Coal Geology of Adams, Blaine, Richardson, and Sitka Quadrangles, Kentucky, and Louisa Quadrangle, Kentucky–West Virginia

GEOLOGICAL SURVEY BULLETIN 1526

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By PHILIP T. HAYES *and* CAROL WAITE CONNOR

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Resources and physical and chemical characteristics of the Pennsylvanian-age bituminous coal are noted. Stratigraphy, structure, and depositional history are discussed, in relation to published geologic quadrangle maps

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COAL GEOLOGY OF ADAMS, BLAINE, RICHARDSON, AND SITKA QUADRANGLES, KENTUCKY, AND LOUISA QUADRANGLE, KENTUCKY-WEST VIRGINIA

By PHILIP T. HAYES and CAROL WAITE CONNOR

ABSTRACT

The report area, a part of the Appalachian Plateau physiographic province, contains outcropping rocks of the Lee, Breathitt, Conemaugh, and Monongahela(?) Formations of Pennsylvanian age. The Lee Formation, of which only about 45 m is exposed, is made up predominantly of sandstone and minor siltstone. The Breathitt Formation, about 250 m thick, is made up of interbedded sandstone, siltstone, shale, coal, underclay, and limestone, in roughly decreasing order of abundance. The Conemaugh Formation and overlying Monongahela(?) Formation, together about 135 m thick, are roughly similar to the Breathitt, but the only coal and limestone are in the lower part of the Conemaugh. The outcropping rocks of the Lee Formation are interpreted to have been deposited in a barrier-island complex. The Breathitt Formation, from base to top, is interpreted to represent a succession of environments from estuary or lagoon to lower delta plain to upper delta plain to alluvial plain. The Conemaugh and Monongahela(?) Formations apparently represent a return to deposition on a lower delta plain.

A total of about 370 million short tons (336 million t) of demonstrated and inferred coal resources in 18 coal beds or zones underlie the area. Three of these units, the Van Lear coal bed and the Peach Orchard and Richardson coal zones, contain more resources and have produced more coal than the other 15 beds or zones combined, though 7 other beds or zones are of local importance. Thirty samples of coal from 14 beds were subjected to standard coal analysis, and 45 samples of coal were subjected to trace-element analysis. The standard analyses indicate that most of the coal in the area is of high-volatile B or A bituminous rank but that some is high-volatile C bituminous in rank. The indicated sulfur content of several of the coals is less than 1 percent but several others have sulfur contents in the 2–5 percent range. Some geographic and stratigraphic variations of certain trace elements within the coals are noted.

INTRODUCTION

LOCATION

This report describes the geology and provides coal resources and analytical data for five 7½-minute quadrangles within the Appalachian coal region. Four of the quadrangles, bounded by lats 37°52′30″ N. and 38°07′30″N. and by longs 82°37′30″W. and 82°52′30″W., are in Johnson and Lawrence Counties, Ky.; and one quadrangle, bounded by lats 38°N. and 38°07′30″N. and by longs 82°30′W. and 82°37′30″W., is approximately half in Lawrence County, Ky., and half in Wayne County, W. Va. (fig. 1).

DESCRIPTION OF PROJECT

The geologic mapping of the five quadrangles described herein was done as a part of the U.S. Geological Survey and Kentucky Geological Survey cooperative 1:24,000-scale mapping project of the State of Kentucky. These five quadrangles were selected for additional detailed study of the coal geology as little previous scientific coal research had been done in them. The resultant geologic quadrangle maps are basically similar to other Kentucky geologic quadrangle maps but differ in that only coal beds of potential commercial value (except coal beds used as stratigraphic color breaks) are shown and in that thicknesses of individual coal beds are shown at numerous localities. The published quadrangle maps should be used by the reader of this report for a better understanding of this report's contents; they are U.S. Geological Survey Geologic Quadrangle Maps of the Sitka quadrangle (Hayes, 1977), the Richardson quadrangle (Sanchez and others, 1978), the Louisa quadrangle (Connor and Flores, 1978), the Adams quadrangle (Ward, 1978), and the Blaine quadrangle (Pillmore and Connor, 1978).

PREVIOUS WORK

Very little work has been done previously on the coal geology of the report area. Crandall (1905) very briefly described some of the coal along the Levisa Fork in the Richardson quadrangle. Phalen (1912) mapped several coal beds in a very general way in the Blaine, Adams, and Louisa quadrangles. Hauser (1953) mapped and described several coal beds of the Sitka quadrangle in somewhat greater detail. Huddle, Lyons, Smith, and Ferm (1963) summarized all previous study of the coals of the area in a report on the coal resources of eastern Kentucky. Of primary use to us were a structure contour map of Lawrence County by Hudnall and Pirtle (1926) and geologic maps of adjacent quadrangles by Outerbridge (1964, 1966, 1977), Jenkins (1966), Sharps (1967), Rice (1968), and Carlson (1971).

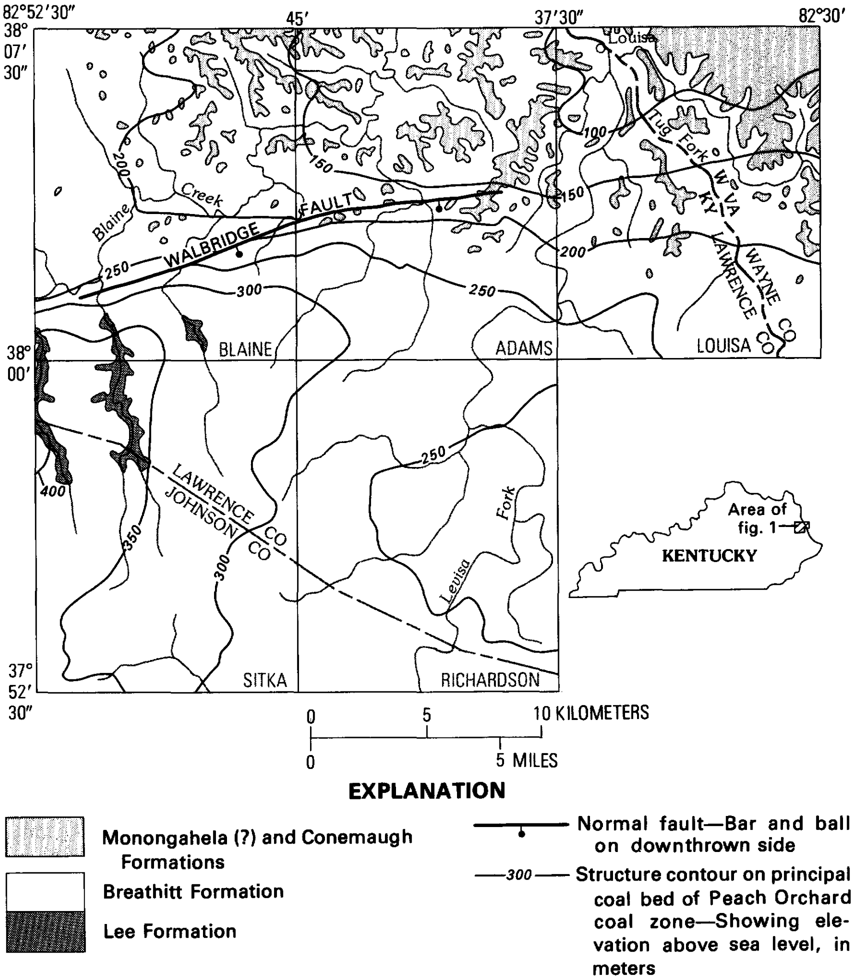


FIGURE 1.—Generalized geologic map of Pennsylvanian rocks in Adams, Blaine, Richardson, and Sitka quadrangles, Kentucky, and Louisa quadrangle, Kentucky–West Virginia.

