United States Department of the Interior
Geological Survey

Sources of Data, Procedures, and Bibliography for Coal Resource Investigation of Western Maryland

by

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Abstract

A coal resource investigation of the five coal fields of western Maryland was undertaken by the U.S. Geological Survey, Reston, Virginia, beginning November 1979. The objective was to determine the coal resources of Maryland (exclusive of lignite). Data used in the report were partly obtained from previously published maps and literature that were based primarily on site-specific information from two U.S. Bureau of Mines drilling projects during the late 1940s, surface mining permits, underground mine documents, water well logs, coal company drilling records, and unpublished field notes. Structure contour maps were prepared as a basis for correlation of the coal beds. Coal bed maps that were prepared at a scale of 1:24,000 showed areas of surface and underground mining. The extent of surface mining was based partly on aerial photography taken in May 1979. Mined-out underground areas were determined from previously published reports and from company mine maps obtained from the U.S. Bureau of Mines. Stratigraphic and coal thickness data were documented on computer forms and were submitted to the National Coal Resources Data System (NCRDS); the coal bed maps were also submitted for digitizing of point and line data. From these data, NCRDS programs will compute the coal resources for the five coal fields of western Maryland.

Introduction

The U.S. Geological Survey began in the fall of 1979 a study of the coal resources of the two coal-producing counties of Maryland. The purpose was to provide new coal resource estimates. This study is important because of continued expansion of coal mining in western Maryland.

This report describes the sources of information and explains the procedures in the collection and analysis of geologic data used in the preparation of coal bed maps for coal resource calculations for the coal fields of western Maryland. Other reports will present the coal resource estimates generated from the basic data collected during this study. A brief overview of the stratigraphy, geologic setting, and history of coal mining in western Maryland is included in this report to provide a framework for understanding the methodology used. Also included is a bibliography on Maryland coal (exclusive of lignite).

Coal resource investigations of western Maryland began with stratigraphic work by Clark and others (1905) and continued with Swartz and Baker (1920). In the late 1940's, U.S. Bureau of Mines core drilling projects in the Georges Creek, Upper Potomac, and Castleman basins yielded drill cores that were analyzed and correlated by Toenges and others (1949 and 1952). Revisions of coal resource tonnage estimates which were based mainly on prior publications were accomplished by Boyd and Associates (1964) and Weaver and others (1976). A literature survey of these and other references concerning the coal resources of Maryland revealed a lack of published site-specific data. Thus, a significant amount of new data had to be collected and interpreted before a meaningful reestimation of coal resources could be done. Coal bed maps at a scale of 1:24,000 were prepared essentially from basic data. Clark and others (1905) and Swartz and Baker (1920) provided an understanding of the stratigraphy.

Location and Physical Setting

The coal fields of western Maryland are located in the two north-western border counties of the Maryland panhandle. The coal-bearing areas underlie approximately 455 square miles of Garrett and Allegheny Counties, including parts of 21 U.S. Geological Survey 7.5 minute topographic quadrangles (Fig. 1). The coal fields are both structural and topographic basins. They are structurally confined to the cores of four elongate synclines. The coal fields are known as the Georges Creek, the Upper Potomac, the Castleman, the Lower Youghiogheny, and the Upper Youghiogheny basins (Fig. 1). Together, they form the eastern margin of the Appalachian Plateau Province, which extends southward from northern Pennsylvania to Alabama (Clark and others, 1902, p. 28).

The Maryland coal fields are named for the major creek or river which flows through each field and parallels the structural axis of the controlling syncline. Overall, the main drainages are structurally controlled, with jointing affecting the courses of the larger tributaries. A trellis drainage pattern exists in the core of each field; a dendritic pattern has developed in the upper reaches of the heads of the minor branches. The valleys themselves range in character from deep gorges along the Youghiogheny and Potomac Rivers to the relatively shallow flood plains along the Casselman River and Cherry Creek.

The topography of the fields ranges from gently rolling in the Castleman and Upper Youghiogheny basins to steep in parts of the Georges Creek, Upper Potomac, and Lower Youghiogheny basins. The margins of the basins are

