13
PA	Greene	nd	1.50	1.50	nd	1
PA	Indiana	2.14	0.05	7.73	1.32	469
PA	Jefferson	2.51	0.05	7.40	1.59	84
PA	Lawrence	3.68	2.89	4.96	1.12	3
PA	Somerset	2.72	0.96	7.30	1.10	65
PA	Washington	nd	2.17	2.17	nd	1
PA	Westmoreland	2.19	0.95	4.30	0.70	94
WV	Barbour	1.52	0.60	4.20	0.94	12
WV	Grant	3.34	0.26	7.74	2.34	30
WV	Mineral	1.33	0.40	4.00	0.96	12
WV	Monongalia	1.73	0.61	2.90	0.67	13
WV	Preston	2.54	0.28	4.70	0.96	116
WV	Tucker	2.27	0.20	5.90	1.56	39
WV	Upshur	2.54	2.10	2.90	0.30	5
WV	Wetzel	nd	0.62	0.62	nd	1
OH	Athens	4.77	0.71	7.99	2.46	9
OH	Belmont	2.49	1.70	3.10	0.65	5
OH	Carroll	nd	1.90	1.90	nd	1
OH	Columbiana	4.26	1.00	10.00	2.25	25
OH	Gallia	nd	7.60	7.60	nd	1
OH	Guernsey	4.31	0.54	9.10	2.39	47
OH	Harrison	4.05	0.83	7.19	2.14	17
OH	Hocking	8.00	7.10	8.90	1.27	2
OH	Holmes	8.75	8.00	10.30	1.05	4
OH	Jackson	nd	6.63	6.63	nd	1
OH	Jefferson	2.29	0.76	3.26	0.94	5
OH	Lawrence	7.83	3.80	9.80	1.51	12
OH	Monroe	2.81	2.10	3.14	0.48	4
OH	Muskingum	4.82	0.80	9.30	2.43	17
OH	Noble	2.74	1.12	3.90	0.90	11
OH	Perry	5.86	1.56	7.80	2.90	4
OH	Stark	3.67	1.85	6.57	2.54	3
OH	Tuscarawas	6.41	2.83	7.90	2.12	5
OH	Vinton	8.20	7.40	8.90	0.75	3
MD	Allegany	1.34	1.19	1.70	0.19	6
MD	Garrett	1.67	0.60	4.40	1.03	23

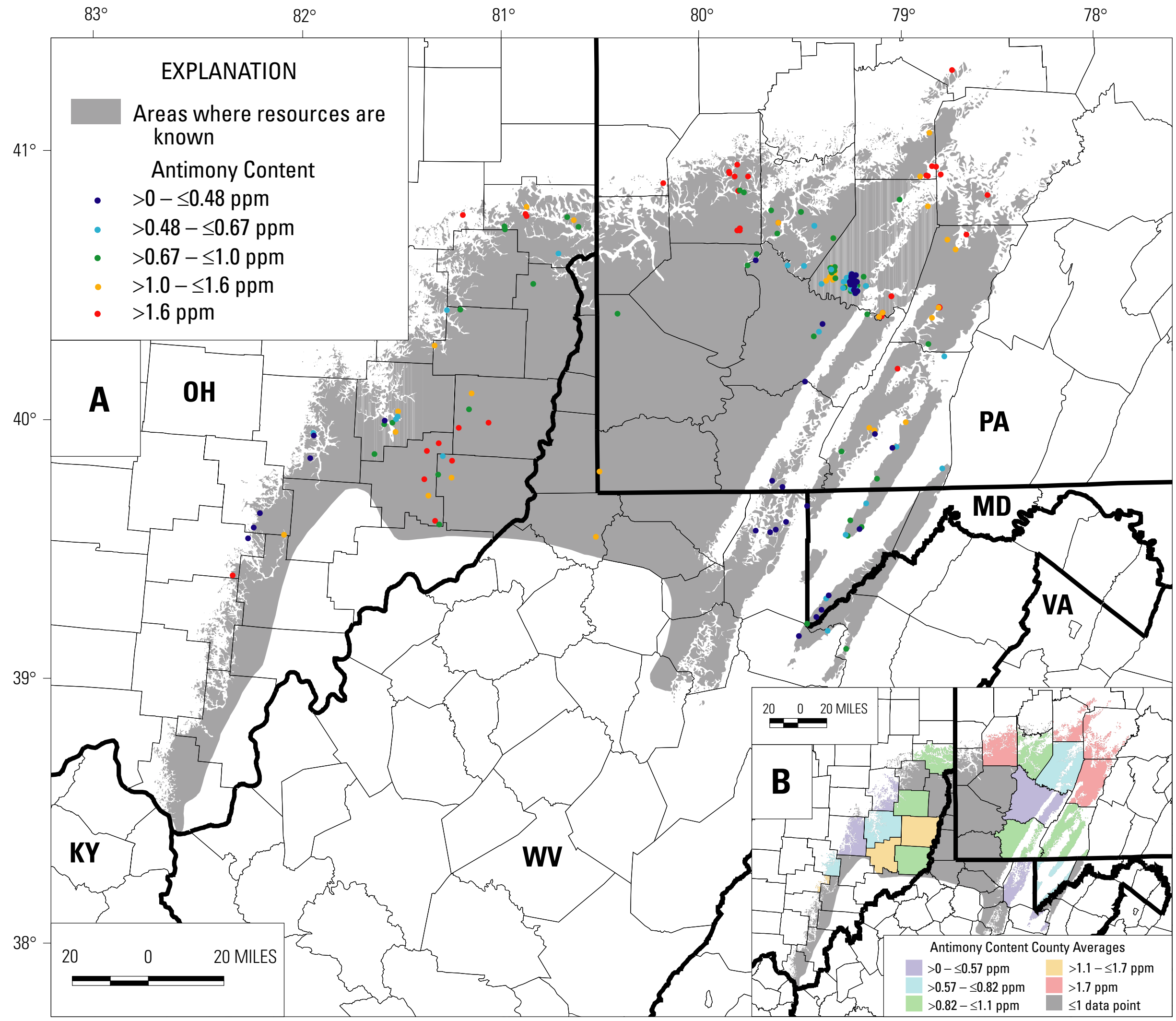


Figure 37. Maps showing antimony content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows antimony contents of 224 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for antimony contents using all 250 records in the geochemical database, including those that are located only to a county level; antimony contents range from 0.19 to 4.5 ppm with a mean value of 1.1±0.83 ppm (table 7). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 7. Antimony content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	1.1	0.19	4.5	0.83	250
PA	na	1.2	0.20	4.5	0.90	180
WV	na	0.55	0.21	1.4	0.38	11
OH	na	1.1	0.19	2.8	0.62	46
MD	na	0.77	0.32	1.7	0.43	13
PA	Allegheny	nd	1.0	1.0	nd	1
PA	Armstrong	0.89	0.50	1.7	0.33	13
PA	Butler	2.6	0.68	4.5	1.1	13
PA	Cambria	1.9	0.67	4.4	1.2	12
PA	Clarion	nd	2.2	2.2	nd	1
PA	Clearfield	2.0	0.46	2.9	0.91	6
PA	Elk	2.4	1.1	3.6	1.7	2
PA	Fayette	1.1	0.20	2.9	1.0	6
PA	Greene	nd	1.3	1.3	nd	1
PA	Indiana	0.82	0.27	2.3	0.46	95
PA	Jefferson	2.7	1.5	4.4	1.2	6
PA	Lawrence	nd	1.8	1.8	nd	1
PA	Somerset	0.92	0.39	1.9	0.49	16
PA	Washington	nd	0.86	0.86	nd	1
PA	Westmoreland	0.57	0.21	0.80	0.26	6
WV	Grant	nd	1.0	1.0	nd	1
WV	Monongalia	nd	0.36	0.36	nd	1
WV	Preston	0.39	0.21	0.77	0.20	6
WV	Tucker	0.46	0.26	0.66	0.28	2
WV	Wetzel	nd	1.4	1.4	nd	1
OH	Belmont	1.7	0.97	2.8	0.78	4
OH	Columbiana	1.1	0.50	2.6	0.60	10
OH	Guernsey	0.80	0.19	1.2	0.32	8
OH	Harrison	1.0	0.86	1.2	0.21	2
OH	Hocking	1.2	0.48	1.9	0.98	2
OH	Jefferson	nd	0.81	0.81	nd	1
OH	Monroe	1.1	0.62	1.7	0.43	4
OH	Muskingum	0.41	0.28	0.67	0.22	3
OH	Noble	1.6	0.79	2.1	0.44	6
OH	Perry	0.64	0.19	1.4	0.70	3
OH	Stark	nd	2.3	2.3	nd	1
OH	Tuscarawas	0.53	0.48	0.57	0.062	2
MD	Garrett	0.77	0.32	1.7	0.43	13

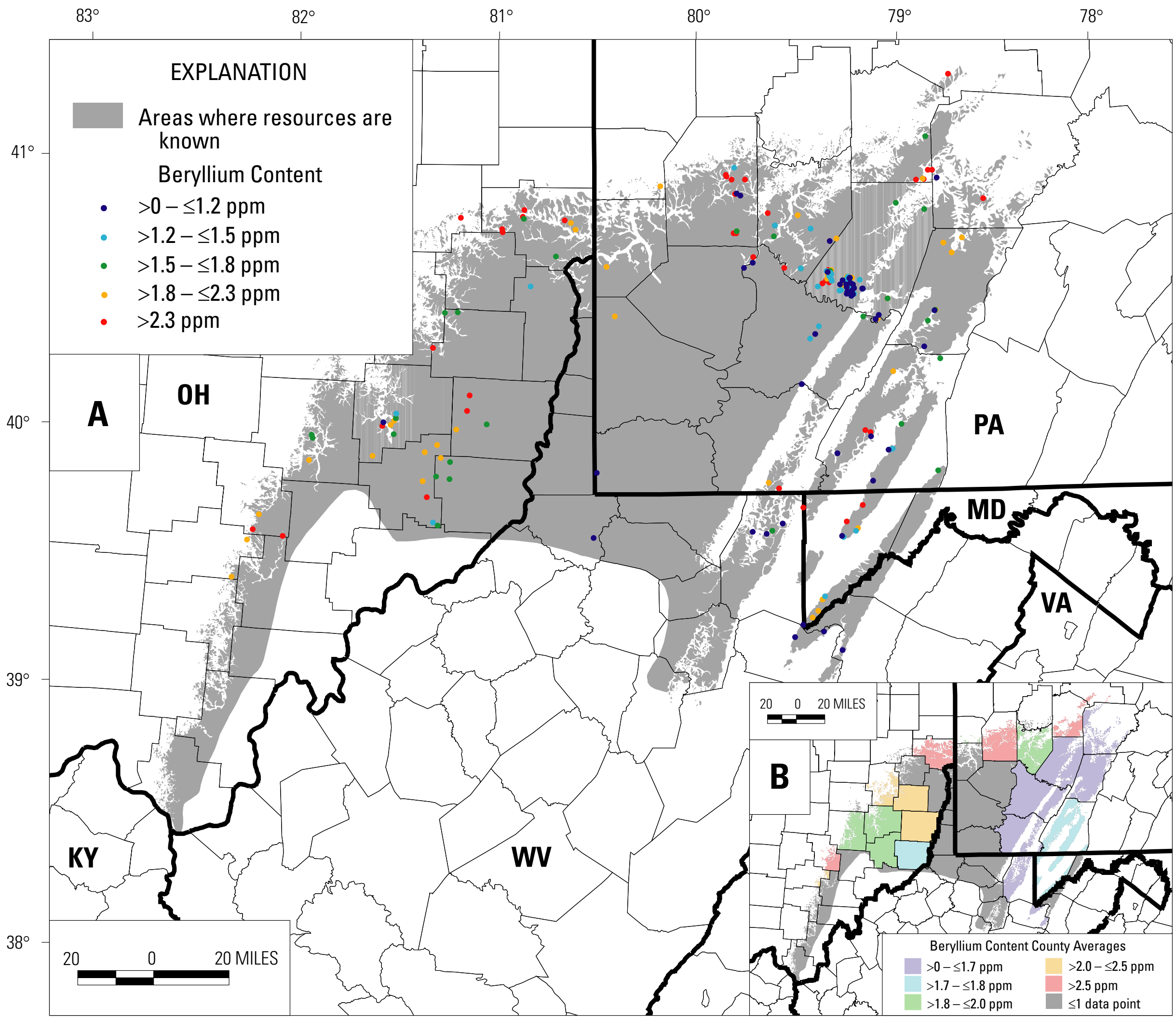


Figure 38. Maps showing beryllium content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows beryllium contents of 226 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for beryllium contents using 257 records in the geochemical database, including those that are located only to a county level; beryllium contents range from 0.21 to 5.0 ppm with a mean value of 1.8±0.81 (table 8). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 8. Beryllium content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	1.8	0.21	5.0	0.81	257
PA	na	1.7	0.39	4.3	0.72	186
WV	na	1.1	0.36	3.7	0.98	11
OH	na	2.3	0.96	5.0	0.88	47
MD	na	1.8	0.21	2.7	0.65	13
PA	Allegheny	nd	3.3	3.3	nd	1
PA	Armstrong	1.9	1.2	3.4	0.63	14
PA	Beaver	nd	1.9	1.9	nd	1
PA	Butler	2.6	0.88	4.3	1.1	13
PA	Cambria	1.7	0.61	2.3	0.49	12
PA	Clarion	nd	2.3	2.3	nd	1
PA	Clearfield	1.7	0.46	3.1	0.92	7
PA	Elk	2.8	2.5	3.1	0.39	2
PA	Fayette	1.7	1.1	2.9	0.66	6
PA	Greene	nd	1.2	1.2	nd	1
PA	Indiana	1.5	0.55	3.2	0.47	95
PA	Jefferson	2.6	1.7	3.3	0.57	6
PA	Lawrence	2.0	1.6	2.3	0.33	3
PA	Somerset	1.8	0.39	3.8	1.0	17
PA	Washington	nd	2.0	2.0	nd	1
PA	Westmoreland	1.2	0.50	1.6	0.38	6
WV	Grant	nd	0.84	0.84	nd	1
WV	Monongalia	nd	1.7	1.7	nd	1
WV	Preston	1.3	0.41	3.7	1.3	6
WV	Tucker	0.5	0.36	0.65	0.21	2
WV	Wetzel	nd	0.79	0.79	nd	1
OH	Belmont	2.5	1.7	3.9	0.98	4
OH	Columbiana	2.9	1.7	4.7	1.1	10
OH	Guernsey	1.9	0.96	3.2	0.66	8
OH	Harrison	2.3	1.6	3.1	1.0	2
OH	Hocking	2.2	2.2	2.2	0.021	2
OH	Jackson	nd	3.0	3.0	nd	1
OH	Jefferson	nd	1.4	1.4	nd	1
OH	Monroe	1.8	1.7	1.9	0.11	4
OH	Muskingum	1.9	1.6	2.2	0.28	3
OH	Noble	2.0	1.4	2.7	0.44	6
OH	Perry	3.6	2.0	5.0	1.5	3
OH	Stark	nd	2.4	2.4	nd	1
OH	Tuscarawas	2.1	1.7	2.6	0.63	2
MD	Garrett	1.8	0.21	2.7	0.65	13

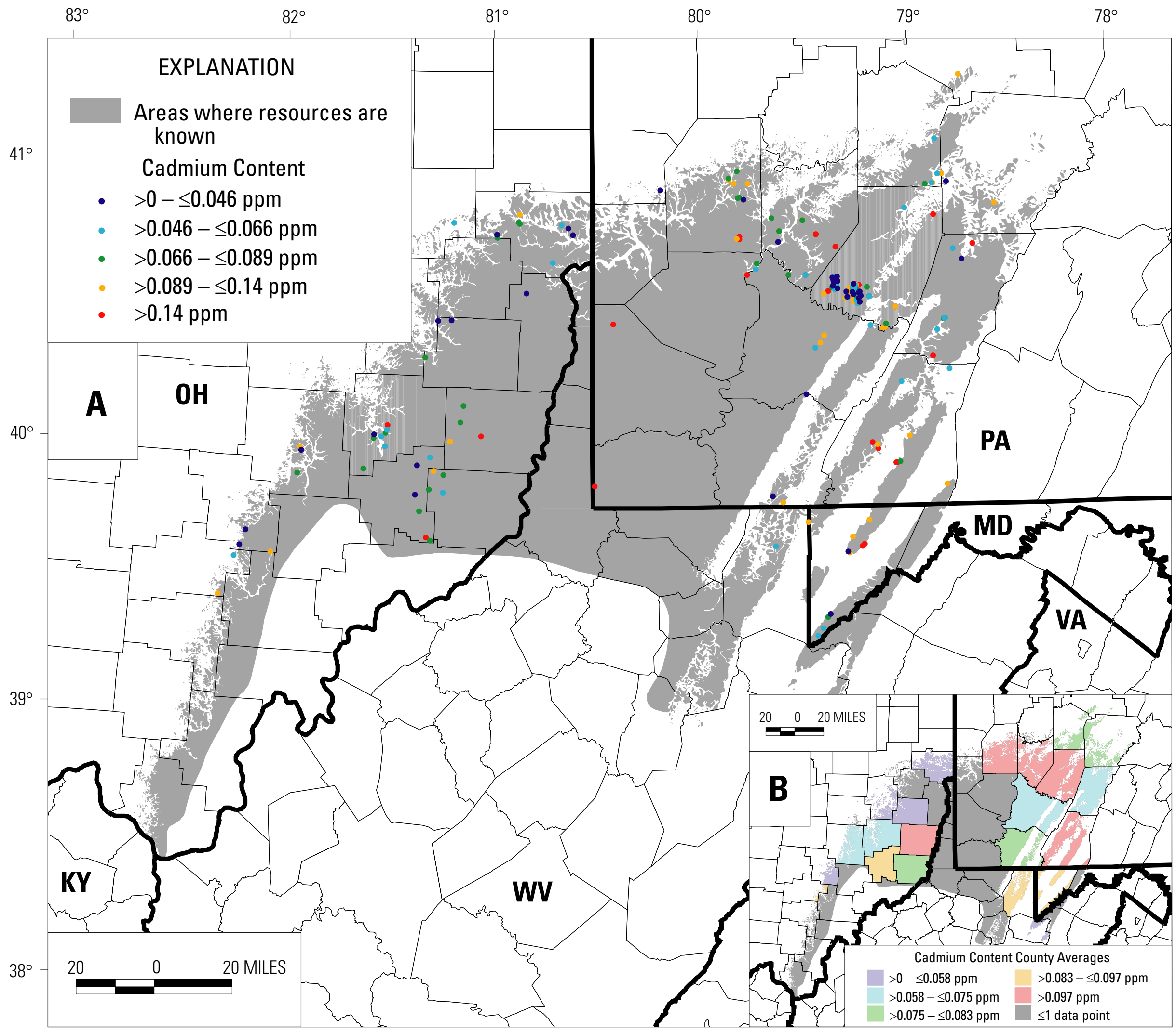


Figure 39. Maps showing cadmium content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows cadmium contents of 214 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for cadmium contents using all 250 records in the geochemical database, including those that are located only to a county level; cadmium contents range from 0.0053 ppm in West Virginia to 0.42 ppm in Pennsylvania with a mean value of 0.093±0.069 ppm (table 9). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 9. Cadmium content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	0.093	0.0053	0.42	0.069	250
PA	na	0.098	0.013	0.42	0.072	180
WV	na	0.10	0.0053	0.32	0.099	11
OH	na	0.073	0.013	0.28	0.050	46
MD	na	0.086	0.022	0.16	0.045	13
PA	Allegheny	nd	0.089	0.089	nd	1
PA	Armstrong	0.11	0.020	0.22	0.066	13
PA	Butler	0.10	0.023	0.17	0.046	13
PA	Cambria	0.071	0.040	0.15	0.028	12
PA	Clarion	nd	0.098	0.098	nd	1
PA	Clearfield	0.070	0.037	0.11	0.033	6
PA	Elk	0.077	0.059	0.095	0.026	2
PA	Fayette	0.079	0.036	0.15	0.046	6
PA	Greene	nd	0.20	0.20	nd	1
PA	Indiana	0.10	0.013	0.42	0.087	95
PA	Jefferson	0.081	0.066	0.12	0.022	6
PA	Lawrence	nd	0.037	0.037	nd	1
PA	Somerset	0.12	0.039	0.28	0.063	16
PA	Washington	nd	0.21	0.21	nd	1
PA	Westmoreland	0.068	0.047	0.10	0.025	6
WV	Grant	nd	0.15	0.15	nd	1
WV	Monongalia	nd	0.0053	0.0053	nd	1
WV	Preston	0.097	0.029	0.24	0.080	6
WV	Tucker	0.042	0.026	0.058	0.022	2
WV	Wetzel	nd	0.32	0.32	nd	1
OH	Belmont	0.14	0.069	0.28	0.095	4
OH	Columbiana	0.056	0.018	0.11	0.027	10
OH	Guernsey	0.075	0.013	0.17	0.045	8
OH	Harrison	0.058	0.041	0.075	0.024	2
OH	Hocking	0.091	0.059	0.12	0.046	2
OH	Jefferson	nd	0.024	0.024	nd	1
OH	Monroe	0.079	0.056	0.10	0.019	4
OH	Muskingum	0.075	0.038	0.11	0.034	3
OH	Noble	0.086	0.024	0.23	0.073	6
OH	Perry	0.056	0.033	0.091	0.031	3
OH	Stark	nd	0.062	0.062	nd	1
OH	Tuscarawas	0.018	0.017	0.019	0.0012	2
MD	Garrett	0.086	0.022	0.16	0.045	13

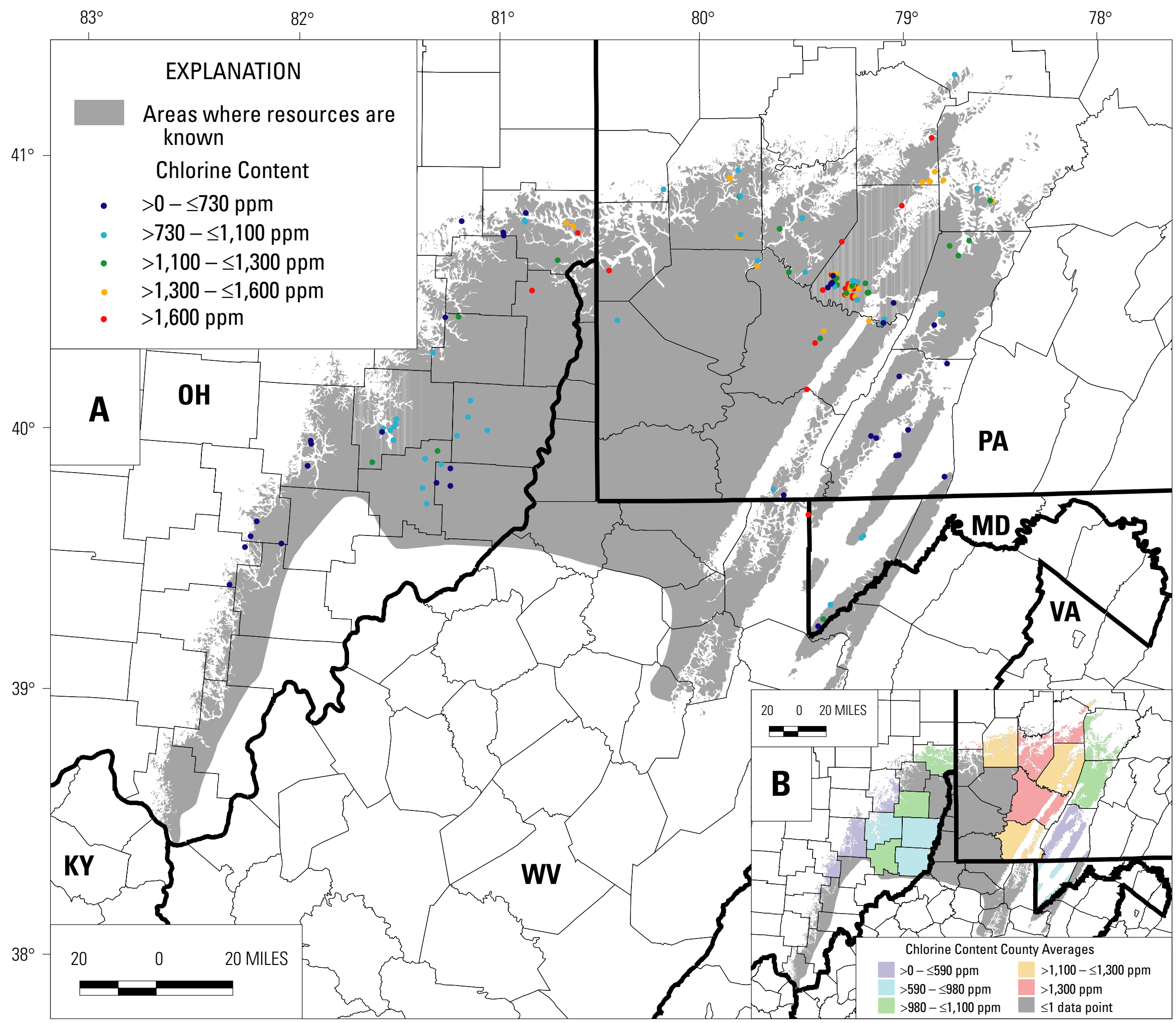


Figure 40. Maps showing chlorine content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania. Map A shows chlorine contents of 166 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for chlorine contents using all 191 records in the geochemical database, including those that are located only to a county level; chlorine contents range from 12 to 2,300 ppm with a mean value of 1,100±490 ppm. High concentrations are found in the northern part of the coal bed. In Armstrong County, Pa., the coal has a minimum chlorine content of 1,100 ppm, a maximum chlorine content of 2,300 ppm, and a mean chlorine content of 1,400±380 ppm (table 10), based on eight samples. The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 10. Chlorine content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county. No data are available for West Virginia.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	1,100	12	2,300	490	191
PA	na	1,200	94	2,300	450	139
OH	na	770	12	1,800	430	45
MD	na	980	520	1,400	310	6
PA	Allegheny	nd	940	940	nd	1
PA	Armstrong	1,400	1,100	2,300	380	8
PA	Beaver	nd	1,790	1,790	nd	1
PA	Butler	1,300	1,000	1,600	210	10
PA	Cambria	1,100	590	1,300	200	11
PA	Clearfield	1,100	94	1,600	490	8
PA	Elk	1,200	1,100	1,300	130	2
PA	Fayette	1,200	300	2,200	800	5
PA	Indiana	1,300	150	2,200	440	66
PA	Jefferson	1,500	1,400	1,800	170	5
PA	Lawrence	1,500	970	1,900	500	3
PA	Somerset	590	190	970	210	13
PA	Washington	nd	1,040	1,040	nd	1
PA	Westmoreland	1,600	1,300	1,800	180	5
OH	Belmont	950	900	980	42	4
OH	Columbiana	1,000	390	1,700	460	10
OH	Guernsey	910	680	1,200	190	8
OH	Harrison	990	820	1,200	240	2
OH	Hocking	120	96	140	30	2
OH	Jackson	nd	470	470	nd	1
OH	Jefferson	nd	1,800	1,800	nd	1
OH	Monroe	620	500	740	99	4
OH	Muskingum	320	220	410	95	3
OH	Noble	1,000	740	1,300	240	4
OH	Perry	180	12	440	230	3
OH	Stark	nd	120	120	nd	1
OH	Tuscarawas	400	270	530	180	2
MD	Garrett	980	520	1,400	310	6