ACKNOWLEDGMENTS

We are grateful to numerous local landowners and strip-mine operators who allowed access to their lands and who supplied us with information on coal exposures. We are indebted to the A. G. P. Coal Co., the Arrington Bros. Coal Co., the Consolidation Coal Co., and the Kentucky Department of Highways for allowing us to examine drill cores and drill records and to the Gaddy Engineering Co., for allowing us to examine some reports on private coal properties. We are especially indebted to Charles L. Rice and William F. Outerbridge of the U.S. Geological Survey for acquainting us with local coal stratigraphy when we were beginning our work in the area and to John C. Horne of the University of South Carolina for sharing his unpublished data on coal beds in highway cuts. Many other geologists also lent help and advice both in the field and during compilation.

METHODS AND DEFINITIONS

The coal resource calculations presented in this report were made in accordance with the standardized methods used by the U.S. Bureau of Mines and the U.S. Geological Survey (1976) except that, for reasons described here, in most cases we were more conservative in the calculation of inferred resources than is customary. The coal beds as depicted on the geologic quadrangle maps of the report area were drawn in accordance with the latest guidelines accepted by the joint U.S. Geological Survey–Kentucky Geological Survey geologic mapping project. In general, the methods for resource calculation and guidelines for coal-bed mapping are compatible, but the reader should be aware of what those methods and guidelines are and the small ways in which they may seem to be in conflict.

Resource calculations were not made for beds that are less than 14 in. (36 cm) thick, and coal beds believed to be less than that thickness are not shown on the geologic maps except where they are important stratigraphic markers separating differently colored stratigraphic units on the maps. On the maps, coal beds more than 14 in. (36 cm) thick are depicted by one symbol within about 1 km of points of observation, such as adits, prospects, strip benches, road cuts, or drill holes, and are depicted by another symbol for an additional 1 km, except in cases where the bed is known to be cut out by channel sands or thins to less than 14 in. (36 cm) in a lesser distance. In the resource calculations, the resources were considered to be demonstrated if they are within 0.75 mi (1.21 km) of an adit, strip mine, or point of measurement, except in cases where the bed is known to be cut out by channel sands or otherwise thinned to less than 14 in. (36 cm) in a lesser distance. U.S. Bureau of Mines and U.S. Geological Survey resource calculation standards dictate that coal resources to a distance of 3 mi (4.8 km) from points of control be considered inferred resources, but because of the lenticular nature of most beds in these quadrangles we generally did not calculate inferred resources beyond the mapped limit of the bed (about 1 mi or 1.6 km). For a few beds known to be laterally extensive, the inferred resources were calculated for a greater distance, but nowhere more than 3 mi (4.8 km) from a point of observation. In the resource tables, coal that occurs in beds greater than 28 in. (71 cm) thick is shown separately from coal that occurs in beds 14–28 in. (36–71 cm) thick. For beds with one or more partings, the thickness of the coal bed is considered to be the total thickness of the coal, exclusive of the partings. In cases where a parting is thicker than the coal benches above or below, the benches are considered to be separate beds.

The resource tables have columns showing coal mined and coal lost in mining prior to 1976. These calculations are relatively simple to make for stripped areas because the area stripped can be seen. Because mine maps are unavailable for a vast majority of the small underground mines, however, it is only possible to estimate how large an area has been worked. In most cases, we assumed that an area within a radius of about 300 ft (90 m) of the adit had been mined or lost in mining.

GEOLOGIC SETTING

The report area, a part of the Appalachian Plateau physiographic province, is underlain by nearly horizontal, sparsely faulted Carboniferous rocks that have been intricately dissected by a dendritic drainage system (fig. 1). There is little flat land, except along the bottoms of some of the major streams, and local relief between drainage courses and adjacent ridges ranges from 60 to 120 m in the northwestern part of the area and from 105 to 150 m in the southeastern part. The highest ground elevation above sea level is about 390 m in the south-central part of the Sitka quadrangle; the lowest point is about 165 m above sea level in the northwest part of the Louisa quadrangle. All of the area drains to the Big Sandy River, which joins the Ohio River about 32 km north of Louisa, Ky. Roughly, the southeast half of the area drains via the Levisa and Tug Forks, which join at Louisa to form the Big Sandy. The remainder of the area drains via tributaries, chiefly Blaine Creek, that join the Big Sandy north of Louisa.

STRATIGRAPHY OF PENNSYLVANIAN ROCKS

All the consolidated rocks that crop out within the report area are assigned to the Pennsylvanian System. The oldest exposed formation is the Lower Pennsylvanian Lee Formation (fig. 2), which is overlain by the Lower and Middle Pennsylvanian Breathitt Formation. The Breathitt Formation of Kentucky is represented in West Virginia by the Kanawha and overlying Allegheny Formations. Above the Breathitt or Allegheny is the Upper Pennsylvanian Conemaugh Formation, which is overlain with undefined contact in this area by the Upper Pennsylvanian Monongahela(?) Formation.

LEE FORMATION

The Lee Formation is present in valley bottoms in three separate outcrop belts in the western part of the report area (fig. 1). Nowhere is its base exposed; the maximum exposed thickness is 45 m near the west