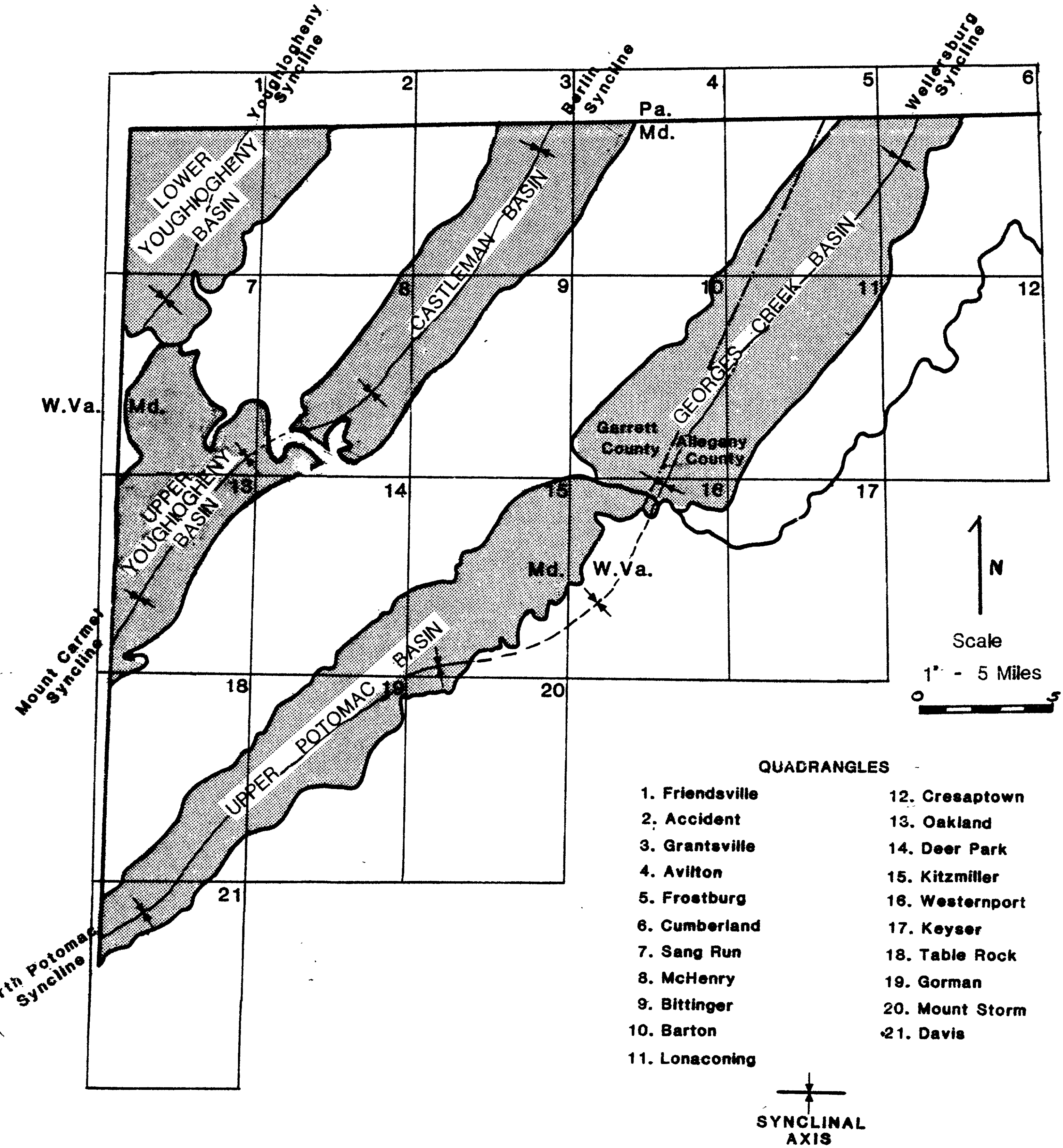

Figure 1: The Coal Basins of Western Maryland

well-defined by sandstone ridges of the Pottsville Formation. Land use throughout the fields is dominantly agricultural, with forests still covering the most of the rugged, undeveloped areas.

Structure

Coal occurs in western Maryland in the cores of four parallel syncline basins, whose axes trend N. 30-40` E. and plunge from <1/2` to 4` to the northeast. The largest synclinal basin is divided by the Savage River into two separate coal basins: the Georges Creek and the Upper Potomac basins. All the synclines are asymmetric and have relatively steep eastern flanks. A brief discussion of each basin follows:

Georges Creek Basin: This basin or coal field is a part of the Wellersburg syncline, which extends northward into Pennsylvania. Dips on the limbs seldom exceed 15`. The basin averages 5 miles in width and is about 18 miles long in Maryland. It contains the most complete section of Pennsylvanian strata in Maryland (Fig. 2) and has the longest history of commercial mining in the state. Important coal beds mined are the Pittsburgh, Redstone, Sewickley, and the Uniontown, the highest bed, which had been previously mis-correlated with the Waynesburg coal bed (Swartz and Baker, 1920), or the Koontz coal bed of Berryhill and DeWitt (1955).

Upper Potomac Basin: This coal field is the southern continuation of the Georges Creek field. Structurally, the area is part of the western limb of the North Potomac syncline, with the eastern limb situated mainly in West Virginia. The Potomac River marks the state boundary and flows parallel to the axis of the basin for some distance. Within the central part of the basin, there are structural anomalies that have not been deciphered by deep drilling or surface investigation.

These anomalies have prevented a full delineation of the stratigraphy. Minable coal beds include a small area of the Pittsburgh coal bed, along with larger areas of the Franklin, Barton, Upper Bakerstown, Lower Bakerstown, Upper Freeport, Upper Kittanning, Lower Kittanning, and Clarion coal beds. Of the minable beds, the Upper Freeport coal bed is the most important. In the southern part of the basin, it ranges from 5.7 to 8.9 ft in thickness and averages 7.8 ft thick, with a few thin shale partings averaging 0.9 ft in thickness. This coal bed is mined in the only active underground operation in Maryland. Large areas of this bed are unmined, as a result the Upper Potomac basin contains the largest area and tonnage of contiguous coal reserves in the State.

Castleman Basin: The Castleman basin is structurally the simplest of the five coal fields. It is a long narrow syncline, which continues across the State line into Pennsylvania. To the south, it is bounded by the Piney Mountain anticline. The youngest coal bed is the Upper Clarysville(?); other important beds are the Upper Freeport, Lower Bakerstown, and Upper Bakerstown. The Lower Bakerstown is the most persistent coal bed in the field and is usually about 30 inches thick with no partings.

Lower Youghiogheny Basin: This basin is one of the least known geologically of the Maryland coal fields. Problems with coal bed correlations appear to be soluble only with deep drilling. The controlling structural feature is a broad northeastward-plunging syncline characterized by gentle limbs. Dips on the eastern limb are as much as 8` and those on the western limb are usually less than 2`. Minable beds in the basin include the highest coal bed which was correlated with the Little Clarksburg coal bed (Swartz and Baker, 1920). Other minable coal beds are the Upper Freeport, Lower Kittanning, and Clarion. The Upper Freeport is consistently 4 to 5 feet thick, with a few thin shale partings. The Lower Kittanning and Clarion coal beds occur within 20 stratigraphic feet of each other and are mined together at some localities in the southern portion of the basin.

Upper Youghiogheny Basin: This is the smallest and least understood coal field in Maryland. It also has the thinnest section of coal-bearing strata including only the lower part of the Conemaugh Formation. It is bounded on four sides by anticlines, making it a wholly enclosed basin. Its western limb lies chiefly in West Virginia. As is true with the other basins, strata on its eastern flanks are relatively steep as compared with the western flanks. Minable coal beds are the Lower Kittanning, Clarion, and Lower Freeport.