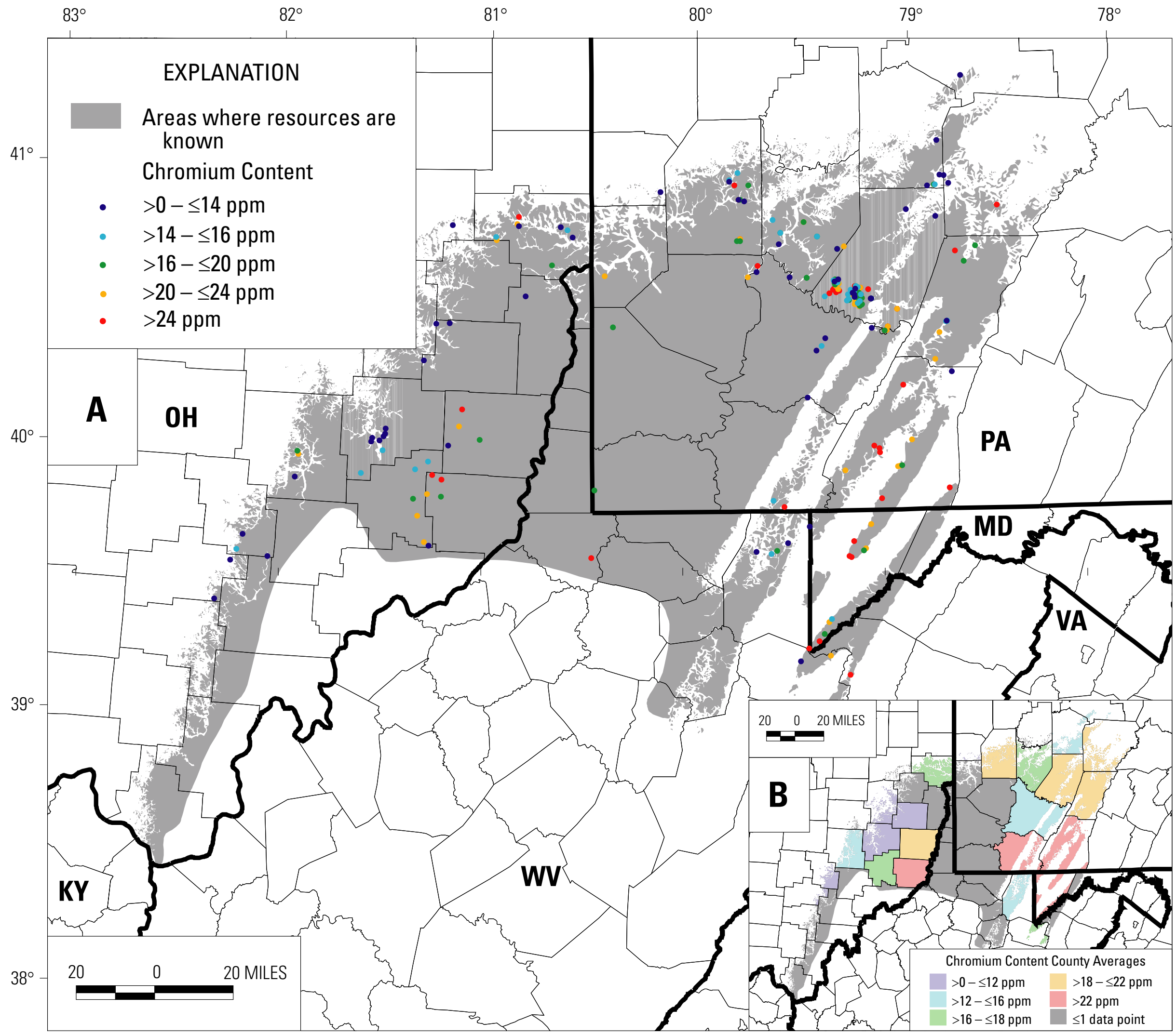


Figure 41. Maps showing chromium content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows chromium contents of 226 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for chromium contents using all 258 records in the geochemical database, inclcuding those that are located only to a county level; chromium contents range from 4.6 to 42 ppm with a mean value of 19±7.1 ppm (table 11). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 11. Chromium content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	19	4.6	42	7.1	258
PA	na	20	4.6	42	6.8	187
WV	na	20	11	39	8.5	11
OH	na	16	6.9	34	6.6	47
MD	na	23	13	40	8.1	13
PA	Allegheny	nd	25	25	nd	1
PA	Armstrong	17	8.6	24	3.8	14
PA	Beaver	nd	24	24	nd	1
PA	Butler	20	13	29	5.0	13
PA	Cambria	19	13	34	5.8	12
PA	Clarion	nd	18	18	nd	1
PA	Clearfield	18	14	28	5.0	7
PA	Elk	14	11	17	4.2	2
PA	Fayette	26	13	42	13	6
PA	Greene	nd	18	18	nd	1
PA	Indiana	20	4.6	41	6.9	96
PA	Jefferson	14	12	17	2.2	6
PA	Lawrence	12	11	12	0.81	3
PA	Somerset	24	14	37	6.6	17
PA	Washington	nd	19	19	nd	1
PA	Westmoreland	15	11	23	4.3	6
WV	Grant	nd	39	39	nd	1
WV	Monongalia	nd	16	16	nd	1
WV	Preston	16	11	26	5.5	6
WV	Tucker	17	13	22	6.1	2
WV	Wetzel	nd	27	27	nd	1
OH	Belmont	22	14	34	8.8	4
OH	Columbiana	18	9.0	29	6.5	10
OH	Guernsey	12	7.3	16	3.0	8
OH	Harrison	10	7.6	13	4.0	2
OH	Hocking	11	11	12	0.89	2
OH	Jackson	nd	6.9	6.9	nd	1
OH	Jefferson	nd	10	10	nd	1
OH	Monroe	25	20	30	5.3	4
OH	Muskingum	16	8.7	22	6.6	3
OH	Noble	18	14	24	4.5	6
OH	Perry	12	7.1	16	4.6	3
OH	Stark	nd	14	14	nd	1
OH	Tuscarawas	10	8.4	13	2.9	2
MD	Garrett	23	13	40	8.1	13

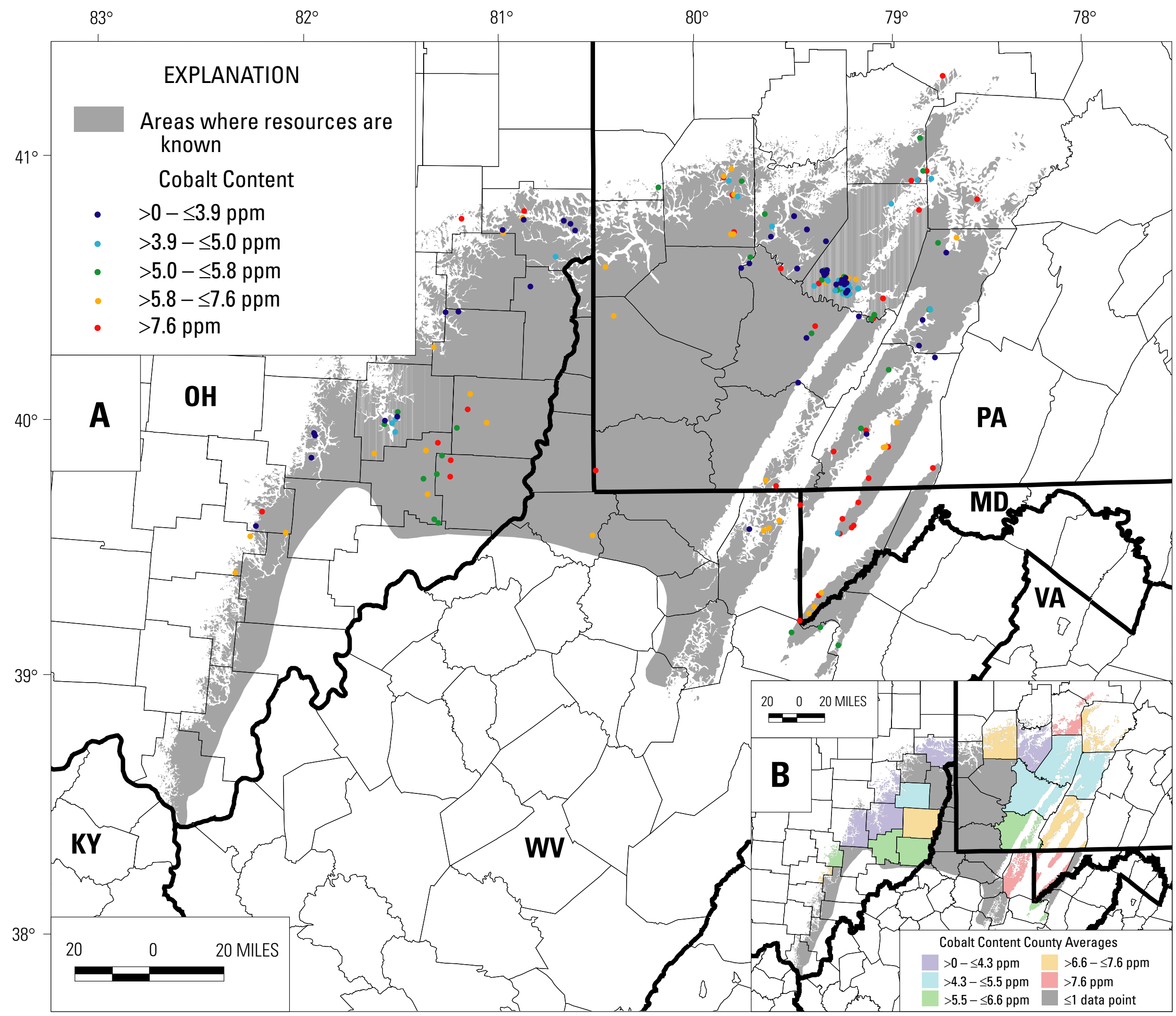


Figure 42. Maps showing cobalt content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows cobalt contents of 225 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for cobalt contents using all 254 records in the geochemical database, including those that are located only to a county level; cobalt contents range from 0.76 to 20 ppm with a mean value of 6.1±3.1 ppm (table 12). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 12. Cobalt content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	6.1	0.76	20	3.1	254
PA	na	6.0	1.4	18	2.9	183
WV	na	7.7	3.2	18	4.0	11
OH	na	5.4	0.76	14	2.7	47
MD	na	9.5	4.5	20	4.5	13
PA	Allegheny	nd	5.4	5.4	nd	1
PA	Armstrong	4.2	2.7	9.1	1.8	13
PA	Beaver	nd	7.5	7.5	nd	1
PA	Butler	7.4	4.0	12	2.4	13
PA	Cambria	5.1	1.4	7.6	1.8	12
PA	Clarion	nd	6.2	6.2	nd	1
PA	Clearfield	7.4	4.4	14	3.1	7
PA	Elk	10	8.9	12	2.2	2
PA	Fayette	6.6	3.9	9.6	2.3	6
PA	Greene	nd	9.9	9.9	nd	1
PA	Indiana	5.5	2.4	18	2.6	95
PA	Jefferson	7.8	4.8	15	3.7	6
PA	Lawrence	nd	5.7	5.7	nd	1
PA	Somerset	7.6	2.1	18	4.3	17
PA	Washington	nd	7.6	7.6	nd	1
PA	Westmoreland	4.5	2.6	9.8	2.7	6
WV	Grant	nd	5.6	5.6	nd	1
WV	Monongalia	nd	8.5	8.5	nd	1
WV	Preston	8.6	3.2	18	5.3	6
WV	Tucker	5.7	5.6	5.7	0.080	2
WV	Wetzel	nd	7.1	7.1	nd	1
OH	Belmont	7.6	5.2	11	2.6	4
OH	Columbiana	4.3	1.7	9.8	2.6	10
OH	Guernsey	4.3	0.76	6.4	1.7	8
OH	Harrison	4.7	2.9	6.5	2.5	2
OH	Hocking	7.0	6.5	7.6	0.77	2
OH	Jackson	nd	14	14	nd	1
OH	Jefferson	nd	2.4	2.4	nd	1
OH	Monroe	6.6	5.2	8.0	1.5	4
OH	Muskingum	3.1	2.8	3.5	0.36	3
OH	Noble	6.5	5.2	8.2	1.2	6
OH	Perry	6.0	2.6	8.8	3.2	3
OH	Stark	nd	8.7	8.7	nd	1
OH	Tuscarawas	2.1	1.3	2.9	1.1	2
MD	Garrett	9.5	4.5	20	4.5	13

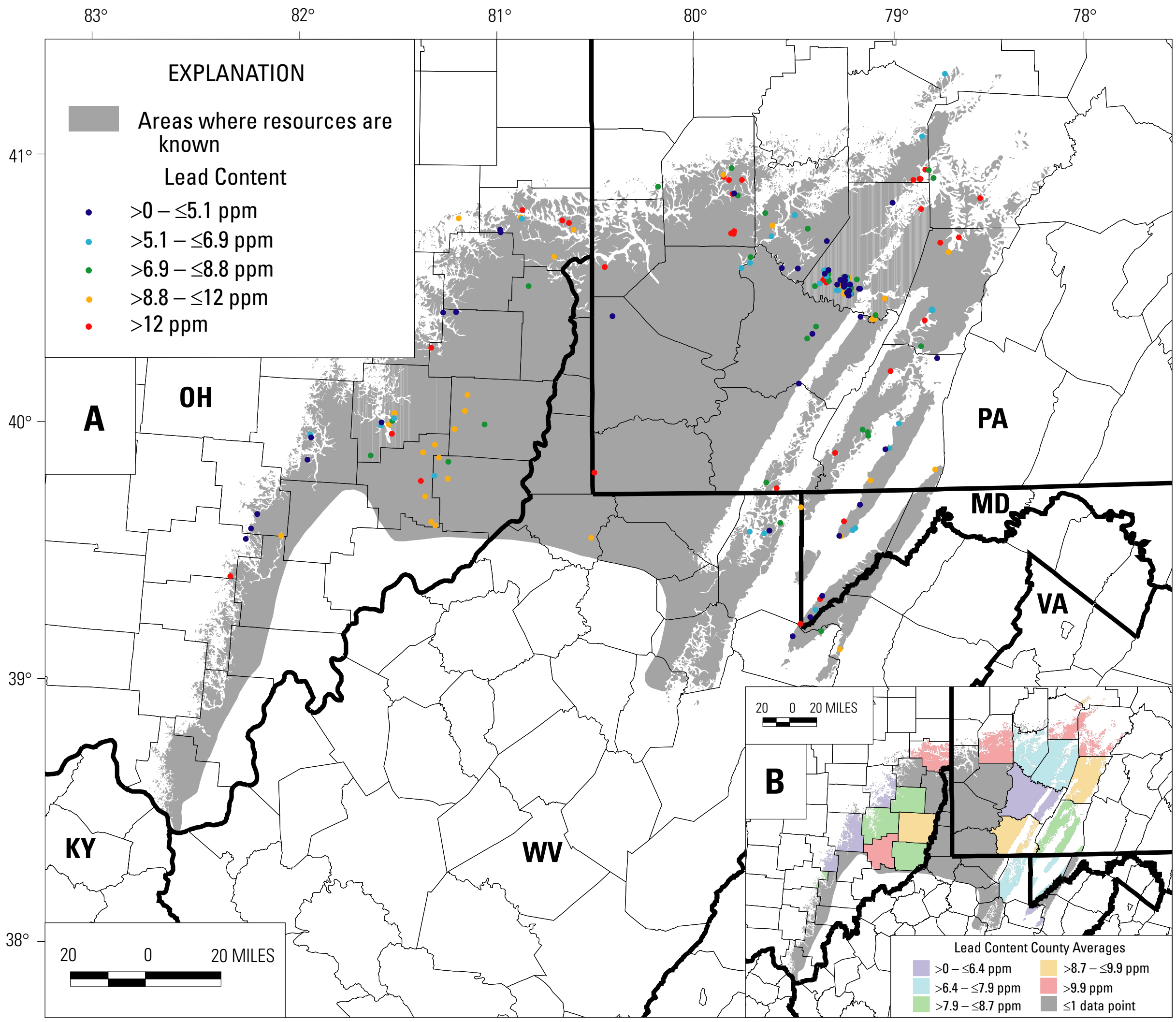


Figure 43. Maps showing lead content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows lead contents of 225 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for lead contents using all 254 records in the geochemical database, including those that are located only to a county level; lead contents range from 1.3 to 27 ppm with a mean value of 8.6±4.4 ppm (table 13). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 13. Lead content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	8.6	1.3	27	4.4	254
PA	na	8.7	1.6	27	4.4	183
WV	na	8.0	4.6	13	2.8	11
OH	na	8.6	1.3	23	4.5	47
MD	na	7.9	1.7	21	5.3	13
PA	Allegheny	nd	7.4	7.4	nd	1
PA	Armstrong	7.5	4.9	12	2.5	13
PA	Beaver	nd	19	19	nd	1
PA	Butler	14	3.8	27	6.4	13
PA	Cambria	8.9	5.3	15	3.3	12
PA	Clarion	nd	17	17	nd	1
PA	Clearfield	11	5.7	18	4.2	7
PA	Elk	8.8	6.1	11	3.7	2
PA	Fayette	9.0	3.9	15	4.3	6
PA	Greene	nd	13	13	nd	1
PA	Indiana	7.7	1.6	19	3.6	95
PA	Jefferson	13	5.4	21	5.9	6
PA	Lawrence	nd	7.9	7.9	nd	1
PA	Somerset	8.3	3.2	17	3.7	17
PA	Washington	nd	4.8	4.8	nd	1
PA	Westmoreland	5.9	3.1	7.9	1.9	6
WV	Grant	nd	9.0	9.0	nd	1
WV	Monongalia	nd	7.9	7.9	nd	1
WV	Preston	7.8	4.6	13	3.3	6
WV	Tucker	6.4	4.9	7.9	2.1	2
WV	Wetzel	nd	11	11	nd	1
OH	Belmont	9.9	8.8	11	1.1	4
OH	Columbiana	11	3.7	23	6.3	10
OH	Guernsey	8.0	1.3	15	4.1	8
OH	Harrison	8.1	3.7	13	6.2	2
OH	Hocking	8.7	3.3	14	7.7	2
OH	Jackson	nd	8.8	8.8	nd	1
OH	Jefferson	nd	7.0	7.0	nd	1
OH	Monroe	8.1	6.5	9.4	1.4	4
OH	Muskingum	3.9	1.9	5.6	1.8	3
OH	Noble	11	9.2	14	1.8	6
OH	Perry	5.7	2.3	11	4.4	3
OH	Stark	nd	9.9	9.9	nd	1
OH	Tuscarawas	2.9	2.8	3.0	0.15	2
MD	Garrett	7.9	1.7	21	5.3	13

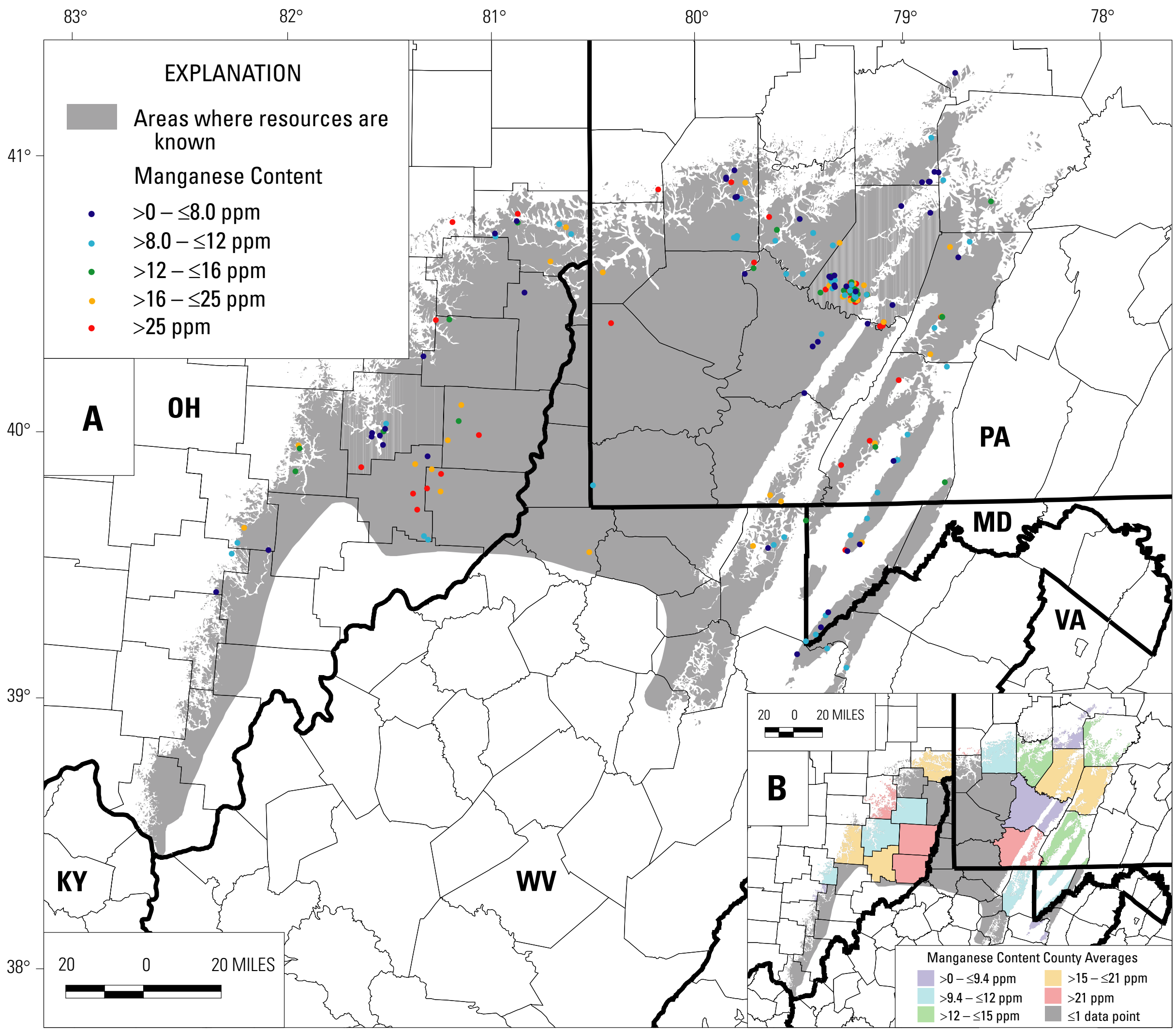


Figure 44. Maps showing manganese content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows manganese contents of 226 geochemical samples for which records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for manganese contents using all 258 records in the geochemical database, including those that are located only to a county level; manganese contentes range from 2.4 to 65 ppm with a mean value of 18±13 ppm (table 14). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 14. Manganese content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	18	2.4	65	13	258
PA	na	19	3.2	65	13	187
WV	na	12	2.4	22	6.0	11
OH	na	17	2.4	56	13	47
MD	na	11	3.2	33	8.1	13
PA	Allegheny	nd	31	31	nd	1
PA	Armstrong	13	8.0	35	7.8	14
PA	Beaver	nd	20	20	nd	1
PA	Butler	12	3.2	39	9.2	13
PA	Cambria	21	4.0	63	16	12
PA	Clarion	nd	9.9	9.9	nd	1
PA	Clearfield	14	7.7	21	4.5	7
PA	Elk	9.4	5.2	14	6.0	2
PA	Fayette	24	5.5	63	21	6
PA	Greene	nd	9.6	9.6	nd	1
PA	Indiana	21	3.6	65	13	96
PA	Jefferson	5.8	3.3	9.9	2.4	6
PA	Lawrence	48	40	53	7.5	3
PA	Somerset	15	3.9	48	12	17
PA	Washington	nd	46	46	nd	1
PA	Westmoreland	8.5	6.4	13	2.4	6
WV	Grant	nd	12	12	nd	1
WV	Monongalia	nd	8.9	8.9	nd	1
WV	Preston	12	3.1	20	5.5	6
WV	Tucker	6.4	2.4	10	5.6	2
WV	Wetzel	nd	22	22	nd	1
OH	Belmont	22	13	37	11	4
OH	Columbiana	16	3.7	46	12	10
OH	Guernsey	10	2.4	35	11	8
OH	Harrison	9.9	5.5	14	6.3	2
OH	Hocking	7.7	3.0	12	6.6	2
OH	Jackson	nd	19	19	nd	1
OH	Jefferson	nd	4.0	4.0	nd	1
OH	Monroe	36	23	56	16	4
OH	Muskingum	18	16	21	2.7	3
OH	Noble	17	7.1	31	10	6
OH	Perry	11	3.7	18	7.3	3
OH	Stark	nd	39	39	nd	1
OH	Tuscarawas	32	29	36	5.2	2
MD	Garrett	11	3.2	33	8.1	13