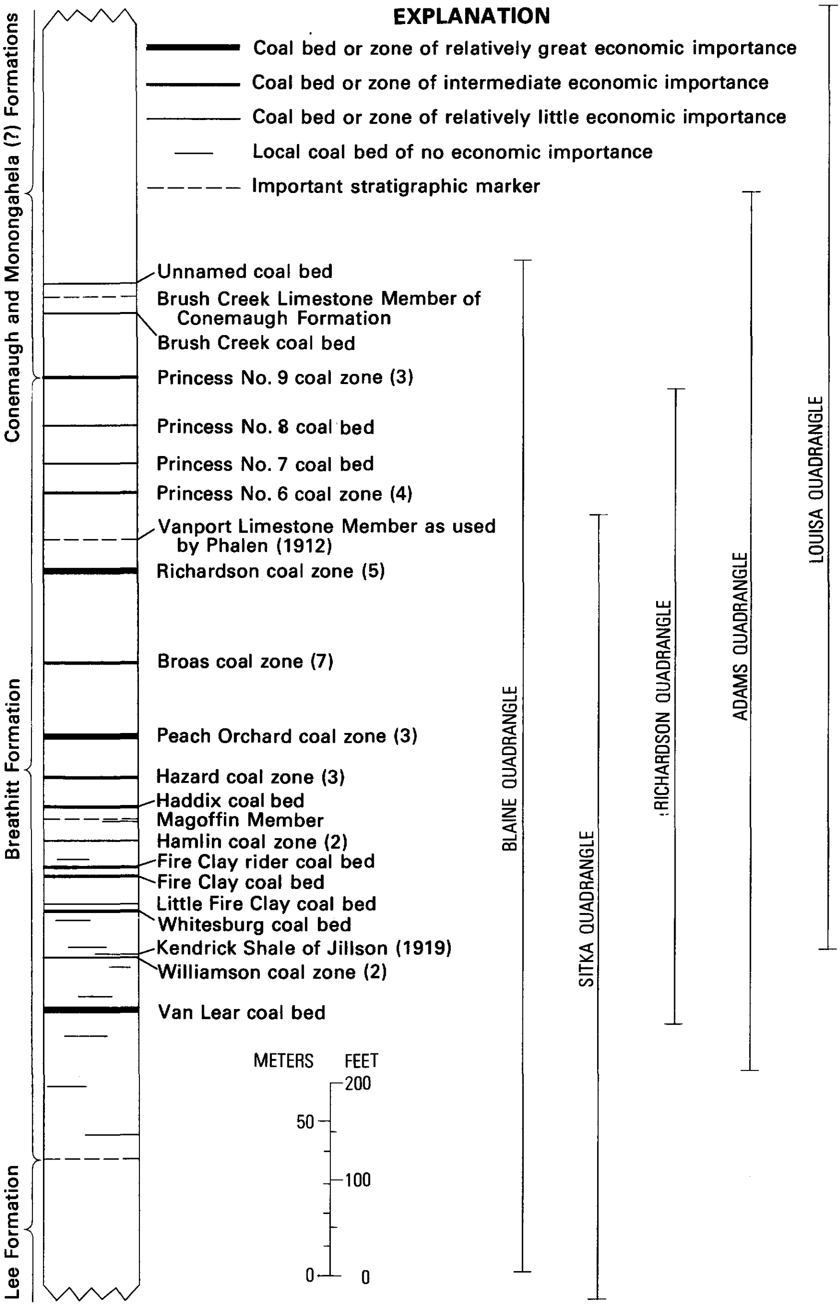


FIGURE 2.—Stratigraphic positions and relative economic importance of coal beds in the study area and the stratigraphic intervals represented in each of the quadrangles of the study area. Numbers in parentheses following zone names indicate maximum number of beds in zone. Scale is approximate.

edge of the area. The exposed part of the formation consists almost entirely of resistant thick beds of fine- to coarse-grained, locally pebbly, crossbedded sandstone; but a few thin interbeds of sandy siltstone occur. Although lenticular coal beds have been found in the Lee in other areas of Kentucky (Huddle and others, 1963), none occur at the surface in the report area. However, several thin allochthonous coal beds were encountered in the Lee in a core hole drilled by the U.S. Geological Survey in the northeastern part of the Blaine quadrangle (Connor, 1975).

The formation is overlain by the Breathitt Formation with a gradational, probably intertonguing, contact.

BREATHITT FORMATION

The Breathitt Formation, approximately 250 m thick (fig. 2), crops out in all parts of the report area except in the northeast corner of the Louisa quadrangle, where it is covered by the overlying Conemaugh and Monongahela(?) Formations. The Breathitt is made up of interbedded sandstone, siltstone, shale, coal, underclay, and limestone, in roughly decreasing order of abundance. Sandstone is relatively more abundant in the upper half of the formation than in the lower half. For convenience's sake the formation is described in six parts.

BASE OF FORMATION TO BASE OF VAN LEAR COAL BED

The thickness of the interval between the base of the Breathitt Formation and the base of the Van Lear coal bed is generally between 45 and 50 m but may range from 37 to 55 m. Silty shale and siltstone are the most abundant constituents of the interval, and sandstone, generally in lenticular bodies, is the next most abundant. The interval also contains as many as three fairly persistent coal beds in the south half of the area, none of which is known to exceed 13 in. (33 cm) in thickness at any place in the report area. At least two zones in the middle third of the interval in the Sitka quadrangle contain biscuit-shaped calcareous concretions as much as several meters in diameter.

BASE OF VAN LEAR COAL BED TO BASE OF WHITESBURG COAL BED

The thickness of the interval between the base of the Van Lear coal bed and the base of the Whitesburg coal bed may be as little as about 21 m and as much as about 42 m within the report area but averages between 30 and 35 m. The Van Lear coal bed, one of the most important commercial beds of the area, is very persistent, lacks partings, and is locally as thick as 34 in. (86 cm). The Van Lear is commonly overlain by clay shale but is locally overlain by channel sandstone. Most of the

12–28-m-thick (averaging 19-m-thick) interval separating the Van Lear from the next overlying coal zone, the Williamson, is made up of silty shale, siltstone, and sandstone, but locally a thin canneloid coal is present 5 or 6 m above the Van Lear. The Williamson coal may occur as one bed or as two beds separated by as much as a meter of rooted shale. The coal beds are locally absent, presumably owing to nondeposition, and are generally only a few inches thick, but one is locally as much as 36 in. (91 cm) thick. The Williamson coal zone is commonly overlain by the Kendrick Shale of Jillson (1919), which, where present, may be as much as 6 m thick. The Kendrick is a dark-gray fissile marine shale that contains fossiliferous limestone concretions. Most of the 8–28-m-thick (averaging 13- to 14-m-thick) interval separating the Williamson coal zone from the Whitesburg coal bed is made up of siltstone, silty shale, and sandstone; a rare thin lenticular coal bed may occur in the interval.

BASE OF WHITESBURG COAL BED TO BASE OF MAGOFFIN MEMBER

The interval between the base of the Whitesburg coal bed and the base of the Magoffin Member generally ranges in thickness from 21 to 35 m and averages about 28 m. Within the interval are five very persistent coal beds or zones. The Whitesburg coal bed at the base, except where locally cut out by overlying channel sandstones, ranges in thickness from a few inches to as much as 42 in. (107 cm). The bed is rarely parted and has been mined at many localities. The Whitesburg may be separated from the Little Fire Clay coal bed, next above, by as little as 0.7 m and by as much as 7.5 m, but the separation is generally 2–4 m. The rock immediately above the Whitesburg is commonly canneloid shale, but most of the interval up to the Little Fire Clay coal bed is usually silty shale, although sandstone or siltstone may be present. The Little Fire Clay coal bed (included as the upper bed of the Whitesburg coal zone in the Blaine quadrangle), called the Upper Whitesburg bed by Huddle, Lyons, Smith, and Ferm (1963), is nearly everywhere less than 10 in. (25 cm) thick but is locally as much as 26 in. (66 cm) thick; it lacks partings. The interval between the Little Fire Clay coal bed and the Fire Clay coal bed, next above, is 5–12 m and averages about 9 m; it consists primarily of sandstone and siltstone or silty shale at most localities. The Fire Clay coal bed is generally less than 10 in. (25 cm) thick but is locally as much as 34 in. (86 cm); it is of moderate economic importance. A flint-clay parting from 1 to 5 cm thick is nearly everywhere found in or adjacent to the Fire Clay coal bed. From 0.7 to 6 m and averaging about 2 m above the Fire Clay coal bed is the Fire Clay rider coal bed. The Fire Clay rider, which is nearly everywhere distinctively canneloid in its upper part, is generally less than 12 in. (30 cm) thick but is locally as thick as 37 in. (94 cm). The interval between the Fire Clay rider coal bed and the Hamlin coal zone may be as little as 3 m or as great as 14 m but generally is between 6 and 10 m. It is made up of varying proportions of siltstone, silty shale, and sandstone, but a rare thin lenticular coal bed may be present. The Hamlin coal zone is commonly made up of two coal beds, each less than 6 in. (15 cm) thick, separated by rooted clay; but in some places only one bed is present. The greatest observed thickness of a bed of the Hamlin zone is 19 in. (48 cm). The thickness of the interval between the Hamlin coal zone and the base of the Magoffin Member may range from as little as 3 m to as much as 13 m but is most commonly about 6–7 m. This interval generally is made up of varying proportions of sandstone, siltstone, and silty shale. Locally in the Richardson and Louisa quadrangles, the top of the interval is occupied by the Taylor coal bed, which is everywhere less than 14 in. (36 cm) thick.