Stratigraphy

Generally, the age of coal-bearing strata in the Maryland coal fields ranges from Early to Late Pennsylvanian in age. Early Permian strata are preserved at several localities in the Georges Creek basin. These strata are assigned to the lower part of the Washington Formation (Fig. 2). The Pottsville, Allegheny, and Conemaugh Formations are exposed to varying degrees in all basins. The Monongahela Formation is confined to the Georges Creek Basin and to Manor Hill in the northern part of the Upper Potomac Basin. Coal beds define the upper and lower stratigraphic boundaries of each formation except the base of the Allegheny, which is not well defined, but is approximately marked by the base of the Lower Mount Savage coal bed, where present, (Fig. 2) or the top of a conglomeratic sandstone (?Homewood Sandstone) of the Pottsville Formation. A brief description of each formation follows:

Pottsville Formation: The Pottsville Formation averages about 240 ft in thickness in Maryland. It rests unconformably on the Mauch Chunk Formation of Late Mississippian age. Pottsville strata are characterized by several beds of massive and commonly conglomeratic sandstone separated by shale and thin coal beds. Coal beds that have been prospected and mined locally have been correlated with the Sharon, Quakertown, and Mercer coal beds.

Allegheny Formation: The Allegheny Formation, which averages about 250 ft in thickness, contains alternating sequences of shale, siltstone, claystone, channel-type sandstone and coal beds. The Bolivar fireclay, which is the underclay associated with the Upper Freeport coal bed, and other less important underclays in the Allegheny have been important commercial sources of fire clay in the past (Waage, 1950). The lower coal beds include the Clarion and the Lower, Middle, and Upper Kittanning, which are generally not persistent, except locally. The top of the Upper Freeport coal bed marks the upper stratigraphic limit of the formation. The Upper Freeport is generally a persistent, thick coal bed that has been identified in each coal basin; however, locally it is absent or thin.

Conemaugh Formation: The Conemaugh Formation records the first appearance of beds containing marine invertebrate fossils in the Pennsylvanian of western Maryland. Four transgressive marine units

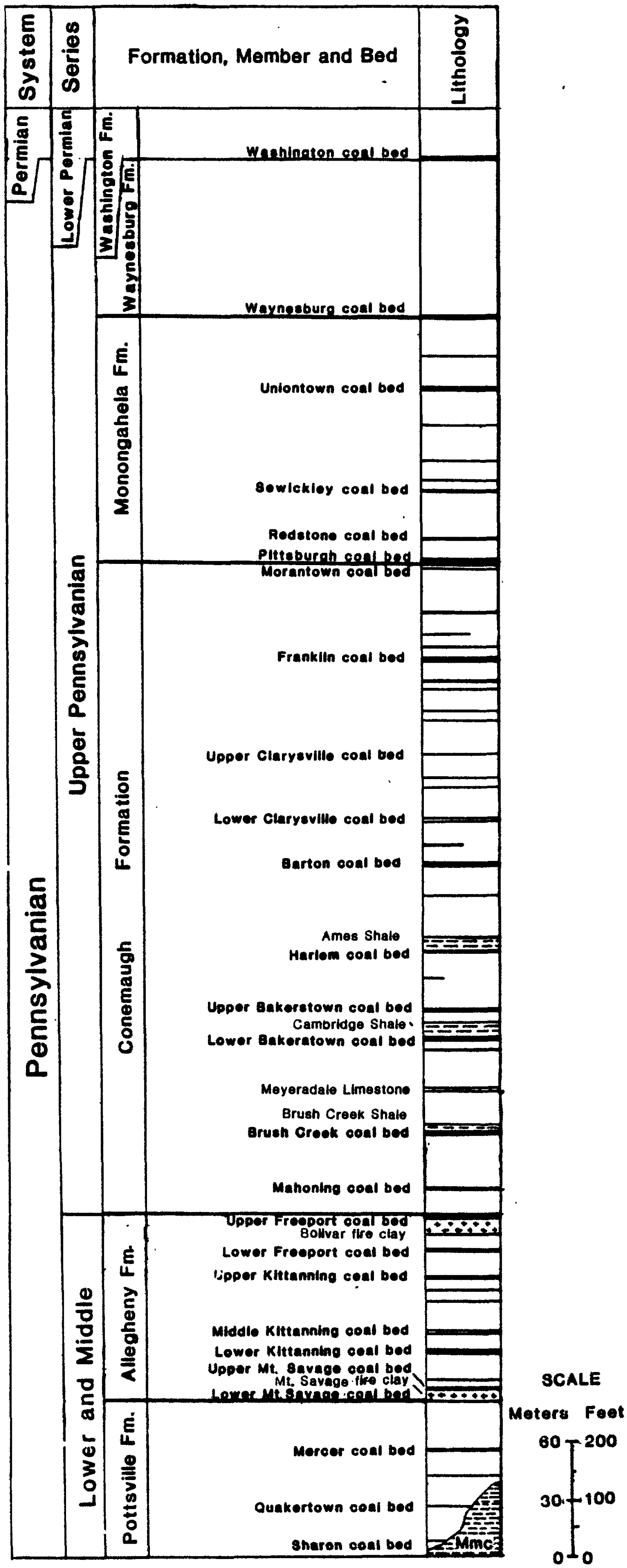

Figure 2: Generalized Stratigraphic Column for Pennsylvanian and Permian of Western Maryland

Mmc, Mauch Chunk Formation, Upper Mississippian

Modified from Swartz and Baker (1920)

have been recognized (Swartz and Baker, 1920). Two of these units directly overlie associated coal beds, as indicated by asterisks in the following:

Marine Unit	Associated Coal Bed or Horizon
Ames Shale (Limestone)	Harlem*
Cambridge Shale	Lower Bakerstown
Meyersdale Limestone	Meyersdale Red Shale
Brush Creek Shale (Limestone)	Brush Creek*

Several thin, fresh water limestone beds have been identified in the upper part of the Conemaugh Formation. Medium-grained channel sandstone is interbedded with shale, siltstone, and thin beds of tabular sandstone. Persistent coal beds are the Franklin and Barton in the Georges Creek basin, and the Barton in basins to the west. The Conemaugh Formation in the Georges Creek Basin is approximately 900 feet thick (Swartz and Baker, 1920). Amsden (1953) has separated the formation into a lower and upper member at the Barton coal bed. In contrast, Berryhill and others, 1971 subdivided the Conemaugh Group into the Casselman and Glenshaw Formations at the Ames Limestone. In this report the precedent of Clark and others (1905), of Swartz and Baker (1920), and of Berryhill and others (1956) is followed and the Conemaugh Formation is not subdivided.