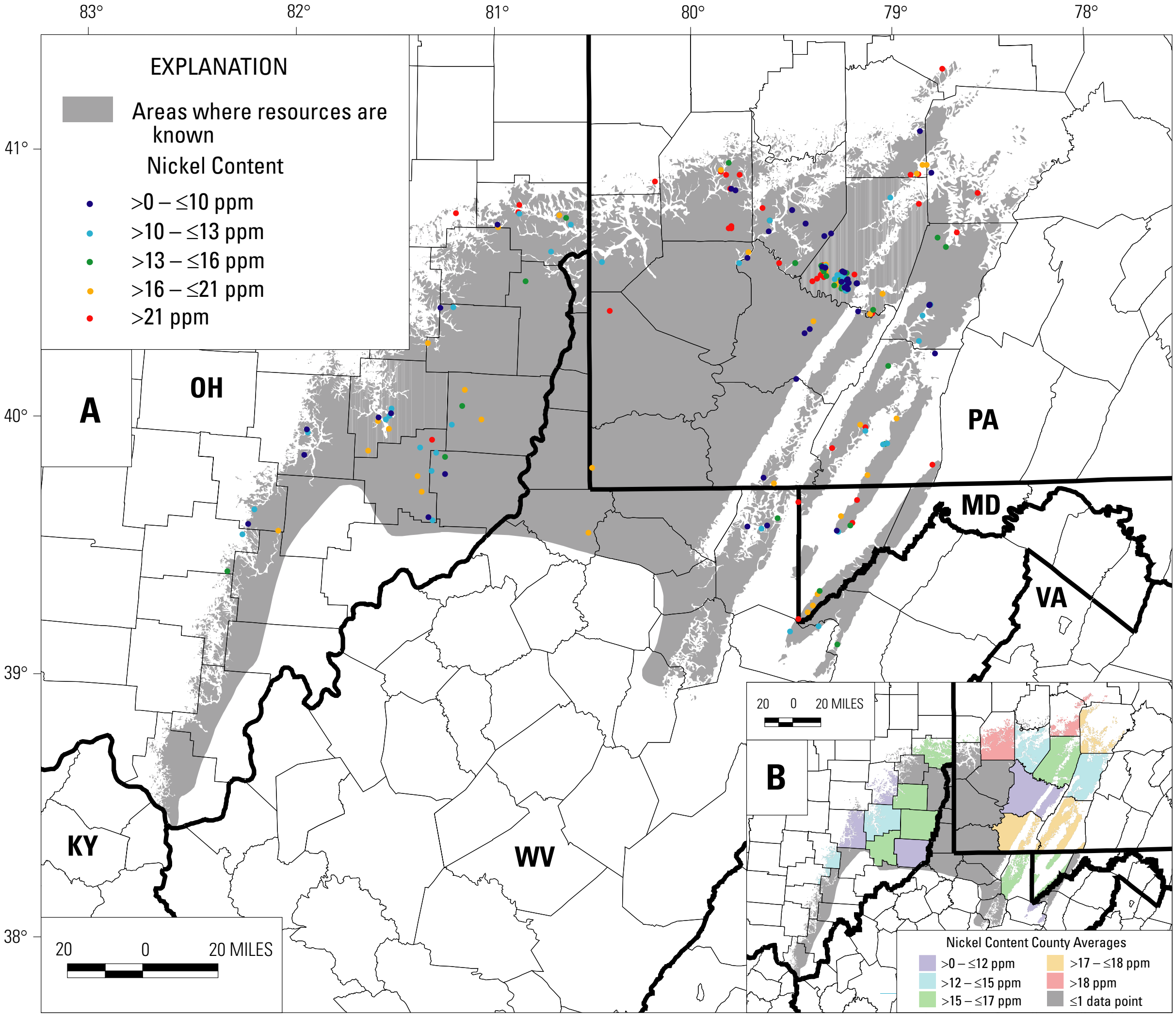


Figure 45. Maps showing nickel content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows nickel contents of 226 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for nickel contents using all 258 records in the geochemical database, including those located only to a county level; nickel contents range from 2.6 to 48 ppm with a mean value of 16±7.6 ppm (table 15). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 15. Nickel content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	16	2.6	48	7.6	258
PA	na	17	5.1	48	7.9	187
WV	na	16	9.3	32	7.1	11
OH	na	15	3.4	36	6.2	47
MD	na	17	2.6	28	7.4	13
PA	Allegheny	nd	18	18	nd	1
PA	Armstrong	14	7.2	31	6.5	14
PA	Beaver	nd	12	12	nd	1
PA	Butler	26	5.9	42	11	13
PA	Cambria	15	10	37	7.2	12
PA	Clarion	nd	21	21	nd	1
PA	Clearfield	17	7.5	27	6.8	7
PA	Elk	28	19	37	12	2
PA	Fayette	18	8.3	44	14	6
PA	Greene	nd	21	21	nd	1
PA	Indiana	16	5.1	48	6.8	96
PA	Jefferson	20	9.3	28	6.7	6
PA	Lawrence	17	12	24	6.7	3
PA	Somerset	18	7.9	37	6.8	17
PA	Washington	nd	26	26	nd	1
PA	Westmoreland	10	7.4	17	3.5	6
WV	Grant	nd	15	15	nd	1
WV	Monongalia	nd	10	10	nd	1
WV	Preston	17	9.3	32	8.9	6
WV	Tucker	11	11	11	0.22	2
WV	Wetzel	nd	19	19	nd	1
OH	Belmont	17	13	21	3.8	4
OH	Columbiana	17	10	36	8.1	10
OH	Guernsey	13	3.4	21	5.5	8
OH	Harrison	16	12	19	4.6	2
OH	Hocking	14	13	14	0.59	2
OH	Jackson	nd	17	17	nd	1
OH	Jefferson	nd	16	16	nd	1
OH	Monroe	12	9.0	14	2.4	4
OH	Muskingum	9.6	7.5	12	2.6	3
OH	Noble	16	9.5	30	7.7	6
OH	Perry	13	9.5	17	3.7	3
OH	Stark	nd	26	26	nd	1
OH	Tuscarawas	6.4	4.0	8.8	3.4	2
MD	Garrett	17	2.6	28	7.4	13

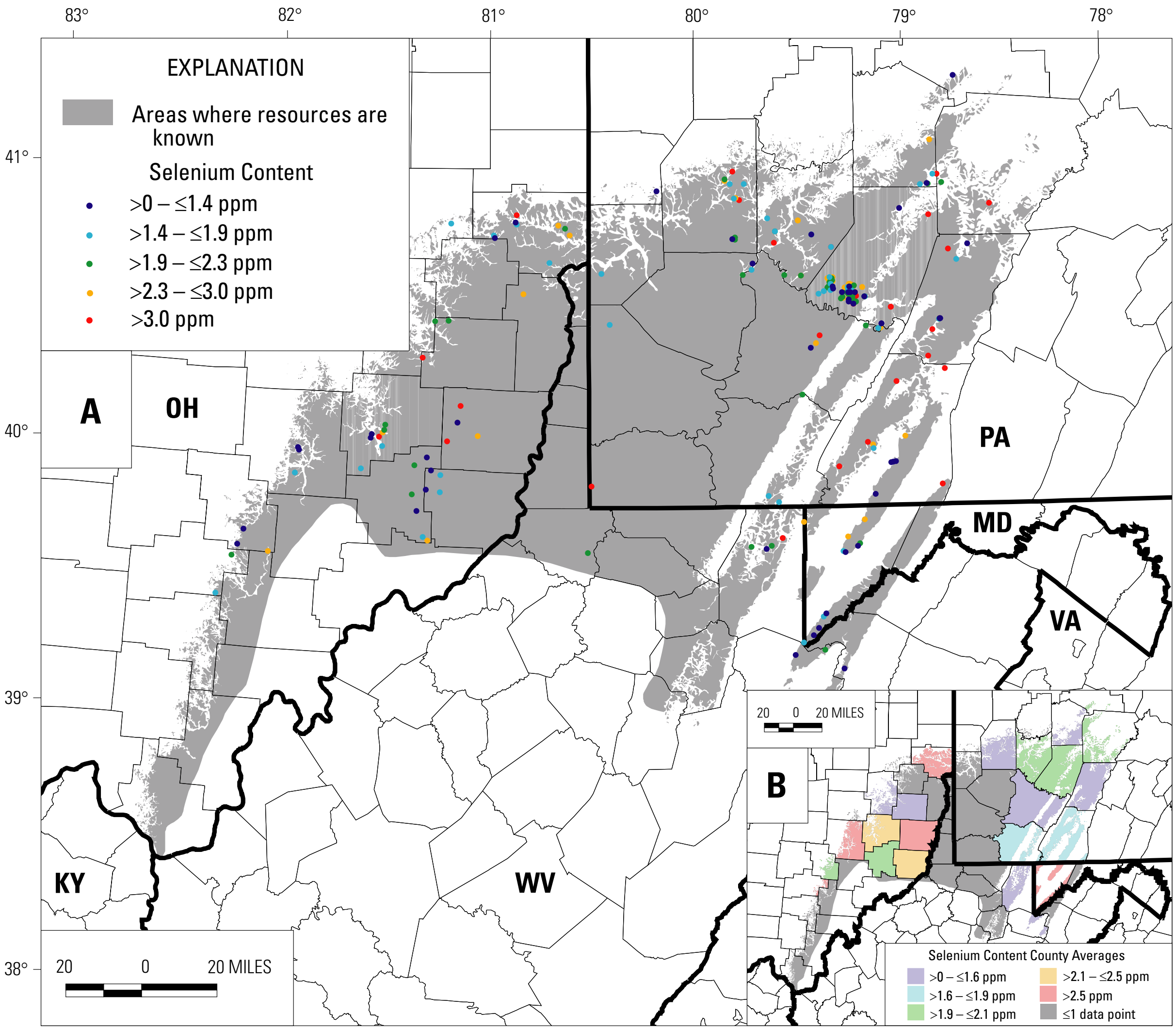


Figure 46. Maps showing selenium content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows selenium contents of 224 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for selenium contents using all 250 records in the geochemical database, including those located only to a county level; selenium contents range from 0.098 to 6.0 ppm with a mean value of 2.0±1.1 ppm (table 16). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 16. Selenium content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	2.0	0.098	6.0	1.1	250
PA	na	1.9	0.098	6.0	1.0	180
WV	na	1.1	0.17	2.7	0.97	11
OH	na	2.6	0.78	5.7	1.1	46
MD	na	2.7	0.63	5.5	1.3	13
PA	Allegheny	nd	0.96	0.96	nd	1
PA	Armstrong	2.1	0.67	6.0	1.5	13
PA	Butler	1.6	0.66	2.2	0.45	13
PA	Cambria	1.2	0.26	2.5	0.65	12
PA	Clarion	nd	0.45	0.45	nd	1
PA	Clearfield	1.9	0.19	3.6	1.2	6
PA	Elk	2.1	0.70	3.4	1.9	2
PA	Fayette	1.9	0.27	3.7	1.2	6
PA	Greene	nd	0.63	0.63	nd	1
PA	Indiana	2.1	0.38	6.0	0.94	95
PA	Jefferson	1.6	0.42	2.4	0.72	6
PA	Lawrence	nd	1.7	1.7	nd	1
PA	Somerset	1.9	0.098	5.1	1.5	16
PA	Washington	nd	3.8	3.8	nd	1
PA	Westmoreland	1.6	0.43	2.8	0.84	6
WV	Grant	nd	0.68	0.68	nd	1
WV	Monongalia	nd	2.5	2.5	nd	1
WV	Preston	1.1	0.20	2.7	1.1	6
WV	Tucker	0.42	0.17	0.66	0.35	2
WV	Wetzel	nd	1.3	1.3	nd	1
OH	Belmont	3.1	2.7	3.6	0.41	4
OH	Columbiana	3.3	2.2	5.6	0.96	10
OH	Guernsey	2.3	1.3	3.0	0.52	8
OH	Harrison	1.6	1.4	1.8	0.28	2
OH	Hocking	4.4	3.1	5.7	1.8	2
OH	Jefferson	nd	2.0	2.0	nd	1
OH	Monroe	2.5	1.9	3.3	0.58	4
OH	Muskingum	2.9	2.0	3.4	0.77	3
OH	Noble	2.0	1.1	2.9	0.72	6
OH	Perry	2.1	0.87	4.3	1.9	3
OH	Stark	nd	0.78	0.78	nd	1
OH	Tuscarawas	1.4	1.2	1.6	0.31	2
MD	Garrett	2.7	0.63	5.5	1.3	13

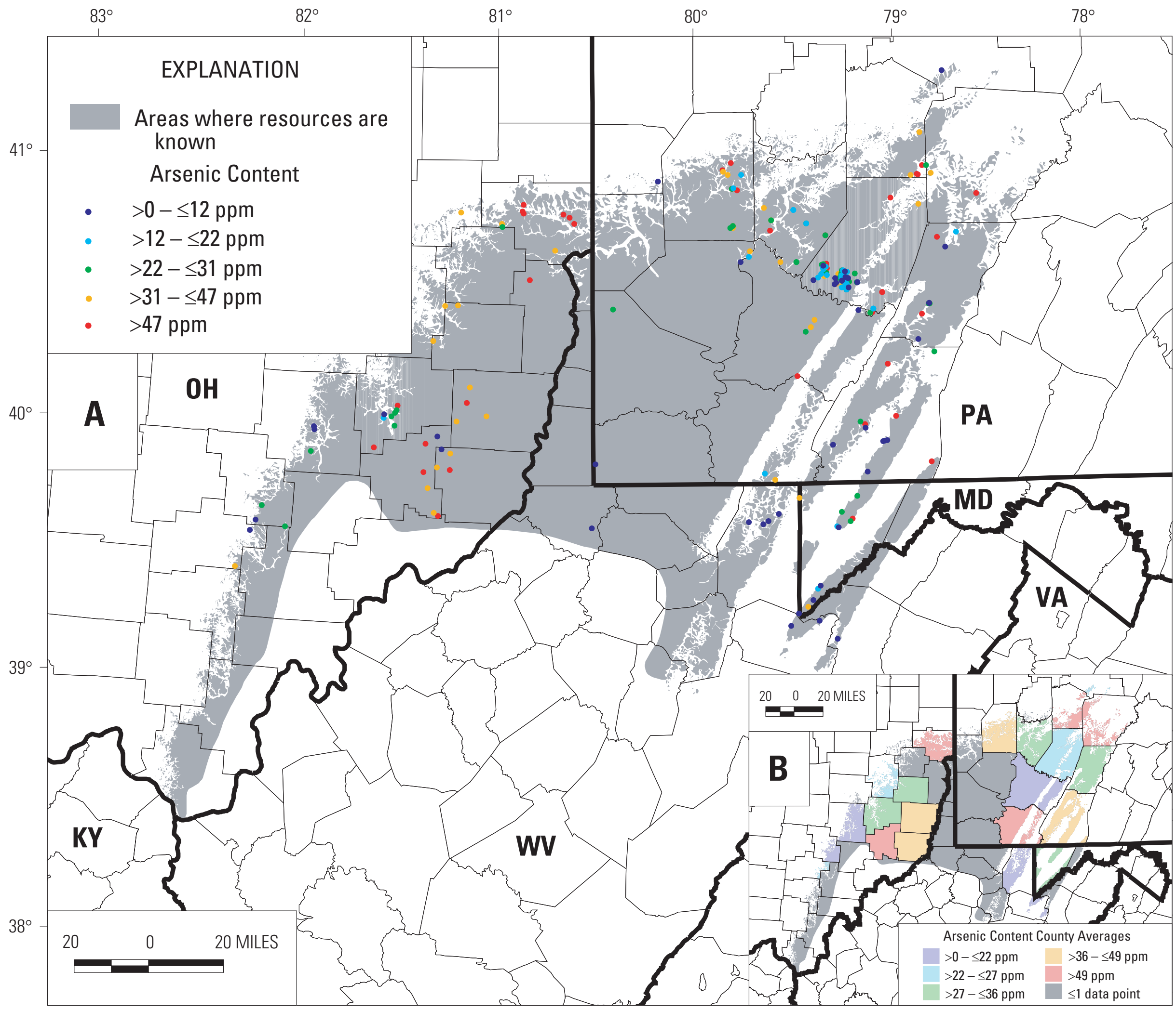


Figure 47. Maps showing arsenic content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows arsenic contents of 224 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for arsenic contents using all 250 records in the geochemical database, including those that are located only to a county level; arsenic contents range from 0.72 to 130 ppm with a mean value of 34±25 ppm (table 17). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 17. Arsenic content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	34	0.72	130	25	250
PA	na	33	0.73	130	23	180
WV	na	16	0.72	41	14	11
OH	na	44	3.9	120	29	46
MD	na	32	4.3	90	24	13
PA	Allegheny	nd	3.3	3.3	nd	1
PA	Armstrong	32	16	60	13	13
PA	Butler	38	17	56	14	13
PA	Cambria	34	6.8	100	26	12
PA	Clarion	nd	46	46	nd	1
PA	Clearfield	74	33	130	37	6
PA	Elk	25	3.2	47	31	2
PA	Fayette	50	15	97	31	6
PA	Greene	nd	26	26	nd	1
PA	Indiana	27	0.73	130	19	95
PA	Jefferson	50	31	71	16	6
PA	Lawrence	nd	8.2	8.2	nd	1
PA	Somerset	38	2.0	110	34	16
PA	Washington	nd	30	30	nd	1
PA	Westmoreland	22	8.3	41	13	6
WV	Grant	nd	9.1	9.1	nd	1
WV	Monongalia	nd	1.2	1.2	nd	1
WV	Preston	17	0.72	34	13	6
WV	Tucker	11	1.3	20	13	2
WV	Wetzel	nd	41	41	nd	1
OH	Belmont	49	36	78	19	4
OH	Columbiana	68	26	120	32	10
OH	Guernsey	36	3.9	110	31	8
OH	Harrison	34	33	35	1.4	2
OH	Hocking	25	9.2	41	23	2
OH	Jefferson	nd	56	56	nd	1
OH	Monroe	43	10	81	29	4
OH	Muskingum	17	9.0	28	10	3
OH	Noble	54	11	90	29	6
OH	Perry	20	8.8	30	11	3
OH	Stark	nd	32	32	nd	1
OH	Tuscarawas	23	13	33	14	2
MD	Garrett	32	4.3	90	24	13

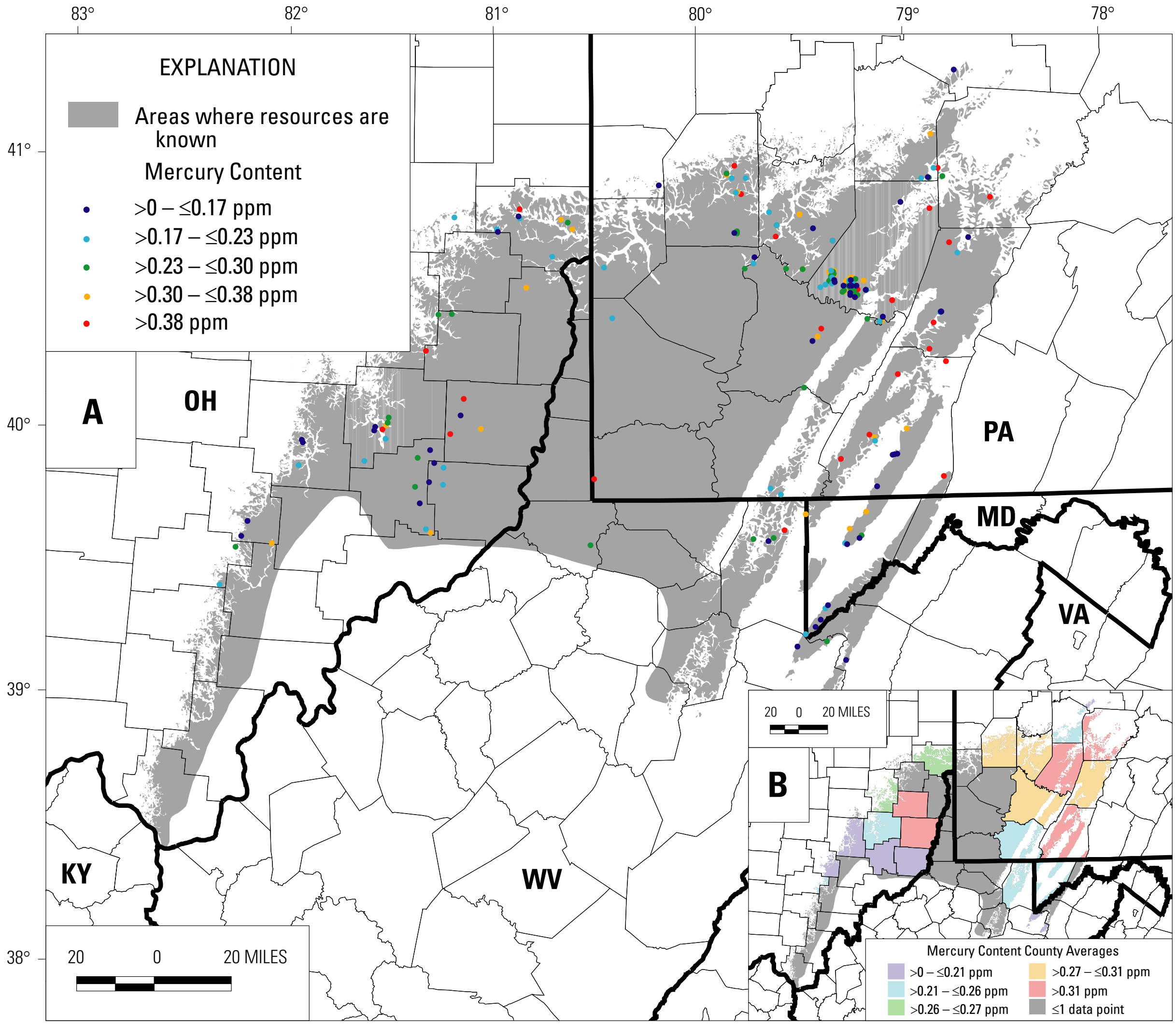


Figure 48. Maps showing mercury content (parts per million (ppm), as-received whole-coal basis) of the Upper Freeport coal bed in Pennsylvania, West Virginia, Ohio, and Maryland. Map A shows mercury contents of 225 samples for which geochemical records are publicly available and located by latitude and longitude (Appendix 8). Map B shows county averages for mercury contents using all 253 records in the geochemical database, including those that are located only to a county level; mercury contents range from 0.0012 to 0.97 ppm with a mean value of 0.30±0.17 ppm (table 18). The values are classified into five categories, each representing 20 percent of the data values. See figure 3 for county names.

Table 18. Mercury content (parts per million) means, ranges, and standard deviations for samples of the Upper Freeport coal bed on an as-received whole-coal basis, by State and county.

[Abbreviations are as follows: na, not applicable; nd, no data available.]

STATE	COUNTY	Mean	Minimum	Maximum	Standard deviation	No. of Samples
ALL	na	0.30	0.0012	0.97	0.17	253
PA	na	0.32	0.0012	0.97	0.17	182
WV	na	0.21	0.0030	0.39	0.13	11
OH	na	0.25	0.033	0.50	0.12	47
MD	na	0.26	0.0012	0.75	0.23	13
PA	Allegheny	nd	0.0099	0.0099	nd	1
PA	Armstrong	0.31	0.17	0.81	0.17	13
PA	Beaver	nd	0.21	0.21	nd	1
PA	Butler	0.29	0.17	0.52	0.10	13
PA	Cambria	0.29	0.044	0.50	0.19	12
PA	Clarion	nd	0.33	0.33	nd	1
PA	Clearfield	0.36	0.15	0.57	0.17	7
PA	Elk	0.17	0.0012	0.34	0.24	2
PA	Fayette	0.25	0.10	0.44	0.11	6
PA	Greene	nd	0.39	0.39	nd	1
PA	Indiana	0.33	0.0012	0.96	0.17	95
PA	Jefferson	0.26	0.047	0.49	0.15	6
PA	Lawrence	nd	0.010	0.010	nd	1
PA	Somerset	0.36	0.040	0.97	0.26	16
PA	Washington	nd	0.22	0.22	nd	1
PA	Westmoreland	0.28	0.099	0.52	0.14	6
WV	Grant	nd	0.17	0.17	nd	1
WV	Monongalia	nd	0.0030	0.0030	nd	1
WV	Preston	0.26	0.069	0.39	0.12	6
WV	Tucker	0.13	0.030	0.24	0.15	2
WV	Wetzel	nd	0.28	0.28	nd	1
OH	Belmont	0.32	0.079	0.45	0.17	4
OH	Columbiana	0.27	0.17	0.48	0.097	10
OH	Guernsey	0.26	0.11	0.50	0.13	8
OH	Harrison	0.36	0.27	0.44	0.12	2
OH	Hocking	0.23	0.19	0.28	0.065	2
OH	Jackson	nd	0.50	0.50	nd	1
OH	Jefferson	nd	0.37	0.37	nd	1
OH	Monroe	0.16	0.070	0.23	0.076	4
OH	Muskingum	0.14	0.067	0.21	0.073	3
OH	Noble	0.21	0.033	0.35	0.11	6
OH	Perry	0.21	0.12	0.35	0.12	3
OH	Stark	nd	0.20	0.20	nd	1
OH	Tuscarawas	0.27	0.24	0.31	0.05	2
MD	Garrett	0.26	0.0012	0.75	0.23	13

Because the Upper Freeport coal bed is bituminous in rank, its total moisture (fig. 36; table 6) tends to be relatively low with a mean of 2.63±1.60 percent for the entire bed (2,015 analyses).

The Clean Air Act Amendments of 1990 listed 12 elements that may adversely affect the environment. These elements include antimony, beryllium, cadmium, chlorine, chromium, cobalt, lead, manganese, nickel, selenium, arsenic, and mercury. For the Upper Freeport coal bed, 258 samples were analyzed for these 12 elements (figs. 37–48; tables 7–18).

ARSENIC AND MERCURY

Two of the elements thought to have particularly adverse effects include arsenic and mercury (figs. 47, 48). The mean arsenic concentration (as-received whole-coal basis) for 250 Upper Freeport coal bed samples is 34±25 ppm (table 17). This compares well to the mean arsenic concentration of 35 ppm for all Appalachian Basin coal (Finkelman and others, 1994), but is significantly higher than the mean of 24 ppm for all U.S. coal (Finkelman, 1993).

For the Upper Freeport coal bed, 253 samples were analyzed for mercury on an as-received whole-coal basis (fig. 48). The mean mercury content of the Upper Freeport coal bed is 0.30±0.17 ppm (table 18). These values are slightly higher than the mean of 0.21 ppm for all Appalachian Basin coal (Finkelman and others, 1994) and almost twice as high as the mean of 0.17 ppm for all U.S. coal (Finkelman, 1993).

RESOURCES

Based on our resource calculations, the original total resource of the Upper Freeport coal bed was 34 billion short tons (table 1). This total resource number includes 22 billion short tons of identified and 12 billion short tons of hypothetical coal (Appendix 12). Because mine maps were not compiled for Allegany and Garrett Counties, Md., and Beaver, Clearfield, Elk, and Lawrence Counties, Pa., the remaining resource estimate of 31 billion short tons (table 1; Appendix 13) is a maximum value. The remaining Upper Freeport coal exhibits similar characteristics of the Pittsburgh coal bed (see Chapter C, this report); it tends to be thinner (fig. 24), it is under somewhat deeper cover (fig. 22), and has a higher ash yield (fig. 30) and sulfur content (fig. 31) than the coal that has already been mined.

In Maryland, the Upper Freeport coal bed underlies much of the Georges Creek basin in western Allegany and eastern Garrett Counties and in the Potomac, Castleman, and Upper Youghiogheny river basins in Garrett County. The original resource of the Upper Freeport coal bed in Maryland is estimated to be 910 million short tons (table 1; Appendixes 12, 13), and about four fifths, or 710 million short tons, was located in Garrett County. About two-thirds of the Upper Freeport coal is in the >3.5- to 7.0-ft and >7.0- to 14.0-ft thickness categories (fig. 49). Only about 3 percent of the coal is under deep (1,000-2,000 ft) overburden (fig. 50); the remaining coal is fairly evenly dispersed between the three shallower overburden categories (0-200 ft, 200-500 ft, and 500-1,000 ft). About 75 percent of the original and remaining coal is in the identified reliability category (fig. 51).