BASE OF MAGOFFIN MEMBER TO BASE OF PEACH ORCHARD COAL ZONE

The interval between the base of the Magoffin Member and the base of the Peach Orchard coal zone varies greatly in both thickness and lithology. The thickness may be as little as 16 m and as great as 64 m, although for the most part it ranges from 21 to 47 m and may average about 27 m. The interval may contain as many as four coal beds, or there may be none. Some variations in lithology are due to nondeposition and some to channel scour and fill.

The Magoffin Member of the Breathitt Formation, which contains marine invertebrate fossils, is apparently absent over extensive areas of the Blaine, Adams, Sitka, and Richardson quadrangles; where present, it varies in lithologic character. It is nowhere more than 6 m thick and is more commonly 1–2 m thick. The Magoffin consists of a bed of resistant, calcareous, fine-grained sandstone as much as 1 m thick, that grades upward into gray, fossiliferous limestone as much as 0.7 m thick. This is overlain by dark-gray, calcareous, sparsely fossiliferous, platy shale. Any or all of these components may be missing locally. The Haddix coal bed lies from 0 to 2 m above the Magoffin Member. The Haddix has been cut out by channel sandstones in many places, but where not cut out, it seems to be persistent. It is thicker than 14 in. (36 cm) at many places and is locally as thick as 34 in. (86 cm). From 3 to 20 m, averaging about 8 m, above the Haddix coal bed lies the Hazard coal bed or zone. The interval between the beds is generally occupied by silty shale but may be occupied by sandstone. In most places the Hazard is one bed, but in the Sitka and Blaine quadrangles an additional one or two beds may occur within a few meters above the top of the principal bed. The Hazard coal bed or the principal bed of the Hazard zone is generally less than 14 in. (36 cm) thick but is locally as thick as 51 in. (130 cm). The thickness of the interval between the Hazard coal bed or zone and the base of the Peach Orchard coal zone may be as little as 5 m or as great as 32 m but is generally in the 6 to 18 m range and probably averages about 12 m. The interval nearly everywhere contains some channel sandstone in addition to silty shale and is commonly dominated by sandstone.

BASE OF PEACH ORCHARD COAL ZONE TO TOP OF RICHARDSON COAL ZONE

The interval from the base of the Peach Orchard coal zone to the top of the Richardson coal zone is 35–75 m thick and averages about 60–65 m thick. This interval contains a considerably higher proportion of sandstone than the underlying part of the Breathitt Formation and contains the thickest coal beds.

The Peach Orchard coal zone, 3–18 m thick and averaging about 10 m thick, usually contains two or three coal beds that commonly contain partings of carbonaceous shale. Individual coal beds in the zone may be as thick as 84 in. (213 cm), exclusive of partings, and nearly everywhere at least one bed of the zone exceeds 14 in. (36 cm) in thickness. The coal beds of the zone are generally separated by siltstone or silty shale. From 8 to 29 m and averaging 14 m above the Peach Orchard coal zone is the Broas coal zone. This interval contains sandstone with some siltstone or silty shale. The Broas coal zone usually contains two coal beds separated by 5–15 m, averaging 9 m, of siltstone and sandstone. The beds of the Broas zone are generally less than 14 in. (36 cm) thick, but locally the upper bed is 63 in. (160 cm) thick, and the lower bed 24 in. (61 cm) thick. The Broas coal zone is separated from the Richardson coal zone, next above, by an interval that may range from 9 to 36 m thick and averages about 20–25 m thick, dominantly of sandstone. The Richardson coal zone generally contains about three coal beds within a zone that averages about 10 m thick. The lowest bed of the zone is the most persistent, and except where locally missing, is nearly everywhere more than 14 in. (36 cm) thick. At one place it is 93 in. (236 cm) thick. Upper beds of the zone are generally thinner than 14 in. (36 cm), but one is locally 58 in. (147 cm) thick.

TOP OF RICHARDSON COAL ZONE TO TOP OF FORMATION

The interval between the top of the Richardson coal zone and the top of the Breathitt Formation, present in its entirety only in the northern tier of quadrangles (fig. 2), ranges in thickness from 33 to 60 m and averages about 50 m, tending to be thicker to the east than to the west. Within the interval is a marine limestone unit, a flint-clay marker bed, and three coal zones any or all of which may be locally cut out by one of the many channel sandstone bodies in the interval.

In parts of the Blaine and Adams quadrangles, the fossiliferous Vanport Limestone Member of Phalen (1912) rests immediately upon or within 1 to 2 m above the top of the Richardson coal zone. The Vanport is probably absent in the other quadrangles because the shallow sea in which it was deposited did not reach that far southeastward. It is cut out over large parts of the Adams and Blaine quadrangles by channel sandstones. Where present, the Vanport, rarely more than 1 m thick, is commonly sideritic and limonitic.

The Princess No. 6 coal zone lies between 5 and 35 m and averages about 10 m above the Richardson coal zone or Vanport Limestone Member. The interval may be occupied by sandstone or siltstone, and a flint-clay marker bed a few centimeters thick can generally be found within a few meters below the base of the Princess No. 6. The Princess No. 6 coal zone was not observed south of the northern tier of quadrangles. In those northern quadrangles, it generally contains three or four coal beds each only a few centimeters thick separated by rooted clay. The greatest observed thickness of any individual bed in the zone is 14 in. (36 cm), but the entire zone may be as much as 3 m thick. The Princess No. 7 coal bed lies 6–10 m, and averages 8 m, above the Princess No. 6 coal zone. The Princess No. 7 is nearly everywhere less than 14 in. (36 cm) thick but is locally as much as 36 in. (91 cm) thick. Ranging from 8 to 14 m and averaging 11 m above the Princess No. 7 coal bed is the Princess No. 8 coal bed. The Princess No. 8 rarely exceeds 14 in. (36 cm) in thickness but locally is 26 in. (66 cm) thick. The Princess No. 8 bed lies between 12 and 24 m and averages about 15 m below the top of the Breathitt Formation. The top of the Breathitt is placed at the top of the main (middle) bed of the Princess No. 9 coal zone in the few areas where that bed occurs; otherwise, it is placed at the lowest occurrence of the reddish-gray and greenish-gray shales of the Conemaugh Formation.