Monongahela Formation: The Monongahela Formation contains at its base, the Pittsburgh coal bed, which has historically been the most heavily mined bed in Maryland. It averages about 8 feet in thickness, but locally attains unusual thicknesses of as much as 22 feet (Swartz and Baker, 1920, p. 72). Other coal beds found stratigraphically above the Pittsburgh are the Redstone, Sewickley, and the Uniontown, previously miscorrelated with the Waynesburg coal bed (Berryhill and Dewitt, 1955). The remainder of the strata are thin sandstones, interbedded shale and sandstone, siltstone, and an increasing number of thin beds of fresh-water limestone. The Monongahela Formation in the Georges Creek basin is approximately 345 ft thick.

Mining History

Coal mining in Maryland began as early as 1782, as shown on a French map indicating a mine at the mouth of Georges Creek (Clark and others, 1905, p. 223). Another early mine was located about a mile north of Frostburg in the valley of Jennings Run where a mine was operating by 1804 (Clark and others, 1905). Coal beds such as the Pittsburgh and the Barton were probably the first beds mined because they were thick and near the surface.

The opening of the National Road in 1818 provided an overland route for coal shipments through Cumberland. The completion of the Baltimore and Ohio Railroad in 1842 and the opening of the Chesapeake and Ohio Canal in 1850 made Cumberland a major coal shipping center. These transportation advances spurred the development of commercially profitable underground mining on the Pittsburgh and Sewickley coal beds in the Georges Creek basin (Clark and others, 1905, p. 514). Production derived from the Georges Creek field increased steadily with the building of cooperative drainage tunnels in order to reach the deeper reserves of the Pittsburgh bed. Peak production occurred in 1907, when over 5.5 million short tons were mined (Fig. 3). At that time, more than 5,000 men were employed in underground mines, in

Maryland (Weaver and others, 1976). Mine output stabilized at 4.5± million short tons per year during the period 1908 to 1918. Almost all of this production was derived from the Pittsburgh coal bed.

After World War I, yearly coal production declined to an average of 1.2 million tons, as the Pittsburgh coal bed and other thick beds neared depletion. World War II brought increased demand, and coal production rose to almost 2 million short tons. A shortage of miners and the gradual depletion of underground resources resulted in the development of strip mining in Maryland. After 1945 coal production dropped to a low of less than 500,000 short tons in 1954. Since that time, coal production steadily rose as strip mining took over as the dominant mining method (Fig. 3).

The Arab oil embargo of 1973-74 resulted in a rapid rise in prices of steam coal and metallurgical coal to record levels and precipitated rapid exploitation of near-surface coal in all basins of western Maryland. The most important beds surface mined in the Georges Creek basin were the Sewickley, Redstone and Waynesburg (Uniontown of this report) coal beds. Near-surface mining of areas previously mined underground in the Pittsburgh coal bed occurred in the Georges Creek basin. The Lower Bakerstown, Upper Freeport, and Lower Kittanning coal beds were surface mined in the coal basins to the west. The Federal Surface Mining Act of 1977 brought stringent land reclamation and permitting requirements which when coupled with a slump in coal prices stalled growth of surface mining in Maryland. The recent development of a large-scale underground mine by the Mettiki Coal Corporation in the Upper Potomac basin prevented a large decrease in Maryland coal production. More than 2.7 million short tons were produced in 1979 (Abar, 1979). The expansion of the current