The Upper Freeport coal in Maryland is high in ash (14.53±5.46 weight percent, as-received whole-coal basis), sulfur (2.90±1.54 weight percent, as-received whole-coal basis), and gross calorific value (13,000±840 Btu/lb as-received whole-coal basis) in comparison to Upper Freeport coal in Pennsylvania, West Virginia, and Ohio (tables 2, 3, 5). Upper Freeport coal has not been produced from Allegany County, Md., since 1985, with a single exception of 599 short tons in 1991 (Appendix 6). Virtually all of Maryland's Upper Freeport production (fig. 16) is from the Mettiki underground mine in Garrett County.

In Pennsylvania, the original and remaining resource of the Upper Freeport coal bed is estimated at 16 billion short tons (table 1; Appendixes 12, 13). The Commonwealth of Pennsylvania reported that Upper Freeport coal production from 1975 to 1995 in Beaver, Clearfield, Elk, and Lawrence Counties (counties where mine maps were not compiled) was about 0.59, 11, 0.67, and 0.27 million short tons, respectively (Appendix 3). Therefore, the USGS remaining resource number of 14 billion short tons is a maximum. Nevertheless, substantial Upper Freeport coal resources remain in Pennsylvania. The coal is relatively thick and shallow with about 40 percent of the remaining coal in the two greatest thickness categories (>3.5 to 7.0 ft and >7.0 to 14.0 ft) (fig. 49) and the shallowest overburden categories (0 to 500 ft) (fig. 50), but only 24 percent of this is in the identified category (fig. 51). The Upper Freeport coal in Pennsylvania is moderate in quality with a mean ash yield of 12.40±3.98 weight percent, as-received basis (table 2); a mean sulfur content of 2.21±0.98 weight percent, as-received basis (table 3); and a mean gross calorific value of 12,980±690 Btu/lb, as-received basis (table 5). The coal generally increases in rank from high-volatile A bituminous in the west to low-volatile bituminous in the east (fig. 35).

In West Virginia, only about 10 percent of the original resource has been mined (4.5 of the original 5.0 billion short tons remaining; Appendixes 12, 13), probably because geologic conditions were not conducive to the deposition and preservation of abundant thick Upper Freeport coal pods. The remaining unmined thick pod, located in southern Marshall and northern Wetzel Counties (fig. 24) is under deep overburden cover (>1,000–2,000 ft; fig. 22) and is

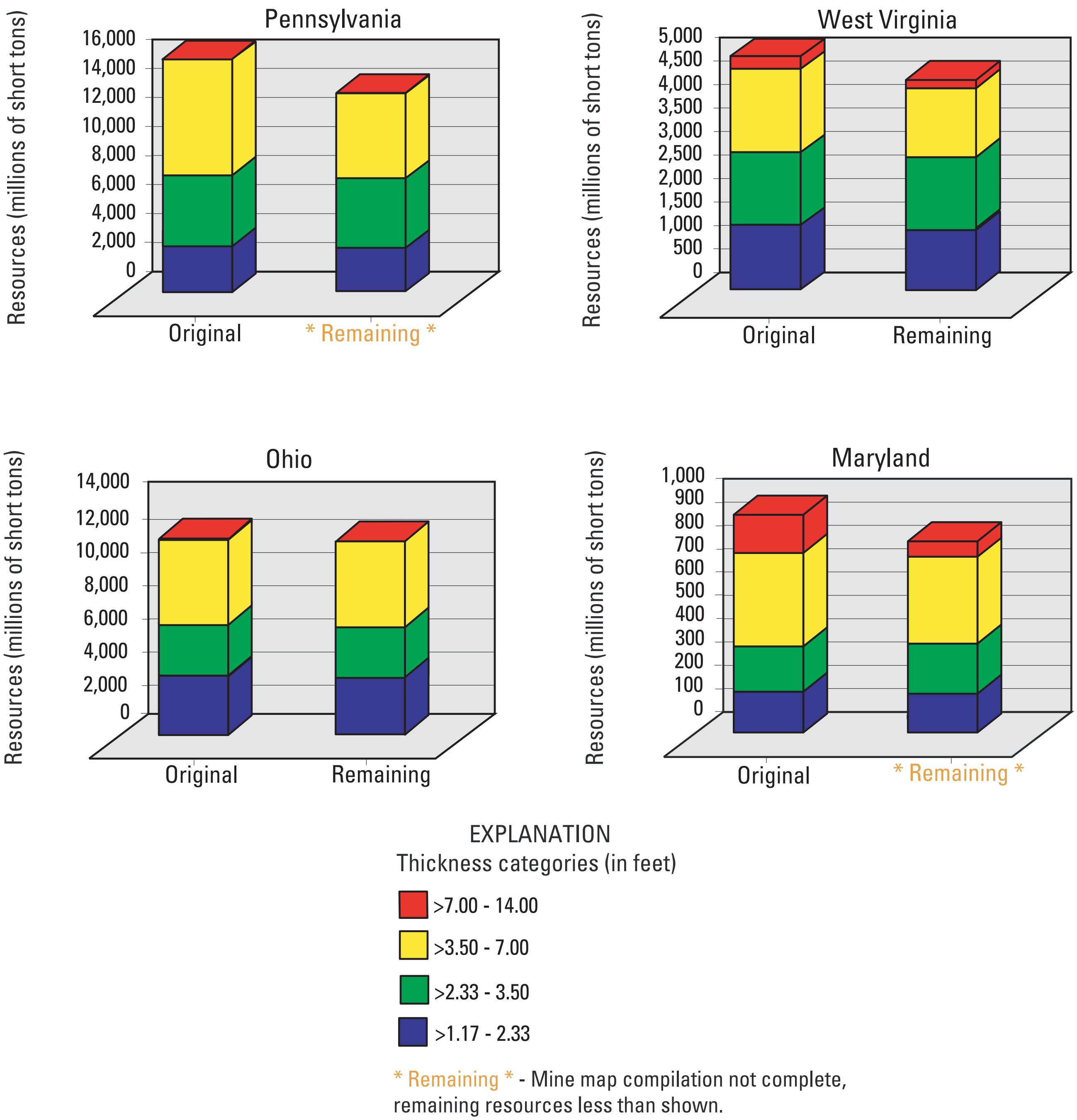


Figure 49. Bar graphs showing original and remaining Upper Freeport coal bed resources (millions of short tons), by State and USGS thickness categories. Most of the Upper Freeport coal is in the >2.33- to 3.5-ft and >3.5- to 7.0-ft thickness categories (Appendixes 12, 13).

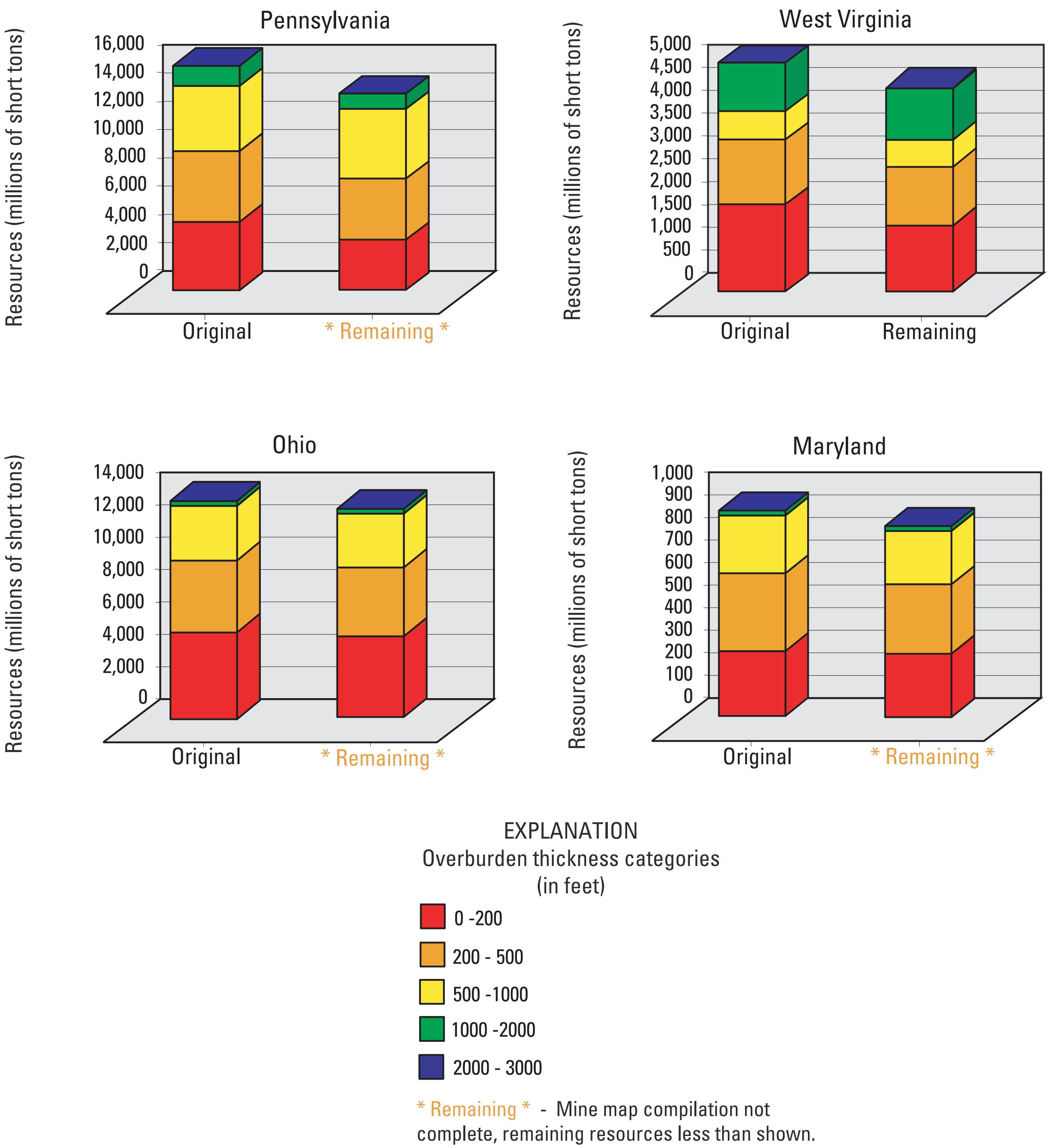


Figure 50. Bar graphs showing original and remaining Upper Freeport coal bed resources (millions of short tons), by State and USGS overburden thickness categories (Appendixes 12, 13). Although the deepest overburden category is classified as up to 3,000 ft, the greatest overburden thickness is actually about 2,000 ft and is in Wetzel County, W. Va..

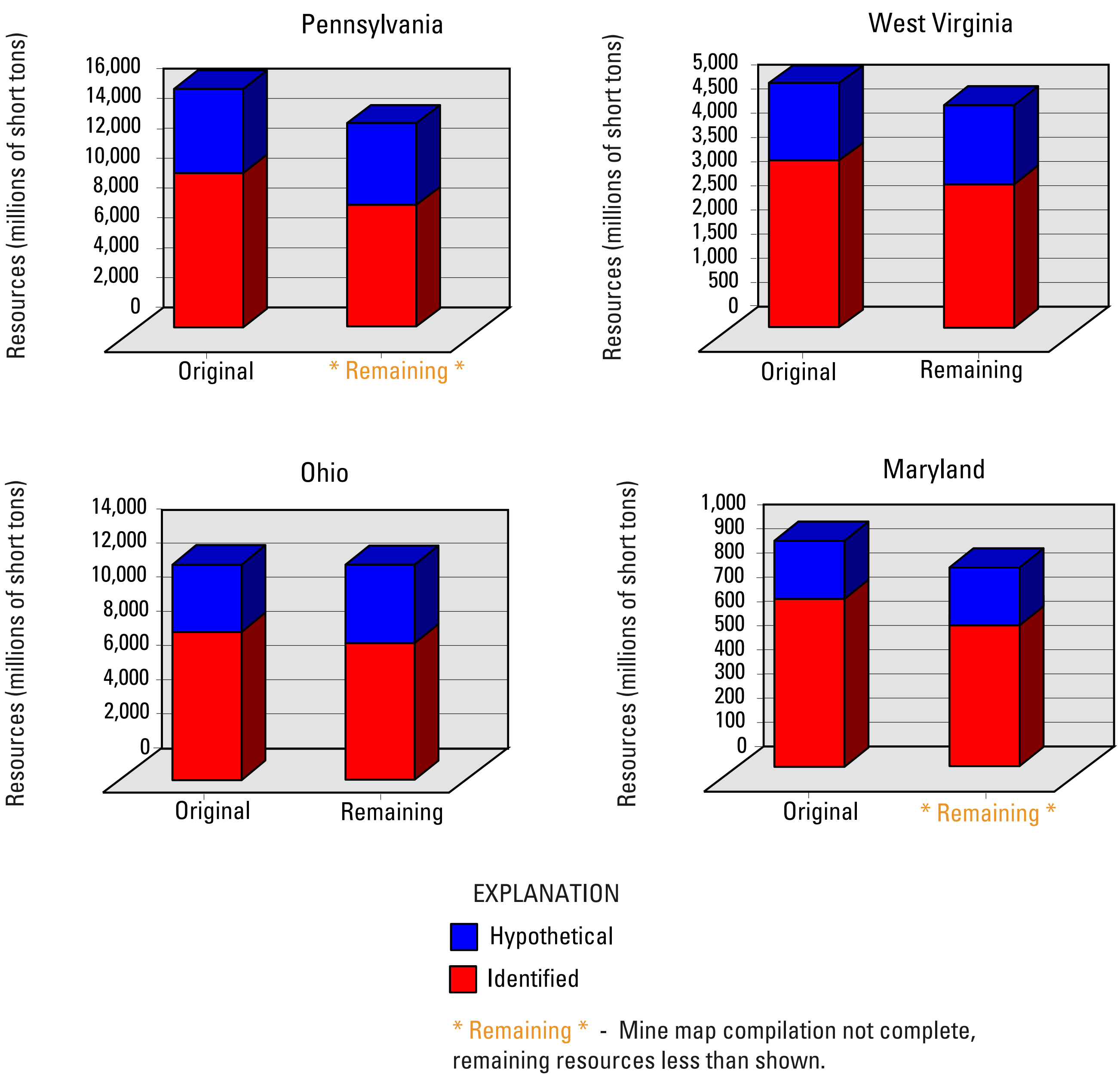


Figure 51. Bar graphs showing original and remaining Upper Freeport coal bed resources (millions of short tons), by State and USGS reliability categories (Appendixes 12, 13).

unlikely to be mined. In general, the coal that has been mined was thick (in the >3.5- to 7.0-ft and >7.0- to 14.0-ft categories; fig. 49) and under shallow overburden cover (fig. 50). West Virginia has the deepest Upper Freeport coal (2,000 ft in Wetzel County) and the highest overall gross calorific values (13,300±660 Btu/lb; table 5). The mean ash yield is moderate (11.28±3.52 weight percent, as received basis) but means range from 8.36±0.92 in Upshur County to 17.33±5.93 weight percent in Barbour County (table 2). Sulfur contents in West Virginia are low in comparison to Upper Freeport coal in Pennsylvania, Ohio, and Maryland, but are still high enough to be placed in the moderate range, with a mean of 2.01±1.13 weight percent (table 3).

More than 95 percent of Ohio's original Upper Freeport resource of 12 billion short tons has not been mined. Most of the mining that has occurred has been from surface mines. Although thick pods (fig. 24) remain under relatively shallow overburden (200-500 ft; fig. 50), the sulfur content (with a mean of 2.83±1.17 weight percent; table 3) is relatively high in comparison to Upper Freeport coal in Pennsylvania and West Virginia. The gross calorific value mean is 12,280±660 Btu/lb (table 5).

CONCLUSIONS

The Middle Pennsylvanian Upper Freeport coal bed of the Allegheny Group has been mined throughout the 20th century and is currently actively mined today, yet a maximum of 31 billion short tons remain out of the original resource of 34 billion short tons. The Upper Freeport coal formed on an extensive surface, and, where peat-forming conditions were optimum, formed thick pods of coal that represent much of the minable resource. Some of these thick pods remain in the northern panhandle of West Virginia and in Ohio, but most appear to be moderately high in ash yield and sulfur content. Some of the remaining Upper Freeport coal in Pennsylvania, West Virginia, Ohio, and Maryland that has not yet been permitted for mining will be mined. However, much of the remaining resource cannot be mined economically under current market conditions. Virtually all Upper Freeport coal is noncompliant (≤1.2 pounds of sulfur dioxide (SO_2) per million Btu; fig. 33). For long-term contracts, the electric utility companies can meet air quality standard regulations by coal blending and purchasing emission allowances. In addition, some power plants that burn Upper Freeport coal have installed flue-gas desulfurization units to meet emission requirements. However, all of these options are expensive. On a per-ton basis of sulfur dioxide, the annualized cost of constructing and retrofitting flue-gas desulfurization units designed to meet the year 2000 sulfur-dioxide emission standards (less than or equal to 0.6 pounds of sulfur per million Btu) mandated by the Clean Air Act Amendments of 1990 (Public Law 101-549) is estimated at $322.00 per ton (Attanasi, 1998). This cost compares to $167.00 per ton to switch to low-sulfur bituminous coal and $113.00 per ton to switch to low-sulfur subbituminous Western coal (Attanasi, 1998).

REFERENCES CITED

American Society for Testing and Materials, 1996, Coals by rank, D388-95, *in* Annual Book of American Society for Testing and Materials Standards: Philadelphia, Pa., American Society for Testing and Materials, p. 164–167.

Attanasi, E.D., 1998, Coal resources, new air quality standards, and sustainability: Nonrenewable Resources, no. 4, p. 271–279.

Brant, R.A., and DeLong, R.M., 1960, Coal resources of Ohio: Ohio Division of Geological Survey Bulletin 58, 245 p.

Cecil, C.B., 1990, Paleoclimatic controls on stratigraphic repetition of chemical and siliciclastic rocks: Geology, v. 18, p. 533–536.

Cecil, C.B., Stanton, R.W., and Dulong, F.T., 1981, Geology of contaminants in coal: Phase I report of investigations: U.S. Geological Survey Open-File Report 81–952–A, 92 p.

Cecil, C.B., Stanton, R.W., Neuzil, S.G., Dulong, F.T., Ruppert, L.F., and Pierce, B.S., 1985, Paleoclimate controls on late Paleozoic sedimentation and peat formation in the central Appalachian basin, U.S.A: International Journal of Coal Geology, v. 5, p. 195–230.

Clark, W.J., 1979, An interfluve model for the Upper Freeport coal bed in part of western Pennsylvania: Columbia, University of South Carolina, unpublished M.S. thesis, 57 p.

Commonwealth of Pennsylvania, 1975–1995, Annual report on mining activities: Harrisburg, Commonwealth of Pennsylvania, Department of Environmental Resources [multiple volumes].

Couchot, M.L., Crowell, D.L., Van Horn, R.G., and Struble, R.A., 1980, Investigation of the deep coal resources of portions of Belmont, Guernsey, Monroe, Noble and Washington Counties, Ohio: Ohio Division of Geological Survey Report of Investigations 116, 49 p.

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

Donaldson, A.C., 1974, Pennsylvanian sedimentation of central Appalachians: Geological Society of America Special Paper 146, p. 47–78.

Donaldson, A.C., and Shumaker, R.C., 1981, Late Paleozoic molasse of central Appalachians: Geological Association of Canada Special Paper 23, p. 99–124.

Energy Information Administration, 1998, Coal industry annual 1997: U.S. Department of Energy, Energy Information Administration Report 0584 (97), 151 p.

Ferm, J.C., 1970, Allegheny deltaic deposits, *in* Morgan, J.P., ed., Deltaic sedimentation, modern and ancient: Society of Economic Paleontologists and Mineralogists Special Publication 15, p. 246–255.

———1974, Carboniferous environmental models in eastern United States and their significance: Geological Society of America Special Paper 146, p. 79–95.

Ferm, J.C., and Staub, J.R., 1984, Depositional controls of minable coal bodies: Special Publication of the International Association of Sedimentologists, v. 7, p. 275–289.

Ferm, J.C., and Weisenfluh, G.A., 1989, Evolution of some depositional models in Late Carboniferous of the Appalachian coal fields: International Journal of Coal Geology, v. 12, p. 259–292.

Finkelman, R.B., 1993, Trace and minor elements in coal, *in* Engel, M.H. and Macko, S.A., eds., Organic geochemistry: New York, Plenum Press, p. 593–607.

Finkelman, R.B., Oman, C.L., Bragg, L.J., and Tewalt, S.J., 1994, The U.S. Geological Survey Coal Quality Database: U.S. Geological Survey Open-File Report 94–177, 42 p.

Freme, F.L., and Hong, B.D., [1999], U.S. coal supply and demand, 1998 review: Energy Information Administration web site at http://www.eia.doe.gov/cneaf/coal/cia/new_yr_revu/coalfeat.html. (Web site accessed July 17, 2001.)

Grimsley, G.P., 1907, Ohio, Brooke, and Hancock Counties: West Virginia Geological Survey [County Report], 378 p.

Hennen, R.V., 1909, Marshall, Wetzel, and Tyler Counties: West Virginia Geological Survey [County Report], 654 p.

———1912, Doddridge and Harrison Counties: West Virginia Geological Survey [County Report], 712 p.

———1913, Marion, Monongalia, and Taylor Counties: West Virginia Geological Survey [County Report], 844 p.

———1917, Braxton and Clay Counties: West Virginia Geological Survey [County Report], 883 p.

Hennen, R.V., and Reger, D.B., 1914, Preston County: West Virginia Geological Survey [County Report], 566 p.

Hohos, E.F., 1979, Paleoenvironmental model of the Upper Freeport coal seam in parts of Indiana and Armstrong counties, Pennsylvania: Columbia, University of South Carolina, unpublished M.S. thesis, 59 p.

Kertis, C.A., 1984, Recognition and prediction of coalbed discontinuities, Indiana and Armstrong Counties, Pennsylvania: Columbia, University of Missouri, unpublished M.S. thesis, 87 p.

Keystone Coal Industry Manual, 1998, Keystone coal industry manual: Chicago, Ill., Intertec Publishing, 818 p.

Knapik, J., 1981, Geology and minability of the Upper Freeport Coal, southeastern Allegheny County, Pennsylvania: Pittsburgh, University of Pittsburgh, unpublished M.S. thesis, 121 p.

Krebs, C.E., and Teets, D.D., 1913, Cabell, Wayne and Lincoln Counties: West Virginia Geological Survey [County Report], 483 p.

Lyons, P.C., and Jacobsen, E.F., 1981, Sources of data, procedures, and bibliography for coal resource investigation of western Maryland: U.S. Geological Survey Open-File Report 81–739, 82 p.

Martino, R.L., McCullough, M.A., and Hamrick, T.L., 1996, Stratigraphic and depositional framework of the Glenshaw Formation (Late Pennsylvanian) in central Wayne County, West Virginina: Southeastern Geology, v. 36, no. 2, p. 65–83.

Maryland Bureau of Mines, 1969–1995, Forty-seventh (through seventy-second) annual report of the Maryland Bureau of Mines: Frostburg, Maryland Bureau of Mines [multiple volumes].

Ohio Division of Labor Statistics, 1945–1946, Coal report: Columbus, Ohio, Department of Industrial Relations, Annual Reports 1945–1946 [multiple volumes].

———1947–1965, Coal and nonmetallic mineral report: Columbus, Ohio, Department of Industrial Relations, Annual Reports 1947–1965 [multiple volumes].

———1966–1981, Annual reports: Columbus, Ohio, Department of Industrial Relations, Annual Reports 1966–1981 [multiple volumes].

———1982–1993, Mining laws of Ohio: Columbus, Ohio, Department of Industrial Relations [multiple volumes].

Pedlow, G.W., III, 1977, A peat island hypothesis for the formation of thick coal: Columbia, University of South Carolina, unpublished Ph.D. dissertation, 103 p.

Puglio, D.G., 1983, Production, distribution, and reserves of bituminous coal, *in* Majumdar, S.K., and Miller, E.W., eds., Pennsylvania coal—Resources, technology, and utilization: Easton, Pa., Pennsylvania Academy of Science Publications, p. 25–42.

Reese, J.F., and Sisler, J.D., 1928, Bituminous coal fields of Pennsylvania; introductory volume, part 3, Coal resources: Pennsylvania Geological Survey, 4th ser., Bulletin M6, 153 p.

Reger, D.B., 1916, Lewis and Gilmer Counties: West Virginia Geological Survey [County Report], 660 p.

———1918, Barbour and Upshur Counties and western portion of Randolph County: West Virginia Geological Survey [County Report], 867 p.

———1923, Tucker County: West Virginia Geological Survey [County Report], 542 p.

———1924, Mineral and Grant Counties: West Virginia Geological Survey [County Report], 866 p.

Reid, B., and Richardson, K., 1995, Role of the underground equipment manufacturer: Mining Engineering, December, 1995, p. 1124–1126.

Rice, D.D., 1995, Geologic framework and description of coal-bed gas plays, *in* Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995 National assessment of United States oil and gas resources—Results, methodology and supporting data: U.S. Geological Survey Digital Data Series DDS–30 [release 1], 1 CD-ROM.

Rogers, H.D., 1858, The geology of Pennsylvania: a government survey, with a general view of the geology of the United States, essays on coal-formation and its fossils, and a description of the coal-fields of North America and Great Britain: Philadelphia, Pa., J.P. Lippincott, v. I and II, 1045 p.

Root, S.I., 1992, Effect of the Transylvania fracture zone on evolution of the western margin of the central Appalachian basin, *in* Bartholomew, M.J., ed., Basement tectonics—Characterization and comparison of ancient and Mesozoic continental margins; Proceedings of the 8th International Conference on Basement Tectonics: Dordrecht, Netherlands, Kluwer Academic Publishers, p. 469–480.

———1996, Recurrent basement faulting and basin evolution, West Virginia and Ohio—The Burning Springs-Cambridge fault zone: Geological Society of America Special Paper 308, p. 127–137.

Root, S.I., and Hoskins, D.M., 1977, North 40° latitude fault zone, Pennsylvania—A new interpretation: Geology, v. 5, p. 719–723.

Ruppert, L.F., Stanton, R.W., Cecil, C.B., Eble, C.F., and Dulong, F.T., 1991, Effects of detrital influx in the Pennsylvanian Upper Freeport peat swamp: International Journal of Coal

Geology, v. 17, p. 95–116.

Sholes, M.A., Edmunds, W.E., and Skema, V.W., 1979, The economic geology of the Upper Freeport coal in the New Stanton area of Westmoreland County, Pennsylvania; a model for coal exploration: Pennsylvania Bureau of Topographic and Geologic Survey Mineral Resource Report 75, p. 1–51.