CONEMAUGH AND MONONGAHELA(?) FORMATIONS

The lower part of the Conemaugh Formation is exposed across the northern part of the Blaine, Adams, and Louisa quadrangles. All of the Conemaugh Formation and the lower part of the Monongahela(?) Formation are exposed only in the extreme northeastern part of the Louisa quadrangle. As in the Louisa quadrangle (Connor and Flores, 1978), we here consider the formation undivided because the Pittsburgh coal bed, defined as the base of the Monongahela Formation, is not present. However, about 110 m above the base of the Conemaugh is an underclay that, in stratigraphic position and appearance, resembles an underclay in the quadrangle to the northwest that Sharps (1967) considered to be a possible lateral equivalent of the Pittsburgh coal bed. Another 25 m of rocks are partly exposed above the underclay. Trough-crossbedded sandstone, relatively more abundant and thicker bedded in the upper part of the interval, is the dominant rock type; inspection of hand specimens indicates that it is more feldspathic than sandstones in the Breathitt Formation. Except where carbonaceous, the intervening claystones and silty claystones are greenish gray, dusky yellow, and grayish red, in contrast to the gray fine-grained rocks of the Breathitt. A 30-cm-thick carbonaceous black shale containing fresh-water conchostracans (small bivalved crustaceans) was found in the northeastern part of the Louisa quadrangle. This black shale unit occurs 30 m above the only marine unit in the Conemaugh in the area and may be a lateral equivalent of the marine Ames Limestone Member, which is present in the quadrangle to the northwest (Sharps, 1967).

The marine Brush Creek Limestone Member, 15–43 m above the base of the Conemaugh, is as thick as 0.6 m. It is exposed in the northern parts of all three quadrangles, becoming thinner to the east and containing smaller and more fragmented and worn fossils in the Louisa quadrangle. No supposition is made as to the exact former southern extent of the Brush Creek Limestone Member because the unit has been removed by erosion south of the central parts of the northern three quadrangles. Coal beds were found only in the lower part of the Conemaugh Formation: an unnamed coal bed occurs about 4 m above the Brush Creek Limestone Member in the Adams and Louisa quadrangles and is locally at least 24 in. (61 cm) thick; the Brush Creek coal bed, about 5 m below the Brush Creek Limestone Member, also occurs in the Adams and Louisa quadrangles and is as much as 32 in. (81 cm) thick; and the uppermost coal bed of the Princess No. 9 coal zone, about midway between the Brush Creek coal bed and the base of the Conemaugh Formation, was found only in core K–1–75 in the central part of the Louisa quadrangle where it is 36 in. (91 cm) thick.

INTERPRETATION OF DEPOSITIONAL HISTORY

We feel that field evidence and core data collected from the report area generally support published reports (Horne and Ferm, 1976; Horne and others, 1974; Ferm, 1974; Ferm and others, 1971; Flores, 1978; Henry and Schweinfurth, 1977) that the major depositional environments of the rocks associated with the coals are successively: open marine, tidal flats, barrier island complex (Lee Sandstone), estuary or lagoon (top of Lee Formation to below Van Lear coal bed), lower delta plain and transitional zone (below Van Lear coal bed through Hazard coal zone), upper delta plain (Peach Orchard coal zone to Princess No. 6 coal zone), alluvial plain (Princess No. 6 coal zone to below Brush Creek Limestone Member), and lower delta plain (Brush Creek Limestone Member to top of section in lower part of Monongahela(?) Formation). (See figs. 3, 4.)

The rocks of the area are exposed as deep as the upper part of the Lee Formation. USGS core hole (K–3–75 (location shown in fig. 5), which was spudded just below the Peach Orchard coal zone, penetrated the Lee Formation and ended in fossiliferous marine limestone (Connor, 1975).

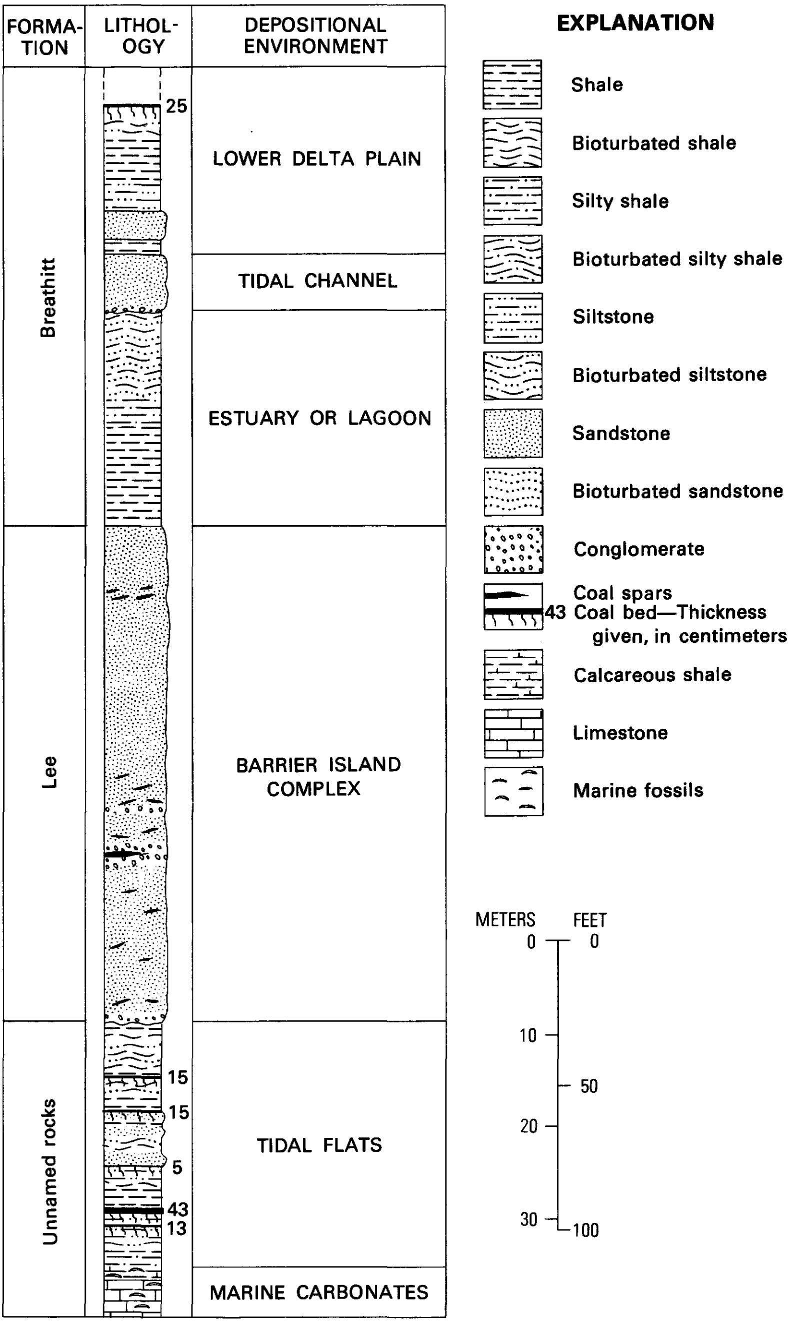


FIGURE 3.—Interpreted environments of deposition of rocks in lower part of USGS corehole K-3-75, from Van Lear coal bed through sandstone of Lee Formation to bottom of hole in fossiliferous marine limestone. Depths below Peach Orchard coal zone at top of core hole are as follows: base of Breathitt Formation, 134 m; base of Lee Formation, 186 m; base of core hole, 220 m.