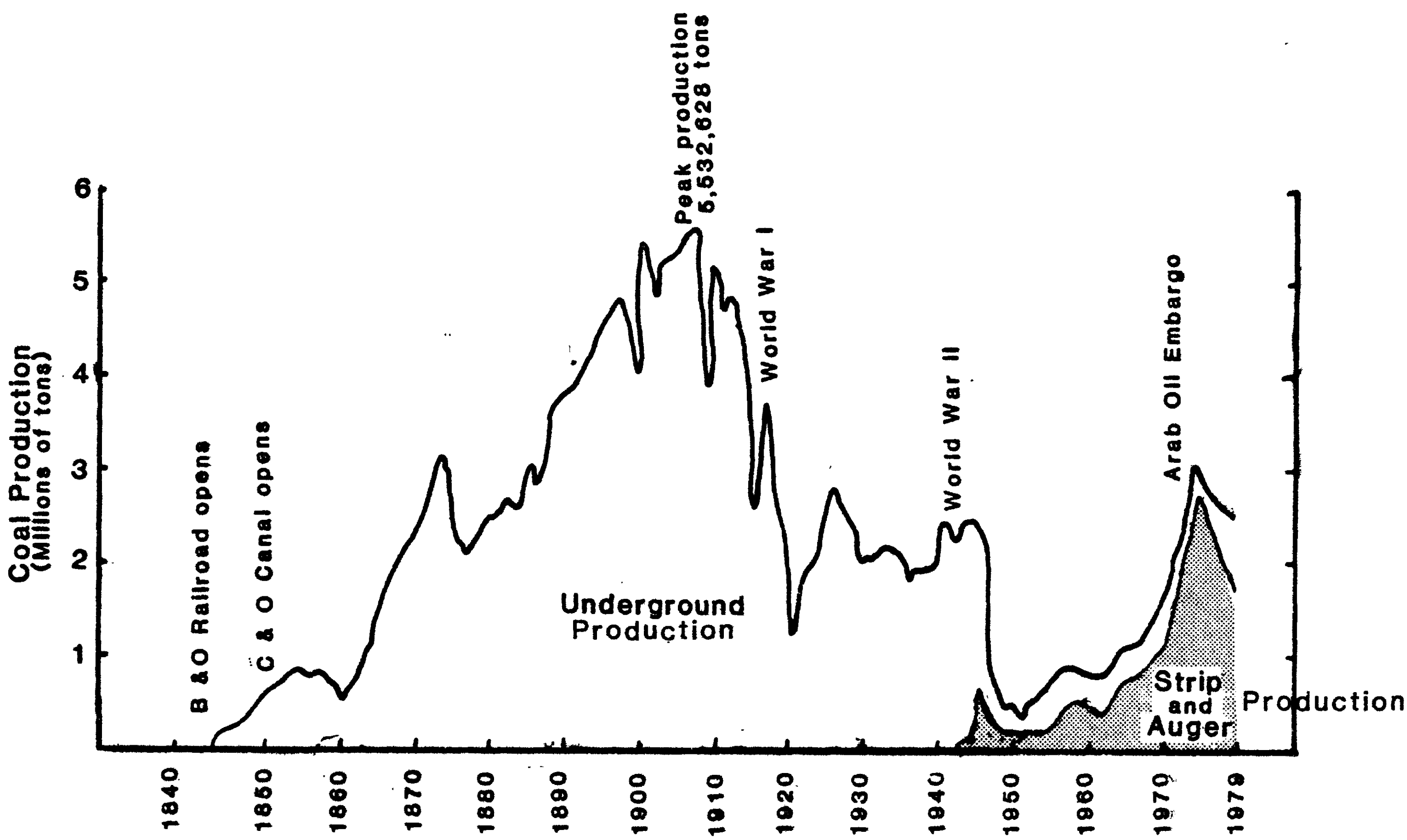

Figure 3: Maryland Coal Production 1840 - 1979

Modified from Weaver and others, 1976.

capacity of the Mettiki along with the projected future opening of a surface mine on the same property in the Lower Bakerstown bed could bring production of this mine to more than 2 million short tons per year by 1985.

Previous Coal Resource Investigations

Initial mapping of the Maryland coal basins was performed by Martin (Clark and others, 1905) and was extended by Swartz and Baker (1920), who established the basic stratigraphy for western Maryland. These two reports record the earliest published data on coal bed thicknesses; the thicknesses are mainly from coal bed sections measured in underground mines. These early reports are remarkably accurate.

From 1946 to 1949, two U.S. Bureau of Mines core drilling programs in western Maryland evaluated the coal resources of the Allegheny Formation and the lower part of the Conemaugh Formation. Twenty-six holes were drilled in the Georges Creek Basin and the northern part of the Upper Potomac basin. These holes ranged in depth from 400 to 1,200 ft. The core logs showing identification of the coal beds were published by Toenges and others (1949). In the Castleman basin, 40 holes were drilled systematically on a one-half mile grid system concentrated in the northern and eastern portions of the basin. Waage (1950) published a geologic map which showed coal croplines based on the drilling. Core logs were interpreted and issued by Toenges and others (1952). These two projects confirmed the results of Clark and others (1905) and Swartz and Baker (1920), allowed extension of these results, and provided new stratigraphic and coal resource data. These data were the primary source of information in the Castleman and Georges Creek basins, and in the northern part of the Upper Potomac basin.

Recent publications concerning Maryland coal (Boyd and Associates, 1964; Weaver and others, 1976; Ford, Bacon, and Davis, Inc., 1951; Hinkle, 1968; Sanner and Benson, 1979) have been mainly reestimations of reserves based on prior publications. Other investigations during the last 10 years have dealt mainly with the peripheral aspects of coal and coal mining, such as, studies of mine drainage pollution abatement (Green Associates, 1971; Skelly and Loy, Inc., 1973; and Baker-Wibberly and Associates, Inc., 1973, 1977).

Sources of Data

Throughout the current study, data on the background geology of the region as well as site-specific information were assembled. In order to make the analysis as up-to-date as possible, emphasis was placed on the interpretation of unpublished data from surface mining permits, water well logs, and recent aerial photography (May 1979). This varied array of sources provided much of the data which was integrated into the project. The following maps were used in our compilation and analysis:

A. Previous Maps

1. County maps

Geological Formations of Garrett County, 1:62,500 (Clark and others, 1902)
Geologic Map of Allegheny County, 1:62,500, (Clark and others, 1900)
Folio on Accident-Grantsville Area, 1:62,500, (Martin, 1908)
Geologic Map of Garrett County, 1:62,500, (Amsden, 1953)
Geologic Map of Allegheny County, 1:62,500, (Berryhill and others, 1956)

2. Maps from the literature

Map of Georges Creek and Upper Potomac basins, 1:36,000, (Swartz and Baker, 1920)
Maps of Georges Creek Basin from U.S. Bureau of Mines Technical Paper 725, 1:36,000, (Toenges and others, 1949)
Geologic Map of the Castleman basin, 1:24,000, (Waage, 1950)

Maps of the Castleman basin from U.S. Bureau of Mines Bulletin 507, 1:24,000, (Toenges and others, 1952)
Maps of the Upper Potomac basin, 1:24,000, (Miller, 1964)
Map of the southern half of the Castleman basin, 1:24,000, (Harvey, 1974)
Map of the Lower Youghiogheny basin, 1:24,000, (Jacobsen, 1980)

3. Mine drainage report maps

Georges Creek basin, 1:18,000, (Green-Gannet Associated Engineers, 1971)
Castleman basin, 1:30,000, (Skelly and Loy Inc., 1973)
Lower Youghiogheny basin, 1:18,000, (Baker-Wibberly, and Associates, Inc., 1973)
Upper Potomac basin, 1:24,000, (Richardson and Dougherty, 1976)
Upper Youghiogheny basin, 1:24,000, (Baker-Wibberly and Associates, 1977)