Skema, V.W., Sholes, M.A., and Edmunds, W.E., 1982, The economic geology of the Upper Freeport coal in northeastern Greene County, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey Mineral Resource Report 76, p. 1–51.

Staub, J.R., 1985, Tectonically controlled distribution of thick minable bodies of the Beckley Seam Coal in southern West Virginia: Columbia, University of South Carolina, unpublished Ph.D. dissertation, 132 p.

Staub, J.R., Esterle, J.S., and Raymond, A.L., 1991, Comparative geomorphic analysis of Central Appalachian coal beds and Malaysian peat deposits: Bulletin de la Société Géologique de France, v. 162, p. 339–351.

Weisenfluh, G.R., and Ferm, J.C., 1984, Geologic controls on the deposition of the Pratt seam, Black Warrior Basin, Alabama, U.S.A.: International Association of Sedimentologists Special Publication 7, p. 317–330.

White, D., 1925, Environmental conditions of the deposition of coal: American Institute of Mining, Metallurgical and Petroleum Engineers, v. 1402, no. 71, 21 p.

Wood, G.H., Jr., Kehn, T.M., Carter, M.D., and Culbertson, W.C., 1983, Coal resource classification system of the U.S. Geological Survey: U.S. Geological Survey Circular 891, 65 p. [Also available on the web at http://energy.er.usgs.gov/products/papers/C891. Accessed September 5, 2001.]

APPENDIX 1

SELECTED BIBLIOGRAPHY OF THE UPPER FREEPORT COAL BED

[Specific references used in the USGS Upper Freeport coal-bed assessment model are found in the References Cited section Chapter D.]

Abbott, M.L., 1950, The Upper Freeport No. 7 coal parting compression flora of the Appalachian Basin [abs.]: American Journal of Botany, v. 37, no. 8, p. 672.

———1961, A coenopterid fern fructification from the Upper Freeport No. 7, coal in southeastern Ohio: Journal of Paleontology, v. 35, no. 5, p. 981–985.

———1962, Lycopod fructifications from the Upper Freeport (No. 7) coal in southeastern Ohio [abs.]: American Journal of Botany, v. 49, no. 6, part 2, p. 668.

———1968, Lycopsid stems and roots and sphenopsid fructifications and stems from the Upper Freeport coal of southeastern Ohio: Palaeontographica Americana, v. 6, no. 38, p. 5–49.

Ashley, G.H., 1926, Geology and mineral resources of the Punxsutawney quadrangle, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 65, 145 p.

———1940, Geology and mineral resources of the Curwensville quadrangle, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 75, 140 p.

Belesky, R.M., Bieniawski, Z.T., and Greenfield, R.J., 1984, Latest research findings from petite seismic trials, *in* Hardy, H.R., Jr., and Leighton, F.W., eds., Proceedings of the third conference; Acoustic emission/microseismic activity in geologic structures and materials: Houston, Texas, Gulf Publishing Company, p. 223–238.

Belt, E.S., and Lyons, P.C., 1987, Middle and Late Pennsylvanian fluvial channel complex deposits and their lateral facies in the Maryland coal fields and adjacent areas [abs.]: Geological Society of America, Abstracts with Programs, v. 19, no. 1, p. 4.

———1987, Nonmarine depositional styles associated with the Upper Freeport coal bed, Maryland and West Virginia, Appalachian Basin [abs.]: Geological Society of America, Abstracts with Programs, v. 19, no. 7, p. 586.

——— 1989a, Thrust ridge paleodepositional model for the Upper Freeport coal bed and associated clastic facies, Upper Potomac coal field, Appalachian Basin, USA [abs.]: International Geological Congress Abstracts, v. 28, no. 1, p. 121.

———1989b, A thrust ridge paleodepositional model for the Upper Freeport coal bed and associated clastic facies, Upper Potomac coal field, Appalachian Basin, U.S.A.: International Journal of Coal Geology, v. 12, p. 293–328.

Berg, T.M., Edmunds, W.E., Geyer, A.R., Glover, A.D., Hoskins, D.M., MacLachlan, D.B., Root, S.I., Sevon, W.D., and Socolow, A.A., 1980, Geologic map of Pennsylvania, 2nd ed.: Harrisburg, Pennsylvania Bureau of Topographic and Geologic Survey, 2 sheets, scale 1:250,000.

Berg, T.M., and Glover, A.D., 1976, Geology and mineral resources of the Sabula and Penfield quadrangles, Clearfield, Elk, and Jefferson Counties, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 74ab, 98 p.

Berry, E.W., 1933, Flora in the roof of the Upper Freeport coal at Callahan's Mine, Teegarden, Ohio: The Ohio Journal of Science, v. 33, no. 3, p. 208–209.

Bragonier, W.A., 1989, Stratigraphy of flint clays of the Allegheny and Pottsville Groups, western Pennsylvania, *in* Harper, J.A., ed., Guidebook for the 54th Annual Field Conference of Pennsylvania Geologists, Johnstown, Pa., October 5–7, 1989: Guidebook for the Annual Field Conference of Pennsylvania Geologists, v. 54, p. 69–88.

Brant, R.A., 1956, Coal resources of the upper part of the Allegheny Formation in Ohio: Ohio Division of Geological Survey Report of Investigations 29, 68 p.

Bushnell, K.O., 1975, Map showing areas that correlate with subsidence events due to underground mining of the Pittsburgh and Upper Freeport coal beds, Allegheny, Washington, and Westmoreland Counties, Pennsylvania: U.S. Geological Survey Miscellaneous Field Studies Map MF–693–C, scale 1:125,000.

Bushnell, K.O., and Peak, J.R., 1975, Map showing depths to the Upper Freeport coal bed, mining activity, and related surface subsidence, and the Redstone coal bed mines, Allegheny, Washington, and Westmoreland Counties, Pennsylvania: U.S. Geological Survey Miscellaneous Field Studies Map MF–693–B, scale 1:125,000.

Cecil, C.B., Dulong, F.T., Whelan, J.F., Stanton, R.W., and Spiker, E.C., 1986, Stable isotope geochemistry of calcite and pyrite in the Upper Freeport coal bed, west central Pennsylvania [abs.], *in* Carter, L.M.H., ed., USGS research on energy resources, 1986; Program and abstracts; Second V.E. McKelvey Forum on Mineral and Energy Resources: U.S. Geological Survey Circular 974, p. 9.

Cecil, C.B., Stanton, R.W., Allshouse, S.D., and Finkelman, R.B., 1979, Geologic controls on mineral matter in the Upper Freeport coal bed, *in* Rogers, S.E., and Lemmon, A.W., Jr., eds., Proceedings, Symposium on Coal Cleaning to Achieve Energy and Environmental Goals: U.S. Environmental Protection Agency Report EPA-600/7-79-098a, v. 1, p. 110–125.

Cecil, C.B., Stanton, R.W., Allshouse, S.D., Finkelman, R.B., and Greenland, L.P., 1979, Geologic controls on element concentrations in the Upper Freeport coal bed: American Chemical Society Preprints of Papers, Fuel Chemistry Division, v. 24, no. 1, p. 230–235.

Cecil, C.B., Stanton, R.W., and Dulong, F.T., 1981a, Appendices of geology of contaminants in coal; Phase I report of investigations: U.S. Geological Survey Open-File Report 81–953–B, 216 p.

———1981b, Geology of contaminants in coal; Phase I report of investigations, U.S. Geological Survey Open-File Report

81–953–A, 92 p.
Cecil, C.B., Stanton, R.W., Dulong, F.T., and Renton, J.J., 1979, Geologic factors that control mineral matter in coal: West Virginia Geological and Economic Survey Bulletin B–37–3, p. 43–56.
———1982, Geologic factors that control mineral matter in coal, *in* Filby, R.H., Carpenter, B.S., and Ragaini, R.C., eds., Atomic and nuclear methods in fossil energy research; Proceedings of the American Nuclear Society Conference: New York, Plenum Press, p. 323–335.
Chao, E.C.T., Minkin, J.A., Thompson, C.L., and Finkelman, R.B., 1979, Petrology of the Upper Freeport coal bed, Indiana County, Pennsylvania [abs.]: U.S. Geological Survey Professional Paper 1150, p. 21–22.
Cheek, R., and Donaldson, A.C., 1969, Sulfur facies of the Upper Freeport coal of northwestern Preston County, West Virginia, *in* Donaldson, A.C., ed., Some Appalachian coals and carbonates; models of ancient shallow water deposition: Morgantown, West Virginia Geological and Economic Survey, p. 279–292.
Cheek, R.B., 1969, Sulfur facies of the Upper Freeport coal (Pennsylvanian) of northwestern Preston County, West Virginia: Morgantown, West Virginia University, unpublished Master’s thesis, 49 p.
Clark, W.J., 1979, An interfluve model for the Upper Freeport coal bed in part of western Pennsylvania: Columbia, University of South Carolina, unpublished Master’s thesis, 57 p.
Corbett, R.G., and Manner, B.M., 1981, Acceptable quality mine drainage from surface bituminous coal mining in east central Ohio [abs.]: The Ohio Journal of Science, v. 81, p. 44.
Craft, J.L., Heyman, L., and Piotrowski, R.G., 1976, Greater Pittsburgh region, thickness of rocks over the Upper Freeport coal, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey Map 49, scale 1:125,000.
Cross, A.T., 1988, Upper Pennsylvanian coals and associated rocks, depositional environments, sedimentation, paleontology, and paleobotany—Upper Ohio River Valley, NE Ohio, and NW West Virginia; Geological Society of America North-Central Section Field Trip Guidebook: East Lansing, Michigan State University, Department of Geological Sciences, 67 p.
Crouch, T.M., Collins, H.R., and Helgesen, J.O., 1980, Abandoned subsurface coal mines as a source of water for coal conversion in eastern Ohio: Ohio Division of Geological Survey Report of Investigations 118, 25 p.
Crowell, D.L., 1995, History of the coal-mining industry in Ohio: Ohio Division of Geological Survey Bulletin 72, 204 p.
Degens, E.T., Williams, E.G., and Keith, M.L., 1958, Application of geochemical criteria [Pennsylvania], Part 2 *of* Environmental studies of Carboniferous sediments: American Association of Petroleum Geologists Bulletin, v. 42, no. 5, p. 981–997.
DeLong, R.M., 1965a, Geology of the Kensington quadrangle, Ohio: Ohio Division of Geological Survey Report of Investigations 55, scale 1:24,000.
———1965b, Geology of the Malvern quadrangle, Ohio: Ohio Division of Geological Survey Report of Investigations 57, scale 1:24,000.
———1968, Bedrock geology of the Dellroy quadrangle, Carroll County, Ohio: Ohio Division of Geological Survey Report of Investigations 68, scale 1:24,000.
———1969, Bedrock geology of the Carrollton quadrangle, Carroll County, Ohio: Ohio Division of Geological Survey Report of Investigations 71, scale 1:24,000.
DeLong, R.M., and White, G.M., 1963, Geology of Stark County: Ohio Geological Survey Bulletin 61, 209 p.
DeWolf, F.W., 1929, Geology and mineral resources of the New Castle quadrangle, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 5, 238 p.
Dodge, C.H., compiler, 1985a, Coal resources of Allegheny County, Pennsylvania, Part 1, Coal crop lines, mined-out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Mineral Resources Report 89, 68 p.
———1985b, Coal resources of Butler County, Pennsylvania, Part 1, Coal crop lines, mined-out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Mineral Resources Report 90, 112 p.
Donaldson, A.C., 1974, Pennsylvanian sedimentation of central Appalachians, *in* Briggs, G., ed., Carboniferous of the southeastern United States: Geological Society of America Special Paper 146, p. 47–78.
Donaldson, A.C., and Shumaker, R.C., 1981, Late Paleozoic molasse of central Appalachians, *in* Miall, A.D., ed., Sedimentation and tectonics in alluvial basins: Geological Association of Canada Special Paper 23, p. 99–124.
DiCiccio, Carmen, 1996, Coal and coke in Pennsylvania: Harrisburg, Pennsylvania Historical and Museum Commission, 223 p.
Dulong, F.T., Cecil, C.B., and Stanton, R.W., 1980, X-ray mineralogy of Upper Freeport coal [abs.]: American Association of Petroleum Geologists Bulletin, v. 64, no. 5, p. 702.
———1986, Regional and local variation of coal quality parameters in the Upper Freeport coal bed, western Pennsylvania [abs.]: Geological Society of America, Abstracts with Programs, v. 18, no. 6, p. 589.
Dulong, F.T., Spiker, E.C., Cecil, C.B., and Stanton, R.W., 1985, Calcite genesis in the Upper Freeport coal bed as indicated by stable isotope geochemistry [abs.]: Geological Society of America, Abstracts with Programs, v. 17, no. 7, p. 569.
———1986, Stable isotope geochemistry of calcite in the Upper Freeport coal bed [abs.], *in* Garbini, Susan, and Schweinfurth, S.P., eds., Symposium proceedings; A National Agenda for Coal-Quality Research: U.S. Geological Survey Circular 979, p. 227.
Energy Information Administration, 1997, Coal industry annual 1996: U.S. Department of Energy, Energy Information Administration Report 0584 (96), 15 p.
Edmunds, W.E., 1968, Geology and mineral resources of the northern half of the Houtzdale 15-minute quadrangle, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 85ab, 150 p.
Edmunds, W.E., and Berg, T.M., 1973, Geology and mineral resources of the southern half of the Penfield 15-minute quadrangle, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 74cd, 184 p.
Edmunds, W.E., Sholes, M.A., and Skema, V.W., 1977, The eco-

nomic geology of the Upper Freeport coal (Pennsylvanian) in the New Stanton area of Westmoreland Co., Pennsylvania; a model study of coal exploration [abs.]: Geological Society of America, Abstracts with Programs, v. 9, no. 3, p. 259.

Faill, R.T., Glover, A.D., and Way, J.H., 1989, Geology and mineral resources of the Blandburg, Tipton, Altoona, and Bellwood quadrangles, Blair, Cambria, Clearfield, and Centre Counties, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 86, 209 p.

Ferm, J.C., 1962, Petrology of some Pennsylvanian sedimentary rocks: Journal of Sedimentary Petrology, v. 32, no. 1, p. 104–123.

———1970, Allegheny deltaic deposits—Deltaic sedimentation, modern and ancient: Society of Economic Paleontologists and Mineralogists Special Publication 15, p. 246–255.

———1974, Carboniferous environmental models in eastern United States and their significance, *in* Briggs, G., ed., Carboniferous of the southeastern United States: Geological Society of America Special Paper 148, p. 79–95.

———1975, Pennsylvanian cyclothems of the Appalachian Plateau, a retrospective view, *in* McKee, E.D., and Crosby, E.J., eds., Paleotectonic investigations of the Pennsylvanian System in the United States; Part II, Interpretive summary and special features of the Pennsylvanian System: U.S. Geological Survey Professional Paper 853, Part II, p. 57–64.

———1979, Allegheny deltaic deposits: a model for the coal bearing strata, *in* Ferm, J.C., and Horne, J.C., eds., Carboniferous depositional environments in the Appalachian region: Columbia, University of South Carolina, Carolina Coal Group, p. 291–294.

———1983, Review of “Coal Resource Classification System of the U.S. Geological Survey, by Gordon H. Wood, Jr., Thomas M. Kehn, M. Devereux Carter, and William C. Culbertson, U.S. Geological Survey Circular 891”: American Association of Petroleum Geologists Bulletin 67, p. 2266–2267.

Ferm, J.C., and Cavaroc, V.V., Jr., 1968, A nonmarine sedimentary model for the Allegheny rocks of West Virginia, late Paleozoic and Mesozoic continental sedimentation, northeastern North America, symposium: Geological Society of America Special Paper 106, p. 1–19.

———1969, A field guide to Allegheny deltaic deposits in the upper Ohio Valley with a commentary on deltaic aspects of Carboniferous rocks in the northern Appalachian Plateau, Ohio Geological Society and Pittsburgh Geological Society Field Trip Guide Book: [Pittsburgh, Pittsburgh Geological Society], 19 p.

Ferm, J.C., and Smith, G.C., 1981, A guide to cored rocks in the Pittsburgh basin: Lexington, University of Kentucky, Department of Geology, 109 p.

Ferm, J.C., and Staub, J.R., 1984, Depositional controls of mineable coal bodies, *in* Rahmani, R.A., and Flores, R.M., eds., Sedimentology of coal and coal-bearing sequences: International Association of Sedimentologists Special Publication, v. 7, p. 275–289.

Ferm, J.C., and Williams, E.G., 1965, Characteristics of a Carboniferous marine invasion in western Pennsylvania: Journal of Sedimentary Petrology, v. 35, no. 2, p. 319–330.

Ferm, J.C., Williams, E.G., Cavaroc, V.V., Jr., Flores, R.M., Henderson, B.K., Webb, J.E., and Zimmerman, R.K., 1979, Allegheny correlations, *in* Ferm, J.C., Horne, J.C., Weisenfluh, G.A., and Staub, J.R., eds., Carboniferous depositional environments in the Appalachian region: Columbia, University of South Carolina, Carolina Coal Group, p. 13–17.

Finkelman, R.B., 1981, Recognition of authigenic and detrital minerals in coal [abs.]: Geological Society of America, Abstracts with Programs, v. 13, no. 7, p. 451.

Finkelman, R.B., Dulong, F.T., Stanton, R.W., and Cecil, C.B., 1979, Minerals in Pennsylvania coal: Pennsylvania Geology, v. 10, no. 5, p. 2–5.

Finkelman, R.B., Simons, D.S., Dulong, R.T., and Steel, E.B., 1984, Semi-quantitative ion microprobe mass analysis of mineral-rich particles from the Upper Freeport coal: International Journal of Coal Geology, v. 3, p. 279–289.

Finkelman, R.B., Stanton, R.W., Cecil, C.B., and Minkin, J.A., 1979, Modes of occurrence of selected trace elements in the Upper Freeport coal [abs.]: American Chemical Society Preprints, Fuel Chemistry Division, v. 24, no. 1, p. 236–241.

Flint, N.K., 1951, Geology of Perry County: Ohio Division of Geological Survey Bulletin 48, 234 p.

———1965, Geology and mineral resources of southern Somerset County, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey County Report 56A, 267 p.

Flores, R.M., 1967a, Relationship of geometry to the origin of the Lower Freeport sandstone (Middle Allegheny) of eastern Ohio: Journal of Sedimentary Petrology, v. 37, no. 2, p. 624–632.

———1967b, Variation in mineral composition during transport: Journal of Sedimentary Petrology, v. 37, no. 1, p. 235–239.

Glass, G.B., 1972, Geology and mineral resources of the Philipsburg 7.5-minute quadrangle, Centre and Clearfield Counties, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 95a, 241 p.

———1977, Geology and mineral resources of the Ramey and Houtzdale quadrangles, Clearfield and Centre Counties, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 85cd, 94 p.

Glover, A.D., 1970, Geology and mineral resources of the southern half of the Clearfield 15-minute quadrangle, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 84cd, 139 p.

———compiler, 1987, Coal resources of Clarion County, Pennsylvania, Part 1, Coal crop lines, mined-out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Mineral Resources Report 92, 120 p.

———compiler, 1990, Coal resources of Cambria and Blair Counties, Pennsylvania, Part 1, Coal crop lines, mined-out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Mineral Resources Report 96, 129 p.

Glover, A.D., and Bragonier, W.A., 1978, Geology and mineral resources of the Hazen, Falls Creek, Reynoldsville, and DuBois quadrangles, Clearfield and Jefferson Counties, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 64, 131 p.

Gray, R.E., 1971, Mine subsidence, support, and stabilization in western Pennsylvania: Geological Society of America, Annual Meeting, Field Trip Guidebook, v. 1971, no. 6, p. 25–35.

Hamilla, D.S., and McGomas, G.A., 1984, The Pennsylvanian invertebrate fauna and a florule from Linton, Ohio [abs.]: Geological Society of America, Abstracts with Programs, v. 16, no. 3, p. 143.

Henderson, B.K., 1979, A mathematical model of some Pennsylvanian stratigraphy, *in* Ferm, J.C., Horne, J.C., Weisenfluh, G.A., and Staub, J.R., eds., Carboniferous depositional environments in the Appalachian region: Columbia, University of South Carolina, Carolina Coal Group, p. 301–304.

Hickok, W.O., IV, and Moyer, F.T., 1940, Geology and mineral resources of Fayette County, Pennsylvania: Pennsylvania Geological Survey County Report 26, 530 p.

Hildenbrand, T.G., and Kucks, R.P., 1984a, Complete Bouguer gravity anomaly map of Ohio: U.S. Geological Survey Geophysical Investigations Map GP–962, scale 1:500,000.

———1984b, Residual total intensity magnetic map of Ohio: U.S. Geological Survey Geophysical Investigations Map GP–961, scale 1:500,000.

Hoffman, R.L., 1963, New genera and species of upper Paleozoic Diplopoda: Journal of Paleontology, v. 37, no. 1, p. 167–174.

Hook, R.W., and Baird, D., 1986, The Diamond Coal Mine of Linton, Ohio, and its Pennsylvanian age vertebrates: Journal of Vertebrate Paleontology, v. 6, no. 2, p. 174–190.

Hook, R.W., and Ferm, J.C., 1988, Paleoenvironmental controls on vertebrate-bearing abandoned channels in the Upper Carboniferous: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 63, p. 159–181.

Hook, R.W., Ferm, J.C., and Miller, T.R., 1995, Allegheny (Upper Carboniferous) depositional models for the Upper Ohio Valley; relation to studies of the Mississippi River delta, past and present [abs.]: Geological Society of America, Abstracts with Programs, v. 27, no. 6, p. 215.

Hook, R.W., Ferm, J.C., and Scanlon, M.W., 1985, Contemporaneous structural controls on Upper Carboniferous sediments in the Upper Ohio Valley [abs.]: Geological Society of America, Abstracts with Programs, v. 17, no. 7, p. 613.

Hook, R.W., and Hower, J.C., 1988, Petrography and taphonomic significance of the vertebrate-bearing cannel coal of Linton, Ohio (Westphalian D, Upper Carboniferous): Journal of Sedimentary Petrology, v. 58, no. 1, p. 72–80.

Hughes, H.H., 1933, Geology and mineral resources of the Freeport quadrangle, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 36, 272 p.

Jacobsen, E.F., 1981, Coal geology of Lower Youghiogheny basin, Garrett County, Maryland [abs.]: American Association of Petroleum Geologists Bulletin v. 65, no. 5, p. 1013–1014.

Jacobsen, E.F., and Lyons, P.C., 1985, Coal geology of the Lower Youghiogheny coal field, Garrett County, Maryland: U.S. Geological Survey Coal Investigations Map C–101, scale 1:24,000.

Jakab, E., Hoesterey, B., Windig, W., Hill, G.R., and Meuzelaar, H.L.C., 1988, Effects of low temperature air oxidation (weathering) reactions on the pyrolysis mass spectra of US coals: Fuel (Guildford), v. 67, no. 1, p. 73–79.

Jake, T., and Dixon, J., 1979, Stop 2; Upper Freeport coals, *in* Donaldson, A., Presley, M.W., and Renton, J.J., eds., Field trip guidebook for Carboniferous coal short course: West Virginia Geological and Economic Survey Bulletin B–37–2, p. 39–46.

Johnson, M.E., 1925, Mineral resources of the Greensburg quadrangle, Westmoreland County, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 37, 162 p.

———1929, Geology and mineral resources of the Pittsburgh quadrangle: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 27, 236 p.

Kessler, T., Sharkey, A.G., Jr., and Freidel, R.A., 1971, Spark source mass spectrometer investigation of coal particles and coal ash: Bureau of Mines Technical Progress Report 42, p. 15.

Kim, Y.C., and Barua, S.L., 1986, Use of conditional simulation to determine the minimum sampling requirements of run of mine coal: Application of Computers and Operations Research in the Mineral Industry, v. 19, p. 145–162.

Knapik, J., 1981, Geology and minability of the Upper Freeport Coal, southeastern Allegheny County, Pennsylvania: Pittsburgh, University of Pittsburgh, unpublished Master's thesis, [pagination unknown].

Knapp, N.F., 1977, Trace elements in Ohio coals: Ohio Division of Geological Survey Report of Investigations 103, 12 p.

Koppe, E.F., 1958, Areal distribution of partings in the Upper Freeport coal, Freeport quadrangle, Pennsylvania: Pennsylvania Academy of Sciences Proceedings, v. 32, p. 128–132.

———1959, Some geological factors affecting the Upper Freeport coal and its quality (Pennsylvania) [abs.]: Mining Engineering, v. 11, no. 7, p. 661.

———1961, Some geological factors affecting the Upper Freeport coal and its quality: Transactions of the American Institute of Mining, Metallurgical and Petroleum Engineers, v. 217, p. 185–189.

———1963, Petrography of the Upper Freeport coal, Harmar and Springdale Mines, Allegheny and Westmoreland Counties: Pennsylvania Bureau of Topographic and Geologic Survey Mineral Resources Report M48, p. 43.

Kosanke, R.M., and Cecil, C.B., 1996, Late Pennsylvanian climate changes and palynomorph extinctions: Review of Palaeobotany and Palynology, v. 90, no. 1-2, p. 113–140.

Lamborn, R.E., 1930, Geology of Jefferson County: Ohio Division of Geological Survey Bulletin 35, p. 304.

———1954, Geology of Coshocton County: Ohio Division of Geological Survey Bulletin 53, p. 245.

———1956, Geology of Tuscarawas County: Ohio Division of Geological Survey Bulletin 55, p. 269.

Lyons, P.C., 1998, The central and northern Appalachian Basin—a frontier region for coalbed methane development, *in* Lyons, P.C., ed., Appalachian coalbed methane: International Journal of Coal Gelogy, v. 38, no. 1-2, p. 61–87.

Lyons, P.C., Jacobsen, E.F., and Flores, R.M., 1984, Paleoenvironmental control of accumulation and quality of Upper Freeport coal bed (Allegheny Formation, Middle Pennsylvanian), Castleman coalfield, Maryland [abs.]: American Association of Petroleum Geologists Bulletin, v.

68, no. 12, p. 1924.

Lyons, P.C., Jacobsen, E.F., and Scott, B.K., 1985, Coal geology of the Castleman coal field, Garrett County, Maryland: U.S. Geological Survey Coal Investigations Map C–98, scale 1:24,000.

Madar, J.M., 1981, Stratigraphic analysis of lower Conemaugh rocks (Pennsylvanian), Indiana and Armstrong counties, Pennsylvania: Pittsburgh, University of Pittsburgh, unpublished Master's thesis, 42 p.

Masterson, D., 1995, Subsurface correlation of the Vanport Limestone in Athens, Gallia, Meigs, and Vinton counties, Ohio: Athens, Ohio University, unpublished Master's thesis, 76 p.