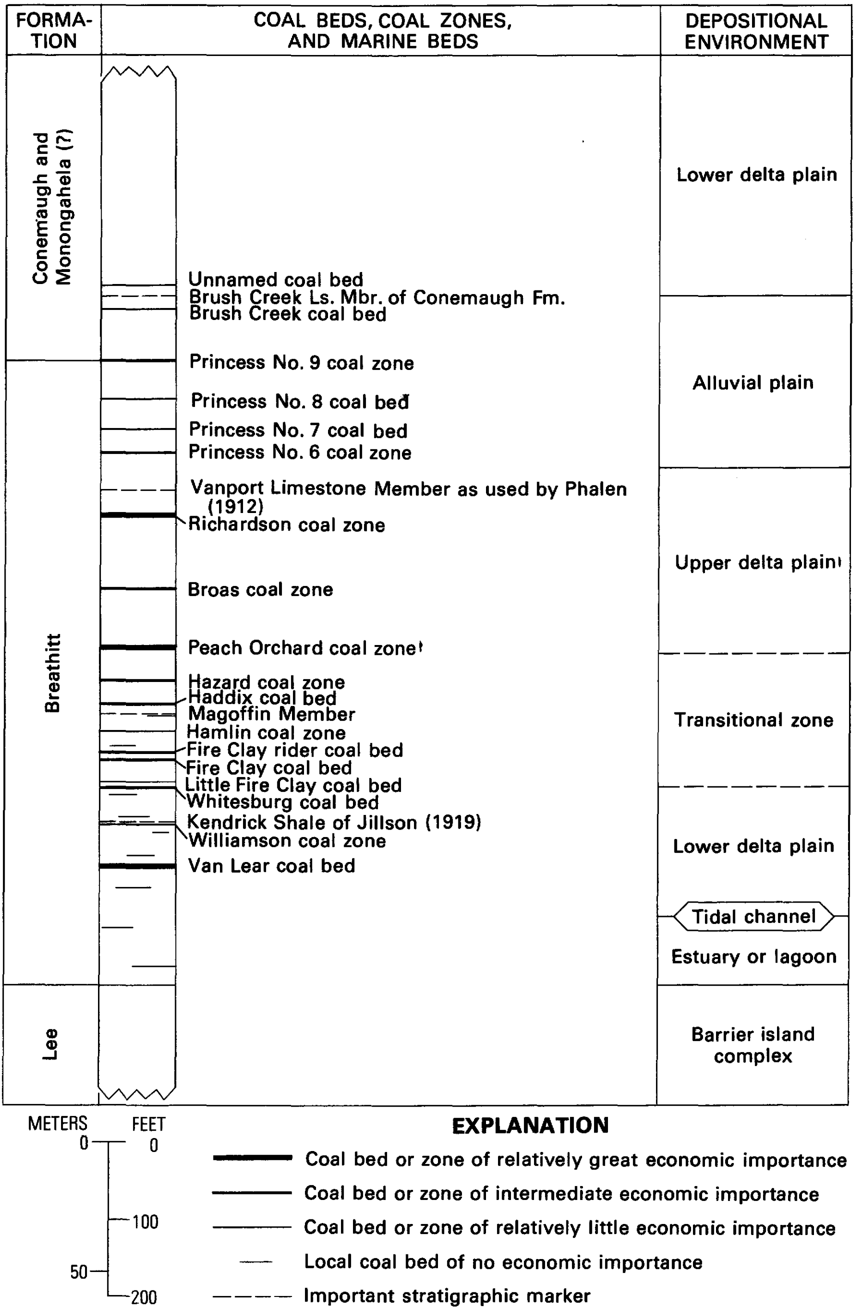


FIGURE 4.—Interpreted environments of deposition of rocks exposed in report area. Scale approximate.

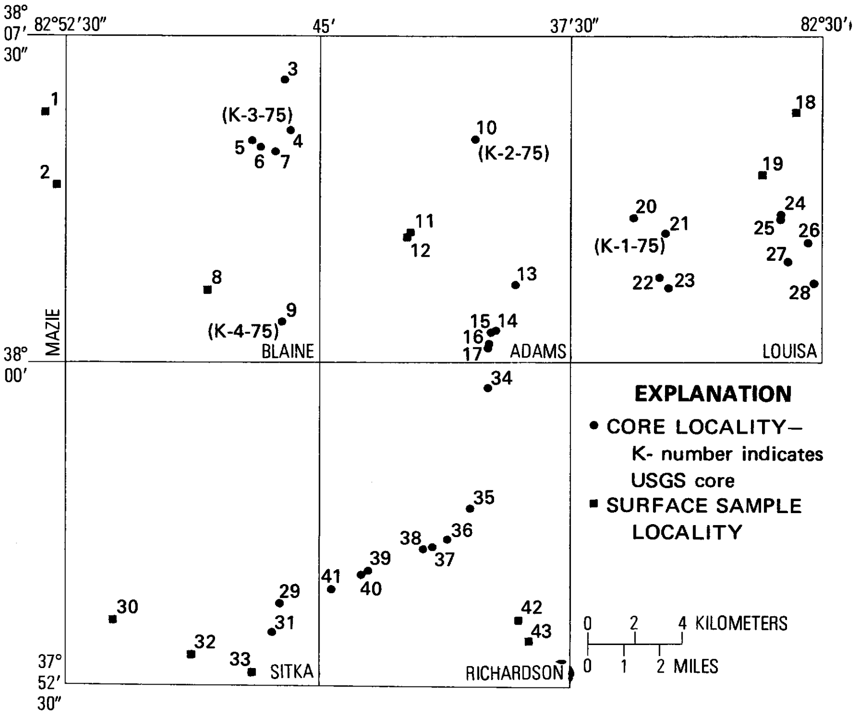


FIGURE 5.—Map showing numbered coal sample localities in and near report area. Description of samples is given in table 3.

The following discussion of the depositional history of the report area is based on core K–3–75 from the marine limestone upward to the top of the Lee Formation (fig. 3); above the Lee the interpretation (summarized in fig. 4) is based on both core data and on field information provided by workers in the five quadrangles (Hayes, 1977; Sanchez and others, 1978; Connor and Flores, 1978; Ward, 1978; and Pillmore and Connor, 1978).

OPEN MARINE CARBONATES AND TIDAL FLATS

ROCKS BELOW LEE FORMATION

The 5 m of marine limestone and overlying fossiliferous calcareous shale at the base of core K–3–75, below the Lee Formation, are considered to have been deposited as an open-marine carbonate mud supporting a rich invertebrate fauna consisting dominantly of crinoids. These carbonates were overlain by terrigenous detritus now representing the next 27 m of rock. These sediments represent a low-energy environment characterized by fine-grained, slightly calcareous clastics. Abundant burrows indicate little current activity, although a few thin layers of fine rippled sandstone suggest low-energy currents. Grayish-red and olive-brown colors indicate partial oxidation, and zones of root penetration and thin coal show local areas of subaerial exposure and development of vascular plants. In view of the open-marine deposits below and barrier-island deposits above, this group of rocks appears to represent a broad coastal low-energy mudflat periodically flooded, perhaps by tidal activity, with some coal-marsh development.

BARRIER-ISLAND COMPLEX

SANDSTONE OF LEE FORMATION

Upon the low-energy tidal flats lies an offshore barrier-island complex represented by the next 52 m of sandstone of the Lee Formation. This rock unit has four distinct subunits with erosional bases bearing pebbles as large as 5 cm in longest dimension. The principal criteria for recognizing barrier environments are according to Horne and Ferm (1976, p. 18):

> * * * lateral relationships and mineralogy of the sandstones. In a seaward direction the sandstones become finer grained and intercalate with red and green calcareous shales and carbonates with marine faunas, whereas in a landward direction, they grade into dark gray lagoonal shales with brackish water faunas. Sandstones of the barrier system tend to be more quartzose and better sorted than those of the surrounding environments. * * *

The seaward-landward criteria are met as is the mineralogical criterion. The sandstone, below the uppermost subunit, is estimated by handlens inspection to be about 70 percent quartz, in contrast to the 35–40 percent quartz in the overlying Breathitt delta-plain sandstones of the report area, as determined in a thin-section study by Flores (1978).