4. Unpublished field notes and maps

Letter to I. C. White from G. C. Martin, unpublished, 1901
Maps and notes from field books, 1:62,500, (C. K. Swartz)
Maps and notes from field books, 1:62,500, (W. A. Price)
Maps and notes from field books, 1:24,000, (N. K. Flint)
Maps and notes from field books, 1:24,000, (T. R. Jake)

The county maps showed the localities at which coal had been mined and the crop lines of the major coal beds in each field. Limestone and sandstone quarries as well as fossil localities in the area were also shown. Maps from the literature showed croplines of coal beds and areas mined out by underground mining. Maps from mine drainage reports illustrated underground mine adits located during fieldwork. Unpublished field notes and maps provided outcrop information and the location of measured sections not found on published maps. All maps were reduced to the scale of 1:24,000. The preparation of master data maps of the 21 quadrangles began with the transfer of all symbols related to mining: prospects, active mines, quarry sites, fossil localities, and stripping. Underground mine adits and prospects from the field maps were similarly plotted. Except for the Georges Creek field, all croplines of coal beds were delineated from basic data and structure contour maps; croplines of coal beds in the Georges Creek basin were derived partly from Swartz and Baker (1920).

B. Previous Literature

1. County reports

Allegany County, Maryland, (Clark and others, 1900)
Garrett County, Maryland, (Clark and others, 1902)
Preston County, West Virginia, (Hennan and others, 1914)
Geology and Water Resources of Garrett, County, Maryland, (Amsden and others, 1954)
Geology and Mineral Resources of Southern Somerset County, Pennsylvania, (Flint, 1965)

2. Coal investigations

Report on the Coals of Maryland, (Clark and others, 1905)
Second Report on the Coals of Maryland, (Swartz and Baker, 1920)
Investigation of the Lower Coal Beds in George's Creek and North Part of Upper Potomac Basin, (Toenges and others, 1949) (U.S.B.M. Technical Paper 725)
Castleman Basin, Garrett County, Maryland, U.S.B.M. Bulletin 507, (Toenges and others, 1952).

3. Reports and articles

The fauna of the Ames and Brush Creek shales of the Conemaugh Formation of western Maryland: Journal of Paleontology, v. 32, no. 1, pp. 97-112, (Lintz, Joseph Jr., 1958).
The fire clays of Maryland, Maryland Geological Survey, v. 11, pt. 2, (Watts and others, 1922).
Bloomington Dam Studies, Upper Potomac Basin, U.S. Army Corps of Engineers, Maps 1:24,000, 1964 and 1969
Report on Lands Surrounding the Bloomington Dam, Upper Potomac Basin, J. Donan and Associates, and Potomac Engineering and Surveying maps, 1:24,000, 1970 and 1971
Keystone Coal Industry Manual "Maryland", Edwards, Coffroth, and Harvey, 1978
Nikeson, 1977, "Why Delta Keeps Growing", Coal Mining and Processing, April 1978, v. 15, no. 4., 1978
Nikeson, 1979, Delta Revisited, Coal Mining and Processing, August, 1980, v. 17, no. 8, 1980
Road Log of US Interstate 48, (Jake and others, 1979)

Each county report provided a description of the basic geology, measured coal sections, and drill logs from the currently mines. Unpublished Masters' Theses (Miller, 1964; Harvey, 1974, and Balsinger, 1958) contained maps and detailed stratigraphic information on small areas within individual coal fields. Reports on the Bloomington Dam Project (Donan and Associates, 1970; Potomac Engineering and Surveying, Inc., 1971; U.S. Army Corps of Engineers, 1964, 1969) gave core logs, measured sections, and coal maps of the surrounding lands in the Upper Potomac basin. Articles in several trade periodicals provided current information regarding the coal industry in western Maryland.

C. Surface Mining Permits

Active and abandoned mine sites were located using surface mining permit applications obtained from the Maryland Bureau of Mines, Frostburg, Maryland. These permits provided the following useful data:

A. name and thickness of the coal bed mined;
B. a generalized geologic cross-section of the overburden;
C. a 1" = 500 ft scale map of the mine site;
D. coal bed crop lines, strike and dip symbols, and underground mine adits in the vicinity, and;
E. locations and logs of drill holes.

These data were integrated with all other information collected by the authors. The site maps from surface mining permits were reduced to a 1" = 1:24,000 scale and then registered with the master maps. Drill-hole locations and the coal outcrops as shown on the site maps were traced directly from the reduced maps onto the master maps. Strike and dip symbols were plotted similarly. Finally all prospect and drill hole data were tabulated on computer sheets for submission to the National Coal Resources Data System (NCRDS).

The generalized geologic cross sections from the surface mining permits were studied to ascertain the existence of:

A. multiple coal beds and their stratigraphic interval, and;
B. marker beds, such as red shales, thick sandstone units, underclays, or other correlative stratigraphic information.

All drill holes, coal sections, and measured sections were assigned data index numbers and were differentiated on the master maps using symbols.

As of July 1, 1980, records had been collected from about 150 active and abandoned surface coal mines in Maryland. In addition, substantial drilling and coal thickness data from one active and four inactive underground mines in the Upper Potomac basin were assembled.

D. Water Well Logs

To obtain additional stratigraphic data, logs of water wells were obtained from the Maryland Department of Water Resources, Annapolis, Maryland. A systematic search of their files was conducted and well logs selected which met two criteria:

A. the well logs contained one or more coal beds, and;
B. the well location could be plotted on a topographic map.

All wells were accurately located in the field to insure proper placement of the wells on the map. As a check on the elevation of the wellhead, the elevation was determined using an aneroid altimeter. The well was generally located using the sketch map on the log and located precisely in the field. Altimetry procedures included locating nearby benchmarks or temporary benchmarks (TBM) in the field and using temperature and pressure corrections to obtain elevations within 10 feet. The aneroid measured elevation of the wellhead was compared to the elevation for the well as plotted on the map, to make sure that they were accurate within 20 feet (one contour line interval).