McCulloch, C.M., Jeran, P.W., and Sullivan, C.D., 1975, Geologic investigations of underground coal mining problems: U.S. Bureau of Mines Report of Investigations 8022, p. 1–30.

Meehan, M., 1980, Geologic factors affecting the mining of the Upper Freeport coal seam in west central Preston County, West Virginia: Pittsburgh, University of Pittsburgh, unpublished Master's thesis, [pagination unknown].

Merrill, G.K., 1979, Occurrences of Pennsylvanian conodonts in eastern Ohio; a brief summary, *in* Ferm, J.C., and Horne, J.C., eds., Carboniferous depositional environments in the Appalachian region: Columbia, University of South Carolina, Carolina Coal Group, p. 175–182.

Minkin, J.A., Finkelman, R.B., Thompson, C.L., Chao, E.C.T., Ruppert, L.F., Blank, H., and Cecil, C.B., 1984, Microcharacterization of arsenic- and selenium-bearing pyrite in Upper Freeport coal, Indiana County, Pennsylvania: Scanning Electron Microscopy, v. 4, p. 1515–1524.

Moebs, N.N., and Sames, G.P., 1989, Water; a hazard and a nuisance: Coal, v. 26, no. 10, p. 60–63.

Moore, T.A., 1981, Structural, optical, and chemical relations in Upper Freeport coal of west central Pennsylvania [abs.]: American Association of Petroleum Geologists Bulletin, v. 65, no. 5, p. 1014.

Moza, A.K., Strickler, D.W., and Austin, L.G., 1980, Elemental analysis of Upper Freeport coal particles: Scanning Electron Microscopy, v. 1980, p. 91–96.

Murrie, G.W., Popp, J.T., Oyler, D., and Shay, D.J., 1983, Analysis of effects of foam stimulation treatment on Upper Freeport coal seam in Indiana County, Pennsylvania [abs.]: American Association of Petroleum Geologists Bulletin, v. 67, no. 9, p. 1457–1458.

Palmer, C.A., and Filby, R.H., 1983, Determination of mode of occurrence of trace elements in the Upper Freeport coal bed using size and density separation procedures, *in* Chun, S.W., ed., Proceedings, 1983 International Conference on Coal Science: Washington, D.C., International Energy Agency, p. 365–368.

Patterson, E.D., 1963, Coal resources of Beaver County, Pennsylvania: U.S. Geological Survey Bulletin 1143–A, p. A1–A33.

Patterson, E.D., and Van Lieu, J.A., 1971, Coal resources of Butler County, Pennsylvania: U.S. Geological Survey Bulletin 1143–C, p. C1–C43.

Pierce, B.S., Spiker, E.C., Stanton, R.W., and Bates, A.L., 1991, Isotopic and petrographic evidence for the origin of pyrite in the Upper Freeport Coal bed [abs.]: Geological Society of America, Abstracts with Programs, v. 23, no. 5, p. 143.

Pierce, B.S., and Stanton, R.W., 1990, Pyritic sulfur and trace element affinities in facies of the Upper Freeport coal bed, Allegheny Formation, west central Pennsylvania [abs.]: U.S. Geological Survey Circular 1060, p. 64–66.

———1990, Coal quality and compositional characteristics of the upper Freeport coal bed, Pennsylvania, source of the Argonne Premium sample: U.S. Geological Survey Open-File Report 90–0697, 28 p.

———1993, Influence of coal bed facies development on the washability of the upper Freeport coal bed, Pennsylvania: The Journal of Coal Quality, v. 12, no. 1, p. 18–23.

Rayburn, J.M., 1924, The deposit of double thick Upper Freeport coal situated in the valley of Allegheny River in Allegheny, Butler, and Westmoreland counties, Pennsylvania: Engineers' Society of Western Pennsylvania, Proceedings, v. 40, no. 1, p. 27–44.

Reidenouer, D., Williams, E.G., and Dutcher, R.R., 1967, The relationship between paleotopography and sulfur distribution in some coals of western Pennsylvania: Economic Geology and the Bulletin of the Society of Economic Geologists, v. 62, no. 5, p. 632–647.

Renton, J.J., and Stiller, A.H., 1987, The acid producing potential of the various lithic units associated with the mining of coal: Morgantown, West Virginia University, Water Resources Institute, 16 p.

Reppert, R.S., 1964, The geology of the Gladesville, West Virginia, 7.5-minute quadrangle: Proceedings of the West Virginia Academy of Science, v. 36, p. 154–157.

Reyes, N.J., and Davis, A., 1976, Pyrite in coal; its forms and distribution as related to the environments of coal deposition in three selected coals from western Pennsylvania: The Pennsylvania State University Special Research Report 110, 141 p.

Roberts, H.H., 1979, A paleoecological study of a lower Allegheny shale in Eastern Ohio, *in* Ferm, J.C., and Horne, J.C., eds., Carboniferous depositional environments in the Appalachian region: Columbia, University of South Carolina, Carolina Coal Group, p. 173–174.

Rogers, H.D., 1858, The geology of Pennsylvania, a government survey, with a general view of the geology of the United States: Philadelphia, Pa., J.B. Lippincott and Co., v. 2, part 1, p. 474–666.

Ruppert, L.F., 1988, Cathodoluminescent quartz grains in the Upper Freeport coal bed, west central Pennsylvania; an indicator of detrital influx: Washington, D.C., George Washington University, unpublished Master's thesis, 73 p.

Ruppert, L., Bragg, L., and Tewalt, S., 1996, The U.S. Geological Survey's National Coal Resource Assessment; the northern and central Appalachian Basin [abs.]: American Association of Petroleum Geologists Bulletin, v. 80, no. 9, p. 1530–1531.

Ruppert, L.F., and Cecil, C.B., 1982, Authigenic quartz in coal [abs.]: U.S. Geological Survey Professional Paper 1375, 22 p.

Ruppert, L.F., Cecil, C.B., Grady, W.R., Stanton, R.W., Dulong, F.T., and Renton, J.J., 1982, Cathodoluminescence of minerals in the Upper Freeport coal bed [abs.]: Geological Society of America, Abstracts with Programs, v. 14, no. 1-2, p. 79.

Ruppert, L.F., Cecil, C.B., and Stanton, R.W., 1987, Sources of quartz in Upper Freeport coal [abs.]: Geological Society of America, Abstracts with Programs, v. 19, no. 7, p. 827.

Ruppert, L.F., Cecil, C.B., Stanton, R.W., and Christian, R.P.,

1985, Authigenic quartz in the Upper Freeport coal bed, west central Pennsylvania: Journal of Sedimentary Petrology, v. 55, no. 3, p. 3–34.
Ruppert, L.F., Minkin, J.A., McGee, J.J., and Cecil, C.B., 1989, Arsenic-bearing cell wall replacement pyrite in Upper Freeport coal bed, west central Pennsylvania [abs.]: American Association of Petroleum Geologists Bulletin, v. 73, no. 8, p. 1038.
Scanlon, M.W., 1991, Depositional modelling and coal mineability—The Upper Freeport seam, northern West Virginia and western Maryland: Lexington, Ky., University of Lexington, unpublished Master's thesis, 81 p.
Seaman, J.C., 1984, Evaluation of local and regional groundwater contamination at the Athens County Landfill: Athens, Ohio University, unpublished Master's thesis, 190 p.
Shaffer, B.N., 1993, Structural implications on the deposition of the Upper Freeport coal bed in eastern Greene County, Pennsylvania [abs.]: American Association of Petroleum Geologists Bulletin, v. 77, no. 8, p. 1474.
———1994, Structural implications on the deposition of the Upper Freeport coal bed in eastern Greene County, Pennsylvania, *in* Schultz, A.P., and Rader, E.K., eds., Studies in eastern energy and the environment: Virginia Division of Mineral Resources Publication 132, p. 183.
Shaffner, M.N., 1946, Geology and mineral resources of the Smicksburg quadrangle: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 55, p. 252.
———1954, Reserves of Upper Freeport and Lower Kittanning coals in New Florence quadrangle: Pennsylvania Department of Internal Affairs Monthly Bulletin, v. 22, no. 3, p. 23–25.
———1958, Geology and mineral resources of the New Florence quadrangle, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 57, p. 165.
———1963, Geology and mineral resources of the Donegal quadrangle, Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey, Topographic and Geologic Atlas of Pennsylvania, No. 48, p. 116.
Shaulis, J.R., compiler, 1985, Coal resources of Fayette County, Pennsylvania, Part 1, Coal crop lines, mined-out areas, and structure contours: Pennsylvania Bureau of Topographic Geologic Survey Mineral Resources Report 91, p. 1–88.
Skema, V.W., compiler, 1988, Coal resources of Westmoreland County, Pennsylvania, Part 1, Coal crop lines, mined-out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Mineral Resources Report 94, p. 1–127.
Smith, A.D., 1985a, Geometry and physical characteristics of mine roof falls; a case study in the Upper Freeport coal seam [abs.]: Geological Society of America, Abstracts with Programs, v. 17, no. 1, p. 63.
———1985b, Statistical methods in mining engineering and geology; expanded ANOVA techniques for three dimensional characterization of mine roof parameters [abs.]: Geological Society of America, Abstracts with Programs, v. 17, no. 5, p. 327.
Spiker, E.C., Pierce, B.S., Bates, A.L., and Stanton, R.W., 1994, Isotopic evidence for the source of sulfur in the Upper Freeport coal bed (west central Pennsylvania, U.S.A.): Chemical Geology, v. 114, no. 1-2, p. 115–130.
Stanton, R.W., Cecil, C.B., and Dulong, F.T., 1980, Forms and associations of pyrite in Upper Freeport coal bed, Homer City, Pennsylvania [abs.]: American Association of Petroleum Geologists Bulletin, v. 64, no. 5, p. 788.
Stanton, R.W., Cecil, C.B., Martino, F., and Kilgore, J.D., 1986, Physical and chemical variables related to coal washability; Upper Freeport coal bed facies [abs.], *in* Garbini, Susan, and Schweinfurth, S.P., eds., Symposium proceedings; A National Agenda for Coal-Quality Research: U.S. Geological Survey Circular 979, p. 255.
Stanton, R.W., Cecil, C.B., Pierce, B.S., Ruppert, L.F., and Dulong, F.T., 1986, Geologic processes affecting the quality of the Upper Freeport coal bed, west central Pennsylvania: U.S. Geological Survey Open-File Report 86–173, p 22.
Stanton, R.W., Pierce, B.S., Cecil, C.B., and Martino, F., 1985, Washability characteristics of facies of Upper Freeport coal bed; Homer City, Pennsylvania area [abs.]: American Association of Petroleum Geologists Bulletin, v. 69, no. 9, p. 1448.
———1986, Quality and extent of facies within the Upper Freeport coal bed; west central Pennsylvania [abs.], *in* Garbini, Susan, and Schweinfurth, S.P., eds., Symposium Proceedings; A National Agenda for Coal-Quality Research: U.S. Geological Survey Circular 979, p. 256.
Stanton, R.W., Pierce, B.S., Moore, T.A., and Cecil, C.B., 1985, Composition and origin of facies of the Upper Freeport coal bed [abs.]: Geological Society of America, Abstracts with Programs, v. 17, no. 7, p. 726.
Stevenson, J.J., 1881, The Upper Freeport coal bed along Laurel Ridge in Preston County, West Virginia: Philadelphia, Pa., Proceedings of the American Philosophical Society, p. 276–279.
Stout, Wilber, 1916, Geology of southern Ohio: Geological Survey of Ohio Bulletin 20, 723 p.
———1918, Geology of Muskingum County: Geological Survey of Ohio Bulletin 21, 351 p.
———1927, Geology of Vinton County: Geological Survey of Ohio Bulletin 31, 402 p.
Stout, Wilber, and Lamborn, R.E., 1924, Geology of Columbiana County: Geological Survey of Ohio Bulletin 28, 408 p.
Streib, D.L, Renton, J.J., and Hidalgo, R.V., 1973, Organic acid content of some upper Pennsylvania coals [abs.]: Geological Society of America, Abstracts with Programs, v. 5, no. 5, p. 440.
Struble, R.A., Collins, H.R., and DeLong, R.M., 1976, Coal resources of a portion of the Pawpaw Creek Watershed, Monroe, Noble, and Washington Counties: Ohio Geological Survey Geological Note 4, 16 p.
Struble, R.A., Collins, H.R., and Kohout, D.L, 1971, Deep-core investigation of low-sulfur coal possibilities in southeastern Ohio: Ohio Geological Survey Report of Investigation 81, 29 p.
Sturgeon, M.T., 1958, The geology and mineral resources of Athens County, Ohio: Ohio Geological Survey Bulletin 57, 600 p.
Swartz, C.K., and Baker, W.A., Jr., 1920, Second report on the coals of Maryland: Maryland Geological Survey, Special Publication v. 11, part 1, 296 p.
Sylviar, C., and Warren, N., 1982, Provenance study of Upper

Freeport (Pennsylvanian; Allegheny Group) and Mahoning (Pennsylvanian; Conemaugh Group) sandstones in eastern Ohio [abs.]: American Association of Petroleum Geologists Bulletin, v. 66, no. 8, p. 1166.

Tewalt, S.J., Oman, C.L., Bragg, L.J., and Finkelman, R.B., 1993, Distribution of mercury in Pennsylvania bituminous coal: A database perspective, *in* Chiang, Shiao-Hung, ed., Coal—Energy and the environment; Proceedings, Tenth Annual International Pittsburgh Coal Conference: Pittsburgh, Pa., University of Pittsbuurgh, Center for Energy Research, p. 1083–1087.

Theissen, Reinhart, and Voorhess, A.W., 1922, A microscopic study of the Upper Freeport coal bed, Pennsylvania: Carnegie Institute Technical Bulletin 2, Coal Mining Investigations, p. 1–75.

Todd, S.J., and Robinson, J., 1979, Evaluation of selected coal seams from the northern Appalachian coal fields, *in* Donahue, J., and Rollins, H.B., eds., Geology of the northern Appalachian coal field, Guidebook, Field trip no. 2: [Falls Church, Va., American Geological Institute] Ninth International Congress of Carboniferous Stratigraphy and Geology, p. C1–C22.

Valero Garcés, B.L., and Gierlowski-Kordesch, E., 1993, Lake level fluctuations in carbonate sequences from the upper Freeport Limestone, Appalachian basin (upper Allegheny Group, Middle Pennsylvanian) [abs.]: Geological Society of America, Abstracts with Programs, v. 25, no. 2, p. 85.

———1994, Lacustrine carbonate deposition in Middle Pennsylvanian cyclothems; the Upper Freeport Formation, Appalachian Basin, USA: Journal of Paleolimnology, v. 11, no. 1, p. 109–132.

Valero Garcés, B.L., Gierlowski-Kordesch, E., and Bragonier, W.A., 1994, Lacustrine facies model for non-marine sequences within cyclothems in the Pennsylvanian (upper Freeport Formation, Appalachian Basin) [abs.]: American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists, Annual Meeting Abstracts, v. 1994, p. 275.

———1994, Lacustrine facies model for nonmarine sequences within cyclothems in the Pennsylvanian (upper Freeport Formation, Appalachian Basin) and its implications, *in* Lomando, A.J., Schreiber, B.C., and Harris, P.M., eds., Lacustrine reservoirs and depositional systems: Society of Economic Paleontologists and Mineralogists Core Workshop No. 19, p. 321–381.

Van Lieu, J.A., and Patterson, E.D., 1964, Coal resources of Lawrence County, Pennsylvania: U.S. Geological Survey Bulletin 1143–B, p. B1–B33.

Waagé, K.M., 1950, Refractory clays of the Maryland Coal Measures: Maryland Department of Geology, Mines, and Water Resources Bulletin 9, 182 p.

Wagner, R.H., and Lyons, P.C., 1997, A critical analysis of the higher Pennsylvanian megafloras of the Appalachian region, *in* Lyons, P.C., and Zodrow, E.L., eds., Euramerican Carboniferous paleobotany and coal geology; Proceedings of the First Walter A. Bell Memorial Symposium: Review of Palaeobotany and Palynology, v. 95, nos. 1-4, p. 255–283.

Wagner, W.R., and Lytle, W.S., 1976, Greater Pittsburgh region revised surface structure and its relation to oil and gas fields: Pennsylvania Bureau of Topographic and Geologic Survey Information Circular 80, p. 1–20.

Wagner, W.R., Heyman, L., Craft, J.L., Edmunds, W.E., and Harper, J.A., 1975, Greater Pittsburgh region structure contour map: Pennsylvania Bureau of Topographic and Geologic Survey Map 43, scale 1:125,000.

Weber, J.N., Bergenback, R.E., Williams, E.G., and Keith, M.L., 1965, Reconstruction of depositional environments in the Pennsylvanian Vanport basin by carbon isotope ratios: Journal of Sedimentary Petrology, v. 35, no. 1, p. 36–48.

Weber, J.N., Williams, E.G., and Keith, M.L., 1964, Paleoenvironmental significance of carbon isotopic composition of siderite nodules in some shales of Pennsylvanian age: Journal of Sedimentary Petrology, v. 34, no. 4, p. 814–818.

Weedman, S.D., 1988a, Continental carbonate deposition in the Pennsylvanian system of the Appalachian Basin; an example from the upper Allegheny Group [abs.]: Geological Society of America, Abstracts with Programs, v. 20, no. 1, p. 78.

———1988b, Depositional environment and petrography of the Upper Freeport limestone in Indiana and Armstrong Counties, Pennsylvania: University Park, Pennsylvania State University, unpublished Ph.D. dissertation, 395 p.

———1989, A depositional model for the Upper Freeport limestone (upper Allegheny Group), Armstrong and Indiana Counties, *in* Harper, J.A., ed., Guidebook for the 54th Annual Field Conference of Pennsylvania Geologists, Johnstown, Pa., October 5–7, 1989: Gudebook for the Annual Field Conference of Pennsylvania Geologists, v. 54, p. 89–99.

———1994, Upper Allegheny Group (Middle Pennsylvanian) lacustrine limestones of the Appalachian Basin, U.S.A., *in* Gierlowski-Kordesch, E. and Kelts, K., eds., Global geological record of lake basins, volume 1: Cambridge, United Kingdom, Cambridge University Press, p. 127–134.

Whelan, J.F., Cecil, C.B., Dulong, F.T., and Stanton, R.W., 1985, Distribution and isotopic composition of sulfur in the Upper Freeport coal of western Pennsylvania [abs.]: Geological Society of America, Abstracts with Programs, v. 17, no. 7, p. 748.

Williams, E.G., 1960, Marine and fresh water fossiliferous beds in the Pottsville and Allegheny Groups of western Pennsylvania, *in* Ferm, J.C., and Horne, J.C., eds., Carboniferous depositional environments in the Appalachian region: Columbia, University of South Carolina, Carolina Coal Group, p. 35–49.

Williams, E.G., Bergenback, R.E., Falla, W.S., and Udagawa, S., 1968, Origin of some Pennsylvanian underclays in western Pennsylvania: Journal of Sedimentary Petrology, v. 38, no. 4, p. 1179–1193.

Williams, E.G., and Bragonier, W.A., 1974, Controls of Early Pennsylvanian sedimentation in western Pennsylvania: Geological Society of America Special Paper 146, p. 135–152.

Williams, E.G., and Ferm, J.C., 1964, Sedimentary facies of the lower Allegheny rocks in western Pennsylvania: Journal of Sedimentary Petrology, v. 34, no. 3, p. 610–614.

Williams, E.G., and Keith, M.L., 1963, Relationship between sulfur in coals and the occurrence of marine roof beds: Economic Geology and the Bulletin of the Society of Economic Geologists, v. 58, no. 5, p. 720–729.

Winston, R.B., and Stanton, R.W., 1987, Paleoecological analysis of a columnar sample from the Upper Freeport coal bed, Allegheny Formation (Pennsylvanian), west central Pennsylvania [abs.]: Geological Society of America, Abstracts with Programs, v. 19, no. 1, p. 66.

Woolsey, L.H., 1906, Economic geology of the Beaver quadrangle, Pennsylvania: U.S. Geological Survey Bulletin 286, p. 1–132.

Wu, L., Beck, R.A., and Biggs, D.L., 1983, A washability study of sized Upper Freeport coal and its pyrite content [abs.]: Geological Society of America, Abstracts with Programs, v. 15, no. 4, p. 228.

Zietz, I., Gilbert, F.P., and Kirby, J.R., Jr., 1980, Aeromagnetic map of Delaware, Maryland, Pennsylvania, West Virginia, and parts of New Jersey and New York: U.S. Geological Survey Geophysical Investigations Map GP–927, scale 1:1,000,000.

APPENDIX 2

RECENT REPORTED ANNUAL PRODUCTION (IN SHORT TONS) OF THE UPPER FREEPORT COAL BED IN PENNSYLVANIA, WEST VIRGINIA, OHIO, AND MARYLAND, ASSEMBLED FROM STATE AGENCIES

[Sources: Ohio Division of Labor Statistics (1969–1981, 1982–1993), Maryland Bureau of Mines (1969–1995), Commonwealth of Pennsylvania (1975–1995), Gayle H. McColloch (West Virginia Geological and Economic Survey, unpublished search of West Virginia Office of Miner's Health, Safety, and Training—Safety Information System (MHST-SIS) database, 1997). Abbreviations are as follows: nd, no data available or the absence of production.]

YEAR	PA	WV	OH	MD
1969	nd	nd	1,443,182	416,165
1970	nd	nd	1,249,644	197,076
1971	nd	nd	793,756	251,622
1972	nd	nd	605,583	101,015
1973	nd	nd	94,517	249,304
1974	nd	nd	314,402	578,638
1975	11,019,575	nd	350,270	545,473
1976	12,033,840	nd	323,912	474,386
1977	12,981,419	nd	457,427	484,354
1978	10,328,550	nd	464,221	431,166
1979	12,896,799	nd	633,907	684,191
1980	13,023,004	nd	426,851	1,269,116
1981	10,355,499	nd	300,351	2,043,014
1982	10,771,263	4,952,422	679,185	1,702,566
1983	10,020,722	5,290,557	599,583	1,582,449
1984	10,210,588	6,879,469	748,813	2,191,556
1985	9,119,023	6,475,363	949,756	1,927,983
1986	8,557,916	6,384,920	1,002,421	2,724,625
1987	9,095,785	6,791,271	639,329	2,434,082
1988	8,855,779	7,591,719	1,027,384	2,069,017
1989	7,420,665	7,202,189	1,227,553	1,917,351
1990	9,184,665	7,902,442	1,248,328	2,089,386
1991	8,474,109	6,340,573	983,140	2,622,105
1992	7,719,539	6,336,578	1,399,707	2,481,803
1993	4,839,093	4,042,018	1,779,194	2,608,687
1994	nd	5,037,266	1,861,773	2,678,887
1995	5,146,086	6,173,398	nd	2,618,022
1996	nd	6,416,773	nd	nd

APPENDIX 3

RECENT REPORTED ANNUAL PRODUCTION (IN SHORT TONS) OF THE UPPER FREEPORT COAL BED IN PENNSYLVANIA, BY COUNTY

[Source: Commonwealth of Pennsylvania (1975–1995). Abbreviations are as follows: nd, no data available or the absence of production.]

Year	Allegheny	Armstrong	Beaver	Bedford	Blair	Butler	Cambria	Clarion
1975	610,522	2,742,375	165,740	nd	1,901	423,823	372,232	82,616
1976	517,677	2,998,402	99,003	nd	1,088	456,058	324,133	84,307
1977	647,568	3,059,029	30,398	nd	nd	717,037	365,139	118,471
1978	469,855	2,616,622	27,460	nd	5,340	322,861	369,193	39,066
1979	660,481	2,957,278	27,460	nd	nd	640,594	416,187	39,714
1980	778,124	2,682,742	11,729	nd	nd	325,551	544,894	7,492
1981	592,276	1,970,252	nd	nd	nd	162,149	46,064	22,010
1982	679,196	2,171,084	6,482	16,535	nd	437,020	118,607	64,719
1983	583,713	2,160,974	nd	nd	nd	647,741	71,839	41,882
1984	624,065	2,211,762	nd	nd	32,936	858,326	179,804	33,619
1985	595,503	2,150,177	4,296	nd	nd	991,651	157,774	16,709
1986	528,004	2,419,446	15,306	nd	nd	1,047,623	157,097	6,830
1987	530,587	2,643,712	12,248	nd	nd	603,966	379,068	16,823
1988	555,482	2,518,939	41,387	nd	nd	1,146,987	115,658	21,577
1989	632,949	2,209,563	50,197	nd	nd	1,188,414	140,495	nd
1990	625,357	2,507,724	31,688	nd	nd	1,298,350	74,577	9,204
1991	475,752	2,788,247	63,647	nd	nd	766,341	165,888	nd
1992	269,253	3,093,575	nd	nd	nd	354,806	94,289	nd
1993	nd	2,495,248	nd	nd	nd	15,971	120,988	18,355
1995	nd	2,831,160	nd	nd	nd	58,192	142,454	nd
Total	10,376,364	51,228,311	587,041	16,535	41,265	12,463,461	4,356,380	623,394

Year	Clearfield	Clinton	Elk	Fayette	Fulton	Greene	Indiana	Jefferson
1975	252,146	nd	46,913	28,112	nd	nd	3,982,574	168,874
1976	430,553	nd	55,975	120,268	nd	nd	4,358,578	416,113
1977	500,349	nd	66,672	356,054	nd	nd	4,097,717	582,510
1978	730,497	nd	61,485	284,834	nd	nd	3,217,392	370,674
1979	1,189,427	nd	34,359	188,039	nd	nd	4,217,308	365,980
1980	1,138,262	nd	121,994	135,590	nd	nd	4,905,981	323,339
1981	1,317,037	4,407	136,136	62,577	nd	nd	3,869,196	374,106
1982	583,820	nd	13,211	258,514	nd	nd	4,804,468	379,203
1983	875,534	nd	5,052	130,049	nd	nd	4,721,626	301,514
1984	761,154	nd	35,663	nd	nd	nd	4,109,269	307,574
1985	203,997	nd	28,761	nd	nd	nd	4,151,591	330,957
1986	567,655	nd	968	8,957	nd	nd	2,549,345	237,152
1987	351,306	nd	2,529	nd	nd	nd	3,305,743	221,474
1988	581,310	nd	31,278	50,930	73,153	nd	2,458,067	244,233
1989	270,355	nd	14,345	1,570	nd	nd	1,822,904	149,879
1990	238,205	nd	13,034	6,784	nd	nd	3,935,861	155,860
1991	166,002	nd	nd	9,603	nd	nd	3,660,256	113,075
1992	295,355	nd	nd	45,754	nd	nd	3,214,850	93,686
1993	213,544	nd	nd	26,951	nd	nd	1,553,186	56,894
1995	195,739	nd	2,352	51,706	nd	nd	1,480,998	102,253
Total	10,862,247	4,407	670,727	1,766,292	73,153	nd	70,416,910	5,295,350

APPENDIX 3—CONTINUED

Year	Lawrence	Lycoming	Somerset	Tioga	Washington	Westmoreland	Total annual Production
1975	nd	38,360	1,163,939	16,147	nd	923,301	11,019,575
1976	nd	nd	1,311,464	nd	nd	860,221	12,033,840
1977	nd	nd	1,332,249	nd	nd	1,108,226	12,981,419
1978	13,361	nd	1,250,181	nd	nd	549,729	10,328,550
1979	nd	nd	1,477,367	nd	nd	682,605	12,896,799
1980	nd	nd	1,520,691	nd	nd	526,615	13,023,004
1981	nd	nd	1,309,602	nd	nd	489,687	10,355,499
1982	nd	nd	961,374	nd	nd	277,030	10,771,263
1983	2,375	nd	463,738	nd	nd	14,685	10,020,722
1984	nd	nd	514,267	nd	nd	542,149	10,210,588
1985	143,827	nd	330,847	nd	nd	12,933	9,119,023
1986	32,426	nd	267,119	nd	nd	719,988	8,557,916
1987	46,553	nd	242,318	nd	nd	739,458	9,095,785
1988	44,251	nd	166,253	nd	nd	806,274	8,855,779
1989	nd	nd	95,823	nd	843,956	215	7,420,665
1990	4,398	nd	283,623	nd	nd	nd	9,184,665
1991	nd	nd	220,650	nd	nd	44,648	8,474,109
1992	nd	nd	219,386	nd	nd	38,585	7,719,539
1993	nd	nd	337,956	nd	nd	nd	4,839,093
1995	nd	nd	265,372	nd	nd	15,860	5,146,086
Total	287,191	38,360	13,734,219	16,147	843,956	8,352,209	192,053,919

APPENDIX 4

RECENT REPORTED ANNUAL PRODUCTION (IN SHORT TONS) OF THE UPPER FREEPORT COAL BED IN WEST VIRGINIA, BY COUNTY.