ESTUARY OR LAGOON

ROCKS FROM BASE OF BREATHITT FORMATION TO BELOW VAN LEAR COAL BED

The barrier complex sediments are succeeded by deposits of a lagoon or estuary that lay landward of the bar. The back-barrier environment is characterized by Horne and Ferm (1976, p. 21) as

> * * * sequences of organic-rich dark gray shales and siltstones which are directly overlain by thin laterally discontinuous coals or burrowed sideritic zones. These lagoonal-bayfill sequences coarsen upward, are extensively burrowed, and often contain marine to brackish faunas. Seaward, they intertongue with orthoquartzitic sandstone of barrier origin, whereas in a landward direction, they intertongue with subgraywacke sandstone of fluvial-deltaic origin. These lagoonal deposits are 25 to 80 feet [7.5 to 24 meters] thick * * *

The 23 m of sediments of this environment, conformable with the underlying barrier sand, consist of medium-dark-gray shale with siltstone streaks and dark-gray silty shale in the lower part coarsening to rippled and intensively burrowed interlaminated shale and sandstone in the upper part. No coal beds occur, probably because the water depth was too great. South of the Blaine quadrangle core location, in the Sitka quadrangle, several thin coal beds crop out in this interval, indicative that the shoreline of the lagoon or estuary lay in that direction.

Above the lagoon sediments in the core is a 7-m-thick fine sandstone with ironstone pebbles at the erosional base. This probably was deposited in a tidal channel which coursed through the lagoon (J. C. Ferm, oral commun., 1978).

LOWER DELTA PLAIN

ROCKS FROM BELOW VAN LEAR COAL BED TO WHITESBURG COAL BED

The approximately 50 m of sediments in the next environment, the lower delta plain, consist of coarsening-upward sequences each 5–15 m thick with coal and root-penetrated rocks at the top and bottom. These sequences consist of dark-gray clay shale with siltstone streaks, which grades upward into medium-gray silty shale, siltstone with sandstone streaks, and sandstones at the top. Burrows are common in the lower part of the sequences. Where the sandstone at the top of the sequence is thin, less than 1 m, the lower contact is gradational; but where the sandstone is on the oder of 2–3 m thick, the basal contact is generally erosional. The coarsening-upward pattern is believed to reflect bay sedimentation, and the sandstones at the top, crevasse splays or distributary mouth bars. Coal beds are thin (less than a meter thick) but generally persistent. These features are consistent with Horne and Ferm's description of the lower delta plain (Ferm, 1974, p. 87–88; Horne and Ferm, 1976, p. 11–14).

The lower part of the bay above the Williamson coal zone contains marine fossils representing a marine incursion. These shales, the Kendrick Shale of Jillson (1919), are found at scattered outcrops in the southern two quadrangles, and in the southernmost part of the Adams and Louisa quadrangles, but not in the Blaine quadrangle. North of the outcrop areas, the Kendrick is in the subsurface, and only three cores that intersected this horizon were available: USGS core K–3–75 in northeastern Blaine quadrangle, a company core in west-central Adams quadrangle, and USGS core K–4–75 in southeastern Blaine quadrangle (locations of USGS cores are shown in fig. 5). None of these cores contain fossiliferous Kendrick Shale, but 2–6 m of burrowed interlaminated shale and siltstone or siltstone and sandstone occur at its approximate position, indicating that the Kendrick sea was present in this area.

TRANSITIONAL ZONE

ROCKS FROM WHITESBURG COAL BED TO BASE OF PEACH ORCHARD COAL ZONE

Between the lower delta plain, described previously, and the upper delta plain, above the Peach Orchard coal zone, is a transitional zone. In the report area this is represented by about 50–65 m of sediments. Bay deposits, individually 1.5–9 m thick, are thinner than in the lower delta plain. Channel-sand deposits are common but less abundant and thinner than in the upper delta plain. Coal beds attain a maximum thickness of 1.3 m. Deposits of a marine incursion, the Magoffin Member of the Breathitt Formation, are found in the southern third of the Louisa quadrangle and at scattered localities in the other four quadrangles of the report area. The authors of the geologic maps of those quadrangles considered the Magoffin to be absent over much of the area. The Magoffin is absent in USGS core K–3–75 but present in K–4–75 and in a company core in west-central Adams quadrangle.

UPPER DELTA PLAIN

ROCKS FROM BASE OF PEACH ORCHARD COAL ZONE TO BASE OF PRINCESS NO. 6 COAL ZONE

The 60–65 m of upper delta plain deposits are characterized by thick channel sands and by fewer and thinner interdistributary bay deposits than in the lower delta plain. The coal beds are thicker than in any other environment represented in the report area. Some are persistent, others erratically distributed; maximum thickness is 2.4 m. Root-penetrated rocks, probably representing shallow ponds or levees, are common. Owing in part to lateral migration of streams, individual 1.5–6-m-thick sandstone units with erosional bases are stacked one upon another commonly to 15 m thick. An unusually thick (more than 30 m) sandstone sequence is found just south of the projected trace of the Walbridge fault (fig. 1) in the Louisa quadrangle in a zone about 0.8 km wide, where the Princess No. 5 through Princess No. 8 coal beds are absent. The stacking of sandstone bodies in this area supports and geographically extends the conclusion of Horne and Ferm (1976) that the stacking of sandstones in the Adams quadrangle along U.S. Highway 23, just west of Levisa Fork, was caused by diversion of streams along the subsiding block of a basement fault. The Walbridge fault may also have influenced or controlled the location of the transgression of the Vanport sea in the Adams quadrangle. The Vanport Limestone Member occurs only south of that fault, in a band less than 1.5 km wide from within 3 km of the east border to the west edge of the quadrangle. In the Blaine quadrangle, the limestone is absent in the northeastern part: company cores show that the interval is occupied by thick sandstone bodies that interfinger westward and southward with silty clays, carbonaceous shales, and root-penetrated silts and clays. Beyond this zone the limestone is found at scattered localities to the west and south in an arc 1.5–3 km wide from the northwest corner of the quadrangle south and east to where it joins the Vanport of the Adams quadrangle. The previously mentioned Magoffin Member also occurs only south of the Walbridge fault.

ALLUVIAL PLAIN

The alluvial-plain sediments differ from the upper delta plain sediments mainly in having markedly thinner and few coals. The sandstone channel deposits are coarser grained, more feldspathic. The finer grained flood-plain deposits, considering the area beyond the report area, are widespread.

ROCKS FROM BASE OF PRINCESS NO. 6 COAL ZONE TO TOP OF BREATHITT FORMATION

The thin coals in this 30–40-m interval are fairly persistent and commonly have many partings. A few coal beds are as thick as a meter, with limited lateral extent. The sandstones have lateral extents of at least 5 km. The fine-grained sediments are gray.