Each water well log was assigned an index number. The thickness of the coal beds penetrated in each water well and the stratigraphic intervals between coal beds were recorded on computer sheets. Because the coal beds were not named in the logs, it was necessary to either relate the well to nearby surface mining or compare the interval between beds to the established stratigraphy of Swartz and Baker (1920) in order to identify the beds. About 200 water wells were located during the study.

E. Underground Mine Documents

Mine maps were obtained from the U.S. Bureau of Mines, Pittsburgh, Pa., to determine areas previously mined underground for resource calculation purposes. The areal extent of mining on each map was outlined, along with areas of pillars-remaining differentiated from areas with pillars-removed. Thickness data from drill holes shown on the maps were recorded. All underground mine maps were reduced to 1:24,000 so that mined-out areas could be traced directly onto the coal bed maps. About 580 underground mine documents were used in the study.

F. Aerial Photography

Aerial photographs of the coal fields of western Maryland, taken during May, 1979, at a scale of 1:12,000, were obtained from Air Photographics, Inc., Martinsburg, W. Va. Areas of active and abandoned surface mining were located and compared with stripped areas shown on U.S. Geological Survey topographic maps photo-revised 1974 based on aerial photography taken 1974 (except for the topographic map of the Davis quadrangle which is based on aerial photography taken in 1966). Currently active mining areas were located by identifying on the aerial photographs bright cleared areas with open pits or shadow-casting highwalls. Mining machinery, spoil piles, and large sediment control ponds were used to identify and delineate the mines. Abandoned unreclaimed strip mines were identified by spoil piles, vegetative overgrowths, and lack of mining machinery. Previously mined areas which had been reclaimed were more difficult to recognize because the highwall was usually covered. Although the irregular texture of the reclaimed land contrasted with the more uniform tone of pastures and cultivated fields, this did not prevent well-vegetated mines from being missed initially. Other distinctive features which aided detection of reclaimed areas were terraces and berms used for sediment control. Field checking was used extensively to support stereoscopic interpretation of the photos.

G. Mine Drainage Pollution Studies

Studies of coal-mine related drainage have been made on many of the major watersheds in the Maryland coal fields (see previous maps). These reports contained test borings and geologic interpretations of structure and its relation to ground and surface water movement. The major accomplishment of these reports from a coal resource standpoint was the field location of underground mine adits which are the biggest source of acid mine drainage problems in the coal basins. The pollution studies contained important data on coal bed correlations and subsurface structure. Maps showing both structure and coal bed outcrop projections from these studies aided our interpretations.

H. Field Work

Only limited field studies were undertaken due to the severe time limitations imposed by the necessity for report completion and by the extent of the area investigated. Limited field checking was performed in the Lower Youghiogheny basin during August, September, and November, 1980, by Jacobsen, and in the Castleman basin in November, 1980, by Lyons, Jacobsen, and Bryan Scott. Time in the field was spent primarily spotting water wells, visiting the active mines in the basin, and measuring coal and highwall sections. Verification of information derived from the surface mining permits was difficult in former mine sites that had been reclamated and revegetated. Most measuring of exposures of coal beds in the Lower Youghiogheny basin was done by Jacobsen who was guided by a published road log for Interstate 48 (Jake and others, 1979).

Compilation of Data

Data were compiled on twenty-one 7.5 minute U.S. Geological Survey quadrangle sheets covering the coal fields of Maryland (Fig. 1). A numerical index system was devised according to basin so that records of each drill hole, measured section, coal section, or other data point could be maintained. For example, all data points in the Georges Creek basin were identified by a number such as 50-GC. Data points in the other basins were similarly recognized: (UP, Upper Potomac basin; CB, Castleman basin; LY, Lower Youghiogheny basin, and; UY, Upper Youghiogheny basin. A legend was developed using symbols to differentiate the data points according to source. This approach enabled a large number of data points from a variety of sources to be handled efficiently and without confusion.

Data from the surface mining permits were plotted according to the method previously described (see Part C, Surface Mining Permits). The 1979 aerial photographs were systematically studied for areas previously surface mined. To obtain maximum accuracy, these areas were traced directly off the photographs onto a mylar sheet, using roads and streams for control points along the flight lines. The mylar overlays were then reduced to 1:24,000 scale, registered with the master maps, and the outlines of stripped areas transferred directly (in red). Underground mine maps were handled similarly; the areal extent of underground workings was outlined, the map was then reduced, aligned with the master map, and traced, with a different color corresponding to each coal bed.

Drill-hole locations from core drilling projects by the U.S. Bureau of Mines (Toenges and others, 1949 and 1952), from mine drainage studies (Skelly and Loy, Inc., 1973; Baker-Wibberly and Associates, Inc., 1973,

1977) and from water well logs were plotted on the master maps. Computer data sheets were filled out for each hole.

Compilation proceeded on a quadrangle by quadrangle basis for each basin. When all data had been plotted, the maps were ready for geologic analysis.

Method of Analysis

The first step in analysis was to relate all data points to a common stratigraphic datum in each quadrangle and basin because a structural interpretation of each quadrangle and basin was essential. This entailed the preparation of structure contour maps based on datum coal beds. The principal criterion used for the selection of the datum beds was persistence in outcrop or in the subsurface. On this basis, the following coal beds were used as datums:

Datum Coal Bed	Basin
Pittsburgh	Georges Creek
Upper Freeport	Upper Potomac
Lower Bakerstown	Castleman
Upper Freeport	Lower Youghiogheny
Upper Freeport	Upper Youghiogheny

All data points at which the datum bed in each basin could be identified were plotted on a mylar overlay along with the elevations of the top of the coal bed at that point. A structure contour map based on the top of the datum bed was then constructed. Other stratigraphic data were projected from above or below to the datum.