[The Upper Freeport coal bed could not be reliably correlated south of Barbour County, W. Va., and therefore counties further to the south were not assessed in this report. However, coal companies do report Upper Freeport coal production south of Barbour County, in Mingo and Logan Counties, and these production numbers have been inluded in this Appendix. Source: Gayle H. McColloch (West Virginia Geological and Economic Survey, unpublished search of West Virginia Office of Miner's Health, Safety, and Training—Safety Information System (MHST-SIS) database, 1997). Abbreviations are as follows: nd, no data available or the absence of production.]

Year	Boone	Grant	Logan	Mingo	Monongalia	Nicholas	Ohio	Preston	Tucker	Upshur	Wayne	Webster	Total annual production
1982	nd	1,969,817	100,183	nd	34,249	nd	nd	2,219,624	203,183	333,262	nd	92,104	4,952,422
1983	nd	1,672,564	14,625	nd	161,304	nd	nd	2,319,842	285,494	336,781	nd	499,947	5,290,557
1984	nd	2,234,757	nd	520	364,307	nd	nd	2,809,342	243,407	367,361	nd	859,775	6,879,469
1985	nd	2,471,593	nd	nd	403,576	nd	nd	2,666,279	153,000	354,470	nd	426,445	6,475,363
1986	nd	1,815,132	80,209	nd	344,092	29,855	nd	3,025,955	162,815	307,681	nd	619,181	6,384,920
1987	nd	1,972,153	nd	7,434	225,014	161,757	nd	3,604,245	101,238	73,347	1.0	646,082	6,791,271
1988	nd	2,441,789	nd	208,615	140,382	206,342	nd	3,754,971	93,424	nd	nd	746,196	7,591,719
1989	nd	3,081,488	28,492	26,806	148,386	4,331	nd	3,815,420	97,266	nd	nd	nd	7,202,189
1990	nd	3,878,798	nd	nd	27,648	217,390	nd	3,580,870	197,736	nd	nd	nd	7,902,442
1991	nd	3,375,373	nd	nd	2,873	nd	nd	2,815,540	132,226	nd	nd	14,561	6,340,573
1992	nd	3,518,831	nd	nd	38,427	nd	nd	2,479,094	107,765	192,461	nd	nd	6,336,578
1993	nd	1,265,594	nd	nd	47,131	nd	nd	2,070,074	91,706	567,513	nd	nd	4,042,018
1994	nd	2,695,267	nd	nd	65,443	nd	591	1,682,558	123,394	470,013	nd	nd	5,037,266
1995	329,104	3,164,032	nd	nd	104,070	nd	nd	1,648,516	127,713	799,963	nd	nd	6,173,398
1996	618,817	3,030,087	nd	nd	26,531	nd	nd	1,736,331	133,648	871,359	nd	nd	6,416,773
Total	947,921	38,587,275	223,509	243,375	2,133,433	619,675	591	40,228,661	2,254,015	4,674,211	1.0	3,904,291	93,816,958

APPENDIX 5

RECENT REPORTED ANNUAL PRODUCTION (IN SHORT TONS) OF THE UPPER FREEPORT COAL BED IN OHIO, BY COUNTY

[Sources: Ohio Division of Labor Statistics (1945–1946, 1947–1965, 1966–1981, 1982–1994). Abbreviations are as follows: nd, no data available or the absence of production.]

Year	Athens	Belmont	Carroll	Columbiana	Coshocton	Gallia	Guernsey	Harrison	Hocking	Holmes	Jackson	Jefferson
1945	204,646	nd	14,465	100,893	nd	48,227	205,985	9,508	16,970	nd	3,121	49,321
1946	292,550	nd	16,012	48,777	26,340	61,122	259,894	9,945	188	nd	18,494	33,007
1947	314,630	nd	30,357	241,979	51,966	71,411	387,681	8,986	1,109	nd	17,304	105,903
1948	263,174	nd	21,058	320,680	61,407	62,476	225,881	27,237	1,277	nd	14,560	214,783
1949	150,382	nd	106,724	240,815	71,572	43,874	144,422	15,536	233	nd	29,295	52,611
1950	165,099	nd	178,910	344,620	85,613	49,731	79,536	24,584	184	8,623	16,148	91,053
1951	124,924	nd	12,251	385,625	194,569	38,863	94,328	47,330	nd	9,630	13,689	111,410
1952	198,069	nd	3,138	354,104	139,076	36,951	118,648	53,075	nd	2,292	6,406	71,669
1953	109,613	nd	53,984	281,659	155,216	32,903	72,712	9,764	nd	nd	5,613	18,532
1954	102,811	3,516	32,013	186,467	131,166	14,673	57,971	4,904	nd	nd	2,699	45,016
1955	125,708	3,026	186,881	113,280	148,427	nd	59,651	10,486	43,702	nd	5,361	109,784
1956	89,510	nd	111,173	229,243	148,641	nd	55,547	7,541	29,382	nd	11,904	136,087
1957	83,883	nd	36,056	252,788	182,743	nd	77,270	10,836	45,022	nd	7,111	78,570
1958	47,471	nd	27,579	334,551	101,241	nd	73,831	47,544	35,267	nd	3,031	69,218
1959	52,169	nd	155,800	317,918	137,277	nd	42,739	17,617	10,693	nd	2,837	130,503
1960	77,800	nd	135,220	216,208	62,241	nd	28,188	10,022	15,466	nd	nd	93,881
1961	51,065	nd	127,552	143,946	nd	nd	18,100	37,171	5,783	nd	nd	107,738
1962	37,305	nd	43,878	112,553	nd	nd	23,083	57,242	7,856	nd	nd	99,665
1963	71,297	nd	19,220	171,779	nd	nd	32,745	125,353	10,024	nd	54,280	39,283
1964	96,596	nd	19,000	248,944	nd	nd	279	132,547	15,965	nd	101,593	21,035
1965	114,091	nd	1,158	165,482	nd	56,186	170	288,216	14,595	nd	nd	82,429
1966	84,935	nd	37,286	30,240	nd	12,302	88	179,046	14,290	nd	nd	101,818
1967	90,172	nd	147,679	19,029	nd	nd	2,781	137,670	9,958	nd	nd	6,544
1968	67,367	nd	161,533	54,806	nd	11,298	22,542	457,850	5,822	nd	nd	4,407
1969	60,132	nd	9,864	3,293	nd	21,479	8,447	1,102,531	28,297	nd	nd	32,370
1970	27,654	nd	143,863	30,142	nd	53,547	7,545	813,404	31,799	nd	nd	36,490
1971	nd	nd	114,475	52,497	nd	14,150	10,000	404,366	40,946	nd	nd	85,619
1972	nd	nd	30,018	75,168	nd	16,243	369,400	nd	52,125	nd	nd	26,357
1973	nd	nd	nd	94,517	nd	nd	nd	nd	nd	nd	nd	nd
1974	nd	nd	nd	106,092	nd	67,294	nd	nd	nd	nd	nd	nd
1975	nd	nd	19,952	77,303	nd	94,335	48,898	nd	nd	nd	nd	nd
1976	1,580	nd	11,664	75,086	nd	nd	133,731	44,283	nd	nd	nd	nd
1977	5,049	nd	30,603	133,303	nd	nd	125,759	467	nd	nd	nd	nd
1978	nd	nd	10,670	133,753	nd	21,729	150,561	nd	nd	nd	4,374	nd
1979	nd	nd	24,193	80,397	nd	nd	157,140	6,840	153,124	nd	nd	nd
1980	nd	nd	17,436	65,220	nd	nd	nd	14,417	135,042	nd	nd	nd

APPENDIX 5—CONTINUED

Year	Athens	Belmont	Carroll	Columbiana	Coshocton	Gallia	Guernsey	Harrison	Hocking	Holmes	Jackson	Jefferson
1981	nd	nd	nd	87,822	nd	7,417	89,938	8,811	nd	nd	nd	nd
1982	nd	nd	nd	199,192	nd	nd	130,947	113,005	73,923	nd	nd	nd
1983	nd	nd	1,490	139,422	nd	nd	125,853	167,269	nd	nd	nd	nd
1984	nd	nd	nd	229,714	nd	nd	119,846	241,165	nd	nd	nd	nd
1985	9,786	nd	147,657	223,021	nd	nd	73,362	292,693	nd	nd	nd	nd
1986	21,441	nd	12,236	285,043	nd	nd	113,311	328,765	nd	nd	nd	20,164
1987	18,114	5,216	4,987	281,364	nd	nd	69,186	35,379	nd	nd	7,800	10,389
1988	2,361	nd	30,481	206,282	nd	nd	120,133	58,167	6,675	nd	8,815	nd
1989	nd	3,029	30,225	259,701	18,217	nd	124,435	37,356	15,306	nd	10,314	nd
1990	nd	7,267	1,155	411,208	nd	nd	156,140	43,062	nd	nd	5,538	nd
1991	3,076	nd	9,734	150,076	nd	nd	212,459	2,569	nd	nd	480	nd
1992	nd	nd	nd	369,921	nd	nd	274,677	8,223	42,147	nd	7,530	178,851
1993	nd	nd	18,622	358,261	nd	nd	240,515	15,701	nd	nd	46,097	269,778
1994	nd	nd	47,490	477,337	nd	nd	182,062	nd	nd	nd	nd	360,405
Total	3,164,460	22,054	2,395,742	9,521,521	1,715,712	836,211	5,128,417	5,468,483	863,170	20,545	404,394	2,894,690

Year	Lawrence	Mahoning	Meigs	Muskingum	Noble	Perry	Stark	Tuscarawas	Vinton	Washington	Total Annual Production
1945	nd	nd	198	14,021	nd	4,492	nd	9,754	18,866	nd	700,467
1946	125	nd	311	8,747	nd	5,781	nd	7,477	35,500	nd	824,270
1947	30	nd	580	17,930	nd	2,968	nd	39,815	143,581	nd	1,436,230
1948	170	nd	270	45,974	353	1,282	5,152	57,788	167,747	6,333	1,497,602
1949	172	nd	nd	153,207	19,267	nd	12,048	17,800	186,113	12,163	1,256,234
1950	nd	nd	nd	302,819	nd	2,073	3,350	8,711	151,282	nd	1,512,336
1951	17,919	nd	nd	269,646	nd	nd	13,855	14,813	25,283	nd	1,374,135
1952	4,661	nd	nd	186,380	183,775	nd	nd	25,081	nd	nd	1,383,325
1953	379	nd	nd	294,036	144,298	nd	nd	5,072	nd	nd	1,183,781
1954	nd	nd	nd	76,708	21,460	25	nd	4,671	7,505	nd	691,605
1955	18	nd	nd	113,476	7,171	nd	nd	6,018	1,950	nd	934,939
1956	nd	nd	nd	52,699	nd	nd	nd	59,104	nd	nd	930,831
1957	212	43,137	nd	50,267	6,000	128,012	1,565	92,112	nd	nd	1,095,584
1958	27,412	10,046	nd	48,868	nd	242,240	nd	229,747	nd	nd	1,298,046
1959	99,374	33,223	nd	46,903	nd	202	nd	253,483	nd	nd	1,300,738
1960	146,363	40,036	nd	44,576	nd	nd	nd	189,820	nd	nd	1,059,821

APPENDIX 5—CONTINUED

Year	Lawrence	Mahoning	Meigs	Muskingum	Noble	Perry	Stark	Tuscarawas	Vinton	Washington	Total Annual Production
1961	73,001	56,602	nd	9,400	nd	nd	nd	123,873	nd	nd	754,231
1962	79,680	52,010	nd	15,541	nd	nd	nd	129,427	nd	nd	658,240
1963	nd	896	nd	14,837	nd	nd	nd	68,744	nd	nd	608,458
1964	nd	nd	nd	20,802	nd	nd	nd	53,322	nd	nd	710,083
1965	nd	nd	nd	51,368	nd	nd	nd	114,158	nd	nd	887,853
1966	399	nd	nd	109,956	nd	nd	nd	196,870	nd	nd	767,230
1967	nd	nd	nd	64,319	nd	nd	nd	99,616	740	nd	578,508
1968	nd	nd	nd	36,372	nd	nd	nd	36,683	nd	nd	858,680
1969	nd	nd	nd	45,774	nd	nd	nd	130,995	nd	nd	1,443,182
1970	1,257	nd	nd	nd	nd	nd	nd	103,376	567	nd	1,249,644
1971	nd	nd	nd	4,000	nd	nd	nd	63,920	3,783	nd	793,756
1972	nd	nd	nd	nd	nd	nd	nd	36,272	nd	nd	605,583
1973	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	94,517
1974	nd	nd	nd	68,444	nd	25,726	nd	46,846	nd	nd	314,402
1975	nd	nd	nd	nd	nd	30,569	nd	79,213	nd	nd	350,270
1976	nd	nd	nd	nd	nd	32,235	390	24,943	nd	nd	323,912
1977	nd	nd	nd	100,443	nd	13,868	10,489	25,903	11,543	nd	457,427
1978	nd	nd	nd	122,560	nd	nd	11,372	9,202	nd	nd	464,221
1979	nd	nd	nd	166,077	nd	8,141	nd	19,182	18,813	nd	633,907
1980	nd	nd	nd	146,164	nd	nd	nd	39,094	9,478	nd	426,851
1981	nd	nd	nd	49,863	nd	3,081	nd	53,419	nd	nd	300,351
1982	nd	nd	nd	92,743	nd	nd	3,479	65,896	nd	nd	679,185
1983	nd	nd	nd	71,267	nd	nd	13,332	69,889	11,061	nd	599,583
1984	nd	nd	nd	20,521	nd	31,453	6,637	99,477	nd	nd	748,813
1985	nd	nd	nd	1,495	nd	19,906	2,551	179,285	nd	nd	949,756
1986	nd	nd	nd	14,984	nd	26,139	1,002	170,940	8,396	nd	1,002,421
1987	nd	nd	nd	nd	nd	22,962	nd	183,932	nd	nd	639,329
1988	nd	nd	nd	nd	nd	69,156	nd	524,689	625	nd	1,027,384
1989	nd	nd	nd	nd	nd	63,083	nd	665,887	nd	nd	1,227,553
1990	nd	nd	nd	nd	nd	174,275	nd	449,683	nd	nd	1,248,328
1991	nd	nd	nd	nd	5,451	118,222	nd	449,302	31,771	nd	983,140
1992	nd	nd	nd	nd	12,967	15,399	nd	489,992	nd	nd	1,399,707
1993	nd	nd	nd	389	11,089	nd	nd	737,068	81,674	nd	1,779,194
1994	nd	nd	nd	nd	nd	nd	nd	663,599	130,880	nd	1,861,773
Total	451,172	235,950	1,359	2,953,576	411,831	1,041,290	85,222	7,225,963	1,047,158	18,496	45,907,416

APPENDIX 6

RECENT REPORTED ANNUAL PRODUCTION (IN SHORT TONS) OF THE UPPER FREEPORT COAL BED IN MARYLAND, BY COUNTY

[Between 1978 and 1995, the Maryland Bureau of Mines reported Freeport production only, without differentiating between the Lower Freeport coal bed and the Upper Freeport coal bed production. Lower Freeport coal production is not significant in Maryland and Freeport production (in red) is used in lieu of Upper Freeport coal bed production data. Source: Maryland Bureau of Mines (1969–1995). Abbreviations are as follows: nd, no data available or the absence of production.]

Year	Allegany	Garrett	Total annual production
1969	nd	416,165	416,165
1970	nd	197,076	197,076
1971	nd	251,622	251,622
1972	nd	101,015	101,015
1973	nd	249,304	249,304
1974	nd	578,638	578,638
1975	nd	545,473	545,473
1976	nd	474,386	474,386
1977	99,863	484,354	484,354
1978	13,950	431,166	431,166
1979	8,793	684,191	684,191
1980	nd	1,269,116	1,269,116
1981	66,276	2,043,014	2,043,014
1982	98,633	1,702,566	1,702,566
1983	nd	1,582,449	1,582,449
1984	33,114	2,191,556	2,191,556
1985	15,166	1,927,983	1,927,983
1986	nd	2,724,625	2,724,625
1987	nd	2,434,082	2,434,082
1988	nd	2,069,017	2,069,017
1989	nd	1,917,351	1,917,351
1990	nd	2,089,386	2,089,386
1991	599	2,622,105	2,622,105
1992	nd	2,481,803	2,481,803
1993	nd	2,608,687	2,608,687
1994	nd	2,678,887	2,678,887
1995	nd	2,618,022	2,618,022
Total	336,395	39,374,038	39,374,039

APPENDIX 7

UPPER FREEPORT COAL BED STRATIGRAPHIC DATABASE

[This spreadsheet contains all of the public records used to model the Upper Freeport coal bed and includes (1) record identifier, (2) longitude (decimal degrees), (3) latitude (decimal degrees), (4) elevation of the Upper Freeport coal bed, and (5) Upper Freeport coal bed thickness, excluding parting. Records that contain a -999 in the elevation or thickness field, were omitted from that coverage.]

CLICK HERE TO GO TO APPENDIX 7

APPENDIX 8

UPPER FREEPORT COAL BED GEOCHEMICAL DATABASE

[This ASCII file contains all of the public records used to model the coal quality for the Upper Freeport coal bed and includes NCAID (northern and central Appalachian index number used for bed data records), source, State, county, longitude (decimal degrees), latitude (decimal degrees), coal province, coal region, coal field, district, coal formation, coal group, coal bed, sample thickness (ft), system, series/epoch, comments, map, collector, pointid (field identification number), estimated rank, lab code, sample type, analytical type, value represented, moisture (percent), total moisture (percent), volatile matter (percent), fixed carbon (percent), ASTM ash (American Society for Testing and Materials; percent), hydrogen (percent), carbon (percent), nitrogen (percent), oxygen (percent), sulfur (percent), SO_2 (lbs/million Btu), gross calorific value (Btu/lb), air dried loss (percent), sulfate sulfur (percent), pyritic sulfur (percent), organic sulfur (percent), free swelling index, ash deformation temperature (degrees Fahrenheit), ash softening temperature (degrees Fahrenheit), ash fluid temperature (degrees Fahrenheit), Hardgrove grindability index, equilibrium moisture (percent), USGS ash (U.S. Geological Survey; percent), Si (percent), Al (percent), Ca (percent), Mg (percent), Na (percent), K (percent), Fe (percent), Ti (percent), S (percent), Ag (ppm), As (ppm), Au (ppm), B (ppm), Ba (ppm), Be (ppm), Bi (ppm), Br (ppm), Cd (ppm), Ce (ppm), Cl (ppm), Co (ppm), Cr (ppm), Cs (ppm), Cu (ppm), Dy, (ppm), Er (ppm), Eu (ppm), F (ppm), Ga (ppm), Gd (ppm), Ge (ppm), Hf (ppm), Hg (ppm), Ho (ppm), La (ppm), Li (ppm), Lu (ppm), Mn (ppm), Mo (ppm), Nb (ppm), Nd (ppm), Ni (ppm), P (ppm), Pb (ppm), Pd (ppm), Pr (ppm), Rb (ppm), Sb (ppm), Sc (ppm), Se (ppm), Sm (ppm), Sn (ppm), Sr (ppm) Ta (ppm), Tb (ppm), Th (ppm), Tl (ppm), Tm (ppm), U (ppm), V (ppm), W (ppm), Y (ppm), Yb (ppm), Zn (ppm), Zr (ppm)]

CLICK HERE TO GO TO APPENDIX 8

APPENDIX 9

METADATA FOR THE UPPER FREEPORT COAL BED GEOCHEMICAL DATABASE

CLICK HERE TO GO TO APPENDIX 9

APPENDIX 10

REFERENCES FOR THE UPPER FREEPORT COAL BED GEOCHEMICAL DATABASE

American Society for Testing and Materials, 1996, Standard practice for calculating coal and coke analyses from as-determined to different bases, D3180–89, *in* Annual book of American Society for Testing and Materials Standards: Philadelphia, Pa., American Society for Testing and Materials, p. 314–316.

Aresco, S.J., and Haller, C.P., 1953a, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1951): U.S. Bureau of Mines Report of Investigations 4934, 93 p.

———1953b, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1952): U.S. Bureau of Mines Report of Investigations 4972, 84 p.

Aresco, S.J., Haller, C.P., and Abernethy, R.F., 1955, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1953): U.S. Bureau of Mines Report of Investigations 5085, 82 p.

———1956a, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1954): U.S. Bureau of Mines Report of Investigations 5221, 77 p.

———1956b, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1955): U.S. Bureau of Mines Report of Investigations 5270, 66 p.

———1957, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1956): U.S. Bureau of Mines Report of Investigations 5332, 67 p.

———1959, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1958): U.S. Bureau of Mines Report of Investigations 5489, 54 p.

———1961, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1960): U.S. Bureau of Mines Report of Investigations 5792, 44 p.

———1962, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1961): U.S. Bureau of Mines Report of Investigations 6086, 41 p.

Aresco, S.J., and Janus, J.B., 1967, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1966): U.S. Bureau of Mines Report of Investigations 6904, 43 p.

———1968, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1967): U.S. Bureau of Mines Report of Investigations 7104, 43 p.

———1969, Analyses of tipple and delivered samples of coal (collected during fiscal year 1968): U.S. Bureau of Mines Report of Investigations 7219, 31 p.

Aresco, S.J., Janus, J.B., and Walker, F.E., 1964, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1963): U.S. Bureau of Mines Report of Investigations 6461, 38 p.

———1965, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1964): U.S. Bureau of Mines Report of Investigations 6622, 38 p.

———1966, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1965): U.S. Bureau of Mines Report of Investigations 6792, 49 p.

Blaylock, D.W., Dowd, J.J., Abernethy, R.F., and Reynolds, D.A., 1955, Estimate of known recoverable reserves of coking coal in Clearfield County, Pa.: U.S. Bureau of Mines Report of Investigations 5166, 36 p.

———1956, Estimate of known recoverable reserves of coking coal in Clarion County, Pa.: U.S. Bureau of Mines Report of Investigations 5231, 27 p.

Botoman, G., and Stith, D. A., 1978, Analyses of Ohio coals: Ohio Division of Geological Survey Information Circular 47, 148 p.

———1981, Analyses of Ohio coals, 1977–1978: Ohio Division of Geological Survey Information Circular 50, 54 p.

———1988, Analyses of Ohio coals, 1982–1984: Ohio Division of Geological Survey Information Circular 55, 17 p.

Bragg, L.J., Oman, J.K., Tewalt, S.J., Oman, C.L., Rega, N.H., Washington, P.M., and Finkelman, R.B., 1998, The U.S. Geological Survey Coal Quality (COALQUAL) Database; version 2.0: U.S. Geological Survey Open-File Report 97–134, 1 CD-ROM.

Briggs, P.H., 1997, Determination of 25 elements in coal ash from 8 Argonne Premium Coal samples by inductively coupled argon plasma-atomic emission spectrometry, *in* Palmer, C.A., ed., The chemical analysis of Argonne Premium Coal samples: U.S. Geological Survey Bulletin 2144, p. 39–43.

Connor, J.J., Keith, J.R., and Anderson, B.M., 1976, Trace-metal variation in soils and sagebrush in the Powder River Basin, Wyoming and Montana: U.S. Geological Survey Journal of Research, v. 4, no. 1, p. 49–59.

Dowd, J.J., Turnbull, L.A., Toenges, A.L., Abernethy, R.F., and Reynolds, D.A., 1951a, Estimate of known recoverable reserves of coking coal in Armstrong County, Pa.: U.S. Bureau of Mines Report of Investigations 4801, 16 p.

———1951b, Estimate of known recoverable reserves of coking coal in Fayette County, Pa.: U.S. Bureau of Mines Report of Investigations 4807, 19 p.

———1951c, Estimate of known recoverable reserves of coking coal in Westmoreland County, Pa.: U.S. Bureau of Mines Report of Investigations 4803, 16 p.

Glick, D.C., and Davis, A., 1991, Operation and composition of the Penn State Coal Sample Bank and Data Base: Organic Geochemistry, v. 17, no. 4, p. 421–430

Golightly, D.W., and Simon, F.O., 1989, Methods for sampling and inorganic analysis of coal: U.S. Geological Survey Bulletin 1823, 72 p.

Janus, J.B., 1976, Analyses of tipple and delivered samples of coal (collected during fiscal year 1975): U.S. Bureau of Mines Report of Investigations 8115, 11 p.

Janus, J.B., and Shirley, B.S., 1973, Analyses of tipple and delivered samples of coal (collected during fiscal year 1972): U.S. Bureau of Mines Report of Investigations 7712, 17 p.

Lord, N.W., 1913, Analyses of coals in the United States with descriptions of mine and field samples collected between July 1, 1904 and June 30, 1910: U.S. Bureau of Mines Bulletin 22, 321 p.

MacLachlan, M.E., Bryant, W.A., Judkins, T.W., Koozmin, E.D., Orndorff, R.C., Hubert, M.L., Murdock, C.R., Starratt, S.W., LeCompte, J.R., and Abston, C.C., 1996, Stratigraphic nomenclature databases for the United States, its possessions and territories: U.S. Geological Survey Digital Data Series DDS–6, version 3.0, 1 CD-ROM.