ROCKS FROM BASE OF CONEMAUGH FORMATION TO BRUSH CREEK COAL BED

Coals of only local distribution are found in this interval. The most obvious difference between these alluvial-plain deposits and those in the interval described previously is the color of the fine-grained sediments. In contrast to the gray color there, here the color is greenish or yellowish gray or strikingly grayish purple or grayish red purple. These clays and silty clays are commonly intermixed with thin limestone layers, lenses, concretions, and nodules, all mostly less than 8 cm thick, probably representing small fresh-water lakes or ponds. The color of the clays and the lack of coals, suggesting oxidizing conditions, and the thin fresh-water limestones are consistent with the interpreted environment of a broad alluvial flood plain.

Henry and Schweinfurth (1977, p. 20) gave a similar interpretation for the Conemaugh and Monongahela Formations in West Virginia:

> The bulk of the sedimentary rocks in the area of the proposed Upper Pennsylvanian Series stratotype are overbank and other flood-plain deposits. * * * The mudstone and claystone beds, particularly those that are grayish-red or variegated, were probably laid down in well flushed and oxygenated marginal lakes or marshes, some of which were extensive. * * * The nodular limestone, marly limestone, and limestone nodules set in calcareous claystone and mudstone were most likely deposited in oxygenated marshes or

lakes. * * * The thin, discontinuous coal beds, carbonaceous shale, and carbonaceous claystone were deposited in stagnant, swampy depressions and marshes between and adjacent to the main stream channels.

LOWER DELTA PLAIN

ROCKS FROM BRUSH CREEK LIMESTONE MEMBER TO TOP OF EXPOSED SECTION IN MONONGAHELA(?) FORMATION

A marine transgression resulted in deposition of the Brush Creek Limestone Member of the Conemaugh Formation, which is found in the extreme northeastern part of the Blaine quadrangle, in the northern part of the Adams quadrangle from the northwest corner to about the middle on the east, and in the north half of the Louisa quadrangle. Limestone with large whole fossils (pelecypods, brachiopods, crinoid stems) is found only in the north-central part of the Adams quadrangle. To the west, south, and east, shells are progressively smaller, more broken and worn, and crinoid stem segments are typically disarticulated. These features indicate a high-energy coastal zone. Though the southern limit of Brush Creek marine conditions cannot be observed, owing to erosion, it is clear that the shoreline of the sea was not far to the south. A few meters above the limestone is a coal bed, probably a brackish-water swamp deposit. About 30 m above the Brush Creek Limestone Member is carbonaceous black shale, 30 cm thick, replete with conchostracans, small bivalved brackish- or fresh-water crustaceans. This unit may be a lateral equivalent of the Ames sea, which did not reach this far south: the nearest outcrop of its deposits is about 18 km to the northwest, in the Fallsburg-Prichard quadrangle (Sharps, 1967).

Above the marine and brackish-water beds are 100 m of lower delta plain deposits. The fine-grained deposits are similar to those of the alluvial plain. The sandstones are as thick as 9 m, have erosional bases, and are noticeably feldspathic, even without viewing with a handlens. Only a few thin carbonaceous shales or coaly shales are found. This part of the section is exposed only in the northeast corner of the Louisa quadrangle.

GEOLOGIC STRUCTURE

Inasmuch as the area is part of the Appalachian Plateau, the rock units are generally nearly horizontal and undisturbed by faulting. The single mapped fault in the area, the Walbridge fault, trends east-northeast for about 18 km from the southwestern part of the Blaine quadrangle to the east-central part of the Adams quadrangle (fig. 1).

This fault, which apparently dies out at both ends, is relatively downdropped on its south side a maximum of several tens of meters. The fault lies precisely along the trend of the north-dipping Walbridge monoclinal flexure, along which dips average 5°–10° and are locally much greater. To the south and north of the fault and monocline are several gently dipping and very gently east plunging anticlines and synclines. As a result of these structural features, the structurally highest part of the area, in which the oldest rocks are exposed, is in the northwestern part of the Sitka quadrangle, and the structurally lowest part of the area, in which the youngest rocks are exposed, is in the northeastern part of the Louisa quadrangle (figs. 1, 2).

COAL BEDS OR ZONES

Resource figures were calculated for 18 coal beds or zones in the report area (table 1). Three of these, the Van Lear coal bed and the Peach Orchard and Richardson coal zones, together contain more resources and have produced more coal in the past than the other 15 beds or zones combined. Seven other coal beds or zones of local importance contain most of the remaining resources; listed from stratigraphically lowest to highest, they are the Whitesburg bed, Fire Clay bed, Fire Clay rider bed, Haddix bed, Hazard zone, Broas zone, and Princess No. 9 zone. The eight remaining coal beds or zones together contain only about 2 percent of the resources. All the 18 coal beds or zones and one additional uncommercial coal bed are described briefly herein in ascending stratigraphic order. (See fig. 2 for depiction of their position.) The total calculated resources of all beds and zones in each quadrangle and county are given in table 2. Figure 6*A* shows the areas for which resources were calculated.

Because only unweathered coal samples can yield meaningful analytical results, no outcrop samples were collected. Samples were collected where available from working strip mines and cores. Sample descriptions are given in table 3 and sample localities are shown in figure 5. A summary of U.S. Geological Survey chemical analyses is given in table 4; bed-by-bed summaries of U.S. Bureau of Mines analyses and U.S. Geological Survey chemical analyses are given in tables 5 and 6; and analyses for 53 samples are given in table 27 near the end of this report.

In the sections following, general comments on heat of combustion (as calculated on a moist, mineral-matter-free basis), ash, and sulfur are made for each coal bed. Elements other than sulfur are mentioned only if their abundance is considered unusual—at least three times greater than or as little as one-third the average of all the coal beds.

TABLE 1.—*Total coal resources stratigraphically by coal bed or zone in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t (metric ton); 1 in.=2.54 cm. >, equal to or greater than. Leaders (---), no resources]

		Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
Coal bed	Coal zone	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Van Lear		28.8	10.6	0.3	2.1	28.5	8.5	17.5	54.5
	Williamson	.5	.1	---	N	.5	.1	---	.6
Whitesburg		33.5	5.2	.4	.2	33.1	5.0	2.8	40.9
Little Fire Clay		3.6	---	N	---	3.6	---	N	3.6
Fire Clay		24.6	.5	.1	.2	24.5	.3	3.7	28.5
Fire Clay rider		20.2	1.3	.1	.1	20.1	1.2	1.6	22.9
	Hamlin	.1	---	---	---	.1	---	---	.1
Haddix		10.6	1.3	.3	.1	10.3	1.2	.2	11.7
	Hazard	14.1	2.1	.7	.2	13.4	1.9	1.6	16.9
	Peach Orchard	71.6	16.3	1.4	.9	70.2	15.4	5.0	90.6
	Broas	16.8	5.4	.1	.5	16.7	4.9	1.1	22.7
	Richardson	36.1	21.2	.6	1.8	35.5	19.4	4.0	59.0
	Princess No. 6	N	---	N	---	N	---	---	N
Princess No. 7		1.6	.1	N	N	1.6	.1	---	1.7
Princess No. 8		2.8	N	N	N	2.8	---	.2	3.0
	Princess No. 9	9.7	2.9	.1	.1	9.6	2.8	.8	13.2
Brush Creek		---	N	---	---	---	N	---	N
Unnamed		.3	---	.1	---	.2	---	---	.2
Total---------		275.0	67.0	4.2	6.2	270.8	60.8	38.5	370.1

TABLE 2.—*Total coal resources by quadrangle and county in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. $\geq$