After the structure maps had been compiled, the outcrop pattern of the coal beds used as the datum and other coal beds were projected onto the master bed maps. Coal beds both stratigraphically above and below the datum bed were identified and correlated, on the basis of marker beds such as marine horizons and known stratigraphic intervals between coal beds. Local to regional recognition of coal beds was made difficult by the tendency of the beds to pinch out or to change character both within and between basins. This difficulty was particularly apparent in the Lower and Upper Youghiogheny basins where little deep drilling has been done.

The limits of strip mining as obtained from the aerial photography was assumed to mark the approximate position of the crop line of individual coal beds. This assumption was used in areas where no other factual data existed. The lateral extent of underground mining also served to control the coal bed crop lines.

In this manner, master bed maps for the identifiable coal beds in each basin were prepared. In order to facilitate coal resource determination, coal maps for each bed by quadrangle were constructed using the master maps. Mylar overlays were registered with the master maps and the crop lines of the coal beds traced off, along with areas that had been surface mined and areas previously underground mined. Another series of quadrangle overlays gave the location of every drill hole and data point within each quadrangle. The computer data sheets and the coal bed maps and data point sheets were submitted to the NCRDS for coal resource calculations.

Sources of Error

Although all data were collected and analyzed carefully, it was recognized that each source had inherent inaccuracy which could affect results. The limitations of each set of data are summarized below.

Coal bed crop lines from mining permit maps tended not to follow geologic structure away from the active mining area. The names of the coal beds given in the permits were not always accurate or even internally consistent. Placement of the generalized sections on the maps was subject to interpretation. Some mines could not be located on the master base maps due to insufficient natural or cultural data. However, it was possible in many places to relate the crop line of the coal bed mined to a known coal bed. It was also unclear whether the coal bed thicknesses given on the permits were from a single site or averaged from many measurements. In some cases, more specific data were obtained from coal companies which indicated the thickness of the partings within the bed.

Water well logs were generally in the form of driller's logs, with vague descriptions of the rock type penetrated (for example, "gray rock" or "hard rock"). Few logs mentioned limestone, and it was doubtful whether drillers could have differentiated between a highly carbonaceous shale and coal. Thus, the only useable data which could be accepted without qualification were:

A. the presence of a coal bed at a certain depth;
B. the stratigraphic interval between two coal beds, and;
C. the thickness of the bed, taken to be accurate to one foot.

Regarding the aerial photography, use of black and white as opposed to color photographs made detection of reclaimed areas difficult. Also, the parallax factor, which distorts heights and areas, was recognized. This effect was minimal in areas of low relief, but pronounced in areas of high relief, for example, in the Lower Youghiogheny basin. The only precaution which was used was careful control from photograph to photograph along the flight line; that is, control points such as roads and streams were traced only to the limits of photograph overlap, from the center of one photograph, before switching to the next photograph. This reduced the distortion which occurred when the plane was not directly over its target. Checking of the areas stereoscopically also helped accuracy.

Another recognized problem was the reduction process which all mining permit maps, underground mine documents, and aerial photography overlays had to go through. Minor problems came in dealing with varying scales on maps, incomplete drill hole descriptions, and miscorrelations in the literature which had to be resolved using recent data.

Fundamental assumptions underlying stratigraphic analysis involved the premise that coal beds could be correlated by stratigraphic interval. The intervals used were mainly those established by Swartz and Baker (1920) and Toenges and others (1949 and 1952), as modified by current detailed local information collected during this study. Assumptions regarding the areal extent of rider seams, intermittent coal beds and regional thickening and thinning were based on geologic interpretation of site-specific data, where available.

The NCRDS and Coal Resource Calculations

An important and unique aspect to this coal resource investigation for western Maryland was the utilization of the National Coal Resources Data System (NCRDS) for the calculation of coal resources from coal bed maps and data collected during the study. The NCRDS, a computerized data system, maintains a permanent file of all data used in preparing the report, such as, both subsurface and outcrop information. Drilling and coal thicknesses were submitted on computer forms; data points were shown on coal-bed maps and drill hole sheets at a scale of 1:24,000. The bed maps recorded the areal extent of each coal bed, areas previously surface mined and areas previously underground mined. Where data permitted, areas on underground mine maps with pillars-remaining were differentiated from areas with pillars-removed. All data from the coal bed maps were entered into NCRDS by a digitizing system. NCRDS computer programs will calculate the coal resources, using the criteria and guidelines published in U.S. Geological Survey Bulletin 1450-B (1976). The final products of the analysis will be resource estimates by coal bed, quadrangle, county, and basin, thickness of coal, reliability, and rank. Accuracy of the computer-generated estimates will be substantiated by local spot-checking using manual planimetry and calculations.

Summary

This coal resource investigation of western Maryland began with a compilation of data from maps, county reports, engineering studies, surface mining permits, water well logs, underground mine documents, drainage pollution studies, and the geological literature and related literature. A lack of up-to-date maps and site-specific data required essentially a unique and basic approach to the problem of coal resource estimation for western Maryland. A systematic search was conducted of recent sources including aerial photography flown in May 1979, which had not been available in previous Maryland coal resource investigations. Along with stratigraphic information provided by two U.S. Bureau of Mines drilling programs (Toenges and others, 1949 and 1952), these data provided a true update of the remaining coal resources, as of May 1979. A structural interpretation of each quadrangle was basic to the analysis of the coal basins. Data derived from pioneering investigates on Maryland stratigraphy by Clark and others (1905) and Swartz and Baker (1920) were utilized in making coal bed correlations. Coal bed outcrop maps (scale, 1:24,000) were prepared and used as the basis for bed maps from which coal resources could be estimated. The National Coal Resources Data System was used both as a permanent file of stratigraphic and coal resource data and for resource computation.

The systematic search for data during the study resulted in a modern bibliography on Maryland coal. This by-product of the original project will be important in building a reference base for future coal resource and stratigraphic studies.

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