Meier, A.L., 1997, Determination of 33 elements in coal ash from 8 Argonne Premium Coal samples by inductively coupled argon plasma-mass spectrometry, *in* Palmer, C.A., ed., The chemical analysis of Argonne Premium Coal samples: U.S. Geological Survey Bulletin 2144, p. 45–50.

Ohio Division of Mines and Reclamation, 1999, Surface coal-mine permits: Columbus, Ohio Division of Mines and Reclamation [available on file at Ohio Department of Natural Resources, 1855 Fountain Square, Building H-3, Columbus, Ohio 43224].

O'Leary, R.M., 1997, Determination of mercury and selenium in 8 Argonne Premium Coal samples by cold-vapor and hydride-generation atomic absorption spectrometry, *in* Palmer, C.A., ed., The chemical analysis of Argonne Premium Coal samples: U.S. Geological Survey Bulletin 2144, p. 51–55.

Suhr, N.H., and Gong, H., 1983, Some procedures for the chemical and mineralogical analysis of coals, *in* A data base for the analysis of compositional characteristics of coal seams and macerals, part 3: University Park, Pennsylvania State University, Coal Research Section, 42 p.

Swanson, V.E., and Huffman, C., Jr., 1976, Guidelines for sample collecting and analytical methods used in the U.S. Geological Survey for determining chemical composition of coal: U.S. Geological Survey Circular 735, 11 p. [re-released as part of Bragg and others (1998), USGS Open-File Report 97–134, CD-ROM, see menu item C735.PDF].

*The Pennsylvania State University Coal and Organic Petrology Laboratories, 1998, The Penn State Coal Sample Bank and Database [unpublished computer database]: University Park, Pa., The Pennsylvania State University [for further information, call (814) 865-6543, fax (814) 865-3573, or email xid@psu.edu.].

Toenges, A.L., Turnbull, L.A., Williams, L., Smith, H.L., O'Donnell, H.J., Cooper, H.M., Abernethy, R.F., and Waagé, K., 1949, Investigation of lower coal beds in Georges Creek and north part of upper Potomac Basins, Allegany and Garrett Counties, Maryland—Reserves, petrography, and chemical characteristics of coals, and stratigraphy of area: U.S. Bureau of Mines Technical Paper 725, 142 p., 31 figs.

Trumbull, James, 1960, Coal fields of the United States, exclusive of Alaska—Sheet 1: Washington, D.C., U.S. Geological Survey Map, scale 1:5,000,000.

Tully, John, 1996, Coal fields of the conterminous United States: U.S. Geological Survey Open-File Report 96–92, scale 1:5,000,000 (available on the web at http://energy.er.usgs.gov/products/openfile/OF96–92. Accessed March 1, 2001).

U.S. Bureau of Mines, 1970, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1969): U.S. Bureau of Mines Report of Investigations 7346, 29 p.

U.S. Bureau of Mines, 1972, Analyses of tipple and delivered samples of coal (collected during the fiscal year 1971): U.S. Bureau of Mines Report of Investigations 7588, 20 p.

*U.S. Geological Survey, 1997, USGS Coal Quality Database (USCHEM) [unpublished computer database]: Reston, Va., U.S. Geological Survey [for further information, contact Linda Bragg at (703) 648-6451 or by email at lbragg@usgs.gov].

*West Virginia Geological and Economic Survey, 1998, West Virginia Geological and Economic Survey Coal Quality Database [unpublished computer database]: Morgantown, West Virginia Geological and Economic Survey [for further information, contact William Grady at (304) 293-3382].

Wallace, J.J., Dowd, J.J., Bowsher, J.A., Abernethy, R.F., and Reynolds, D.A., 1953, Estimate of known recoverable reserves of coking coal in Somerset County, Pennsylvania: U.S. Bureau of Mines Report of Investigations 4998, 20 p.

Wallace, J.J., Dowd, J.J., Williams, L., Abernethy, R.F., and Reynolds, D.A., 1953, Estimate of known recoverable reserves of coking coal in Allegany County, Maryland: U.S. Bureau of Mines Report of Investigations 4970, 18 p.

Wolfson, D.E., Birge, G.W., and Naugle, B.W., 1956, Carbonizing properties of Somerset County, Pennsylvania coals: U.S. Bureau of Mines Report of Investigations 5269, 19 p.

Wood, G.H., Jr., Kehn, T.M., Carter, M.D., and Culbertson, W.C., 1983, Coal resource classification system of the U.S. Geological Survey: U.S. Geological Survey Circular 891, 65 p. [Also available on the web at http://energy.er.usgs.gov/products/papers/C891. Accessed September 5, 2001.]

*All contact information current as of February 13, 2001.

APPENDIX 11

DATA SOURCES FOR THE UPPER FREEPORT COAL BED AREAL EXTENT AND MINED AREA MAP

MARYLAND

SCALE 1:100,000

Brezinski, D., 1998, Extent and structure contour map of the Upper Freeport coal bed in the Potomac and Georges Creek Basins, Allegany and Garrett Counties, Maryland: Maryland Geological Survey Open-File Map 980–03–2, scale 1:100,000.

SCALE 1:24,000

Jacobsen, E.F., and Lyons, P.C., 1985, Coal geology of the Lower Youghiogheny coal field, Garrett County, Maryland: U.S. Geological Survey Coal Investigations Map C–101, scale 1:24,000.

Lyons, P.C., and Jacobsen, E.F., and Scott, B.K., 1985, Coal geology of the Castleman coal field, Garrett County, Maryland: U.S. Geological Survey Coal Investigations Map C–98, scale 1:24,000.

OHIO

SCALE 1:24,000

Caudill, M.R., 1991a, Bedrock geology of the Knoxville, Ohio-West Virginia quadrangle: Ohio Division of Geological Survey Open-File Map C1D6, scale 1:24,000.

———1991b, Bedrock geology of the Wellsville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1E6, scale 1:24,000.

———1991c, Reconnaissance bedrock geology of the Weirton quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1D5, scale 1:24,000.

Caudill, M.R., and Slucher, E.R., 1990, Bedrock geology of the Salineville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1E7, scale 1:24,000.

Larsen, G.E., 1990, Reconnaissance bedrock geology of the Homeworth quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2G1, scale 1:24,000.

———1997a, Reconnaissance bedrock geology of the Byesville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B2H5, scale 1:24,000.

———1997b, Reconnaissance bedrock geology of the New Concord quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B2H6, scale 1:24,000.

———1997c, Reconnaissance bedrock geology of the Norwich quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B2H7, scale 1:24,000.

———1997d, Reconnaissance bedrock geology of the Philo quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B2G8, scale 1:24,000.

———1997e, Reconnaissance bedrock geology of the Rokeby Lock quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B2F8, scale 1:24,000.

———1997f, Reconnaissance bedrock geology of the Ruraldale quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B2G7, scale 1:24,000.

———1997g, Reconnaissance bedrock geology of the Zanesville East quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B2H8, scale 1:24,000.

Larsen, G.E., and Rea, R.G., 1990, Bedrock geology of the New Middletown quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1H5, scale 1:24,000.

Larsen, G.E., and Slucher, E.R., 1996, Reconnaissance bedrock geology of the Elkton quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1G6, scale 1:24,000.

Rice, C.L., 1995a, Reconnaissance bedrock geology of the Ashland quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3D6, scale 1:24,000.

———1995b, Reconnaissance bedrock geology of the Gallia quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3G5, scale 1:24,000.

———1995c, Reconnaissance bedrock geology of the Ironton quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3E6, scale 1:24,000.

———1995d, Reconnaissance bedrock geology of the Oak Hill quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3H5, scale 1:24,000.

———1995e, Reconnaissance bedrock geology of the Sheritts quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3F5, scale 1:24,000.

———1995f, Reconnaissance bedrock geology of the South Webster quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3G6, scale 1:24,000.

———1996a, Reconnaissance bedrock geology of the Aid quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3E4, scale 1:24,000.

———1996b, Reconnaissance bedrock geology of the Catlettsburg quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3D5, scale 1:24,000.

———1996c, Reconnaissance bedrock geology of the Kitts Hill quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3E5, scale 1:24,000.

———1996d, Reconnaissance bedrock geology of the Patriot quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3G4, scale 1:24,000.

———1996f, Reconnaissance bedrock geology of the Rio Grande quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3H4, scale 1:24,000.

———1996g, Reconnaissance bedrock geology of the Vinton quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map A3H3, scale 1:24,000.

———1996h, Reconnaissance bedrock geology of the Waterloo quadrangle, Ohio: Ohio Division of Geological Survey Open-

File Map A3F4, scale 1:24,000.
Schumacher, G.A., 1995a, Reconnaissance bedrock geology of the Albany quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3B2, scale 1:24,000.
———1995b, Reconnaissance bedrock geology of the Athens quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3C1, scale 1:24,000.
———1995c, Reconnaissance bedrock geology of the Jacksonville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3D1, scale 1:24,000.
———1995d, Reconnaissance bedrock geology of the McArthur quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3B4, scale 1:24,000.
———1995e, Reconnaissance bedrock geology of the Mineral quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3C3, scale 1:24,000.
———1995f, Reconnaissance bedrock geology of the Mulga quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3A4, scale 1:24,000.
———1995g, Reconnaissance bedrock geology of the Nelsonville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3D2, scale 1:24,000.
———1995h, Reconnaissance bedrock geology of the Rutland quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3A2, scale 1:24,000.
———1995i, Reconnaissance bedrock geology of the The Plains quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3C2, scale 1:24,000.
———1995j, Reconnaissance bedrock geology of the Union Furnace quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3D3, scale 1:24,000.
———1995k, Reconnaissance bedrock geology of the Vales Mills quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3B3, scale 1:24,000.
———1995l, Reconnaissance bedrock geology of the Wilkesville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3A3, scale 1:24,000.
———1995m, Reconnaissance bedrock geology of the Zaleski quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3C4, scale 1:24,000.
Shrake, D.L., 1995a, Reconnaissance bedrock geology of the Corning quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3E1, scale 1:24,000.
———1995b, Reconnaissance bedrock geology of the Crooksville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3G1, scale 1:24,000.
———1995c, Reconnaissance bedrock geology of the Deavertown quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3F1, scale 1:24,000.
———1995d, Reconnaissance bedrock geology of the Fultonham quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3G2, scale 1:24,000.
———1995e, Reconnaissance bedrock geology of the Gore quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3E3, scale 1:24,000.
———1995f, Reconnaissance bedrock geology of the Junction City quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3F3, scale 1:24,000.
———1995g, Reconnaissance bedrock geology of the New Lexington quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3F2, scale 1:24,000.
———1995h, Reconnaissance bedrock geology of the New Straitsville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3E2, scale 1:24,000.
———1995i, Reconnaissance bedrock geology of the Somerset quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3G3, scale 1:24,000.
———1995j, Reconnaissance bedrock geology of the Zanesville West quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map B3H1, scale 1:24,000.
———1997, Reconnaissance bedrock geology of the Baltic quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2D6, scale 1:24,000.
Slucher, E.R., 1990, Reconnaissance bedrock geology of the Minerva quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2F1, scale 1:24,000.
———1992, Bedrock geology of the Kensington quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1F8, scale 1:24,000.
———1996a, Reconnaissance bedrock geology of the East Liverpool North quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1F5, 1:24,000.
———1996b, Reconnaissance bedrock geology of the Gavers quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1F7, scale 1:24,000.
———1996c, Reconnaissance bedrock geology of the West Point quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1F6, scale 1:24,000.
———1997a, Reconnaissance bedrock geology of the Adamsville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2A8, scale 1:24,000.
———1997b, Reconnaissance bedrock geology of the Birmingham quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2B4, scale 1:24,000.
———1997c, Reconnaissance bedrock geology of the Bloomfield quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2A6, scale 1:24,000.
———1997d, Reconnaissance bedrock geology of the Bowerston quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2D2, scale 1:24,000.
———1997e, Reconnaissance bedrock geology of the Cambridge quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2A5, scale 1:24,000.
———1997f, Reconnaissance bedrock geology of the Conesville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2B8, scale 1:24,000.
———1997g, Reconnaissance bedrock geology of the Coshocton quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2C7, scale 1:24,000.
———1997h, Reconnaissance bedrock geology of the Deersville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2C2, scale 1:24,000.
———1997i, Reconnaissance bedrock geology of the Freeport quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2B3, scale 1:24,000.
———1997j, Reconnaissance bedrock geology of the Fresno quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2C6, scale 1:24,000.
———1997k, Reconnaissance bedrock geology of the Gnadenhutten quadrangle, Ohio: Ohio Division of Geological

Survey Open-File Map C2C4, scale 1:24,000.
———1997l, Reconnaissance bedrock geology of the Killbuck quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2D8, scale 1:24,000.
———1997m, Reconnaissance bedrock geology of the Kimbolton quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2B5, scale 1:24,000.
———1997n, Reconnaissance bedrock geology of the New Bedford quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2D7, scale 1:24,000.
———1997o, Reconnaissance bedrock geology of the New Philadelphia quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2D4, scale 1:24,000.
———1997p, Reconnaissance bedrock geology of the Newcomerstown quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2C5, scale 1:24,000.
———1997q, Reconnaissance bedrock geology of the Old Washington quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2A4, scale 1:24,000.
———1997r, Reconnaissance bedrock geology of the Otsego quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2A7, scale 1:24,000.
———1997s, Reconnaissance bedrock geology of the Plainfield quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2B6, scale 1:24,000.
———1997t, Reconnaissance bedrock geology of the Randle quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2C8, scale 1:24,000.
———1997u, Reconnaissance bedrock geology of the Stone Creek quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2D5, scale 1:24,000.
———1997v, Reconnaissance bedrock geology of the Tippecanoe quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2C3, scale 1:24,000.
———1997w, Reconnaissance bedrock geology of the Uhrichsville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2D3, scale 1:24,000.
———1997x, Reconnaissance bedrock geology of the Wills Creek quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2B7, scale 1:24,000.
Slucher, E.R., and Caudill, M.R., 1996, Reconnaissance bedrock geology of the East Liverpool South quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1E5, scale 1:24,000.
Slucher, E.R., and Larsen, G.E., 1989, Bedrock geology of the East Palestine quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1G5, scale 1:24,000.
———1996a, Reconnaissance bedrock geology of the Columbiana quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1H6, scale 1:24,000.
———1996b, Reconnaissance bedrock geology of the Damascus quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1H8, scale 1:24,000.
———1996c, Reconnaissance bedrock geology of the Hanoverton quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1G8, scale 1:24,000.
———1996d, Reconnaissance bedrock geology of the Lisbon quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1G7, scale 1:24,000.
———1996e, Reconnaissance bedrock geology of the Salem quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1H7, scale 1:24,000.
Slucher, E.R., and Swinford, E.M., 1996, Reconnaissance bedrock geology of the Bergholz quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1E8, scale 1:24,000.
Swinford, E.M., 1996a, Reconnaissance bedrock geology of the Bolivar quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2F4, scale 1:24,000
———1996b, Reconnaissance bedrock geology of the Canton East quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2G3, scale 1:24,000.
———1996c, Reconnaissance bedrock geology of the Dover quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2E4, scale 1:24,000.
———1996d, Reconnaissance bedrock geology of the Mineral City quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2E3, scale 1:24,000.
———1996e, Reconnaissance bedrock geology of the Robertsville quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2G2, scale 1:24,000.
———1996f, Reconnaissance bedrock geology of the Strasburg quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2E5, scale 1:24,000.
———1996g, Reconnaissance bedrock geology of the Waynesburg quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2F3, scale 1:24,000.
———1997, Reconnaissance bedrock geology of the Amsterdam quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C1D8, scale 1:24,000.
Swinford, E.M., and Slucher, E.R., 1996a, Reconnaissance bedrock geology of the Carrollton quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2E1, scale 1:24,000.
———1996b, Reconnaissance bedrock geology of the Dellroy quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2E2, scale 1:24,000.
———1996c, Reconnaissance bedrock geology of the Malvern quadrangle, Ohio: Ohio Division of Geological Survey Open-File Map C2F2, scale 1:24,000.

PENNSYLVANIA

SCALE 1:500,000

Berg, T.M., Edmunds, W.E., Geyer, A.R., Glover, A.D., Hoskins, D.M., MacLachlan, D.B., Root, S.I., Sevon, W.D., and Socolow, A.A., 1980, Geologic map of Pennsylvania, 2nd ed.: Pennsylvania Bureau of Topographic and Geologic Survey, 2 sheets, scale 1:250,000.

SCALE 1:63,360

Bragonier, W.A., and Glover, A.D., 1996, Coal resources of Indiana County, Pennsylvania, Part 1, Coal crop lines, mined out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Report 98, p. 12, 14, 22, 29, 38, 46, 56, 61, 64, 67, 71, 77, 84, 88, 96, 98, 100, 108, 112, 118, 121.
Dodge, C.H., 1985a, Coal resources of Allegheny County,

Pennsylvania, Part 1, Coal crop lines, mined out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Report 89, p. 8, 23, 31, 37, 53, 57.

———1985b, Coal resources of Butler County, Pennsylvania, Part 1, Coal crop lines, mined out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Report 90, p. 4, 12, 16, 19, 23, 38, 42, 52, 58, 61, 65, 71, 77, 82, 86, 92, 94, 100, 106, 111.

Glover, A.D., 1987, Coal resources of Clarion County, Pennsylvania, Part 1, Coal crop lines, mined out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Report 92, p. 11, 23, 37, 75, 82, 89, 96, 110.

———1990, Coal resources of Cambria and Blair Counties, Pennsylvania, Part 1, Coal crop lines, mined out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Report 96, p. 12, 20, 26, 34, 41, 52, 57, 63, 71, 76, 84, 92, 102, 109, 128.

Shaulis, J.R., 1985, Coal resources of Fayette County, Pennsylvania, Part 1, Coal crop lines, mined out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Report 91, p. 7, 22, 30, 38, 43, 58, 71, 73, 83.

Skema, V.W., 1988, Coal resources of Westmoreland County, Pennsylvania, Part 1, Coal crop lines, mined out areas, and structure contours: Pennsylvania Bureau of Topographic and Geologic Survey Report 94, p. 6, 10, 15, 23, 40, 52, 58, 60, 65, 77, 91, 94, 97, 99, 105, 108, 116, 119, 124.

SCALE 1:24,000

Glover, A.D., 1998, Preliminary maps showing structure contours, and crop lines and mined-out areas of the Upper Freeport and Lower Kittanning coal beds in Jefferson County, Pennsylvania: Harrisburg, Pennsylvania Bureau of Topographic and Geologic Survey, unpublished manuscript maps, scale 1:24,000 [available on file at Pennsylvania Bureau of Topographic and Geologic Survey, 1500 North 3rd Street, 2nd Floor Harrisburg, PA 17105-8453].

Glover, A.D., and Bragonier, W.A., 1997, Maps showing structure contours, and crop lines and mined-out areas of the Upper Freeport and Lower Kittanning coal beds in Armstrong County, Pennsylvania: Harrisburg, Pennsylvania Bureau of Topographic and Geologic Survey, unpublished manuscript maps, scale 1:24,000 [available on file at Pennsylvania Bureau of Topographic and Geologic Survey, 1500 North 3rd Street, 2nd Floor Harrisburg, PA 17105-8453].

Shaulis, J.R., 1998, Maps showing structure contours, and crop lines and mined-out areas of the Upper Freeport and Lower Kittanning coal beds in Somerset County, Pennsylvania: Harrisburg, Pennsylvania Bureau of Topographic and Geologic Survey, unpublished manuscript maps, scale 1:24,000 [available on file at Pennsylvania Bureau of Topographic and Geologic Survey, 1500 North 3rd Street, 2nd Floor Harrisburg, PA 17105-8453].

WEST VIRGINIA

SCALE 1:24,000

West Virginia Geological and Economic Survey, 1997a, Upper Freeport coal extent—working map, Adrian quadrangle, West Virginia-Ohio, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997b, Upper Freeport coal extent—working map, Alton quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997c, Upper Freeport coal extent—working map, Antioch quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997d, Upper Freeport coal extent—working map, Audra quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997e, Upper Freeport coal extent—working map, Aurora quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997f, Upper Freeport coal extent—working map, Bellington quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997g, Upper Freeport coal extent—working map, Blackbird Knob quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997h, Upper Freeport coal extent—working map, Blackwater Falls quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997i, Upper Freeport coal extent—working map, Brandonville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997j, Upper Freeport coal extent—working map, Bruceton Mills quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic

Survey Open-File Report 07, scale 1:24,000.

———1997k, Upper Freeport coal extent—working map, Buckhannon quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997l, Upper Freeport coal extent—working map, Century quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997m, Upper Freeport coal extent—working map, Colebank quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997n, Upper Freeport coal extent—working map, Cuzzart quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997o, Upper Freeport coal extent—working map, Davis quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997p, Upper Freeport coal extent—working map, Ellamore quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997q, Upper Freeport coal extent—working map, Erbacon quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997r, Upper Freeport coal extent—working map, Fairmont East quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997s, Upper Freeport coal extent—working map, Fairmont West quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997t, Upper Freeport coal extent—working map, Fellowsville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997u, Upper Freeport coal extent—working map, Friendsville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997v, Upper Freeport coal extent—working map, Gassaway quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997w, Upper Freeport coal extent—working map, Gladesville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997x, Upper Freeport coal extent—working map, Gorman quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997y, Upper Freeport coal extent—working map, Goshen quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997z, Upper Freeport coal extent—working map, Greenland Gap quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997aa, Upper Freeport coal extent—working map, Hacker Valley quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997bb, Upper Freeport coal extent—working map, Hopeville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997cc, Upper Freeport coal extent—working map, Junior quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997dd, Upper Freeport coal extent—working map, Kingwood quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997ee, Upper Freeport coal extent—working map, Kitzmiller quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997ff, Upper Freeport coal extent—working map, Lake Lynn quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997gg, Upper Freeport coal extent—working map, Laneville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.

———1997hh, Upper Freeport coal extent—working map, Leadmine quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic

Survey Open-File Report 07, scale 1:24,000.
———1997ii, Upper Freeport coal extent—working map, Little Birch quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997jj, Upper Freeport coal extent—working map, Masontown quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997kk, Upper Freeport coal extent—working map, Montrose quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997ll, Upper Freeport coal extent—working map, Morgantown North quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997mm, Upper Freeport coal extent—working map, Morgantown South quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997nn, Upper Freeport coal extent—working map, Mount Storm quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997oo, Upper Freeport coal extent—working map, Mount Storm Lake quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997pp, Upper Freeport coal extent—working map, Mozark Mountain quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997qq, Upper Freeport coal extent—working map, Nestorville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997rr, Upper Freeport coal extent—working map, Newburg quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997ss, Upper Freeport coal extent—working map, Newville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997tt, Upper Freeport coal extent—working map, Oakland quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997uu, Upper Freeport coal extent—working map, Orlando quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997vv, Upper Freeport coal extent—working map, Phillippi quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997ww, Upper Freeport coal extent—working map, Rivesville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997xx, Upper Freeport coal extent—working map, Rock Cave quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997yy, Upper Freeport coal extent—working map, Rowlesburg quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997zz, Upper Freeport coal extent—working map, Sang Run quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997aaa, Upper Freeport coal extent—working map, Sutton quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997bbb, Upper Freeport coal extent—working map, Table Rock quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997ccc, Upper Freeport coal extent—working map, Terra Alta quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997ddd, Upper Freeport coal extent—working map, Valley Point quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997eee, Upper Freeport coal extent—working map, Walkersville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000.
———1997fff, Upper Freeport coal extent—working map, Westernport quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic

Survey Open-File Report 07, scale 1:24,000.
———1997ggg, Upper Freeport coal mined out extent—working map, Buckhannon quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997hhh, Upper Freeport coal mined out extent—working map, Cuzzart quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997iii, Upper Freeport coal mined out extent—working map, Davis quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997jjj, Upper Freeport coal mined out extent—working map, Fellowsville quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997kkk, Upper Freeport coal mined out extent—working map, Gorman quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997lll, Upper Freeport coal mined out extent—working map, Kingwood quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997mmm, Upper Freeport coal mined out extent—working map, Kitzmiller quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997nnn, Upper Freeport coal mined out extent—working map, Leadmine quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997ooo, Upper Freeport coal mined out extent—working map, Masontown quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997ppp, Upper Freeport coal mined out extent—working map, Newburg quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997qqq, Upper Freeport coal mined out extent—working map, Mount Storm quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997rrr, Upper Freeport coal mined out extent—working map, Mount Storm Lake quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997sss, Upper Freeport coal mined out extent—working map, Mozark Mountain quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997ttt, Upper Freeport coal mined out extent—working map, Oakland quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997uuu, Upper Freeport coal mined out extent—working map, Rowlesburg quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997vvv, Upper Freeport coal mined out extent—working map, Table Rock quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997www, Upper Freeport coal mined out extent—working map, Terra Alta quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997xxx, Upper Freeport coal mined out extent—working map, Valley Point quadrangle, West , *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].
———1997yyy, Upper Freeport coal mined out extent—working map, Westernport quadrangle, West Virginia, *in* Maps showing areas of coal removed by underground mining for all major coal seams in WV: West Virginia Geological and Economic Survey Open-File Report 07, scale 1:24,000 [mining updated in mid-1980's].

APPENDIX 12

ORIGINAL COAL RESOURCES BY OVERBURDEN, RELIABILITY, AND COAL-BED THICKNESS CATEGORIES FOR THE UPPER FREEPORT COAL BED, BY COUNTY

[Resources are rounded to millions of short tons. Reliability categories are as follows: identified, resources calculated for area within 3 mi of a coal-thickness measurement point; hypothetical, resources calculated for area farther than 3 mi from a coal-thickness measurement. Asterisk indicates less than 10,000 short tons. Abbreviations are as follows: St., State.]

CLICK HERE TO GO TO APPENDIX 12

APPENDIX 13

REMAINING COAL RESOURCES BY OVERBURDEN, RELIABILITY, AND COAL-BED THICKNESS CATEGORIES FOR THE UPPER FREEPORT COAL BED, BY COUNTY

[Resources are rounded to millions of short tons. Reliability categories are as follows: identified, resources calculated for area within 3 mi of a coal-thickness measurement point; hypothetical, resources calculated for area farther than 3 mi from a coal-thickness measurement. Asterisk indicates less than 10,000 short tons; <, mine map compilation not complete, remaining resource values less than shown. Abbreviations are as follows: St., State]

CLICK HERE TO GO TO APPENDIX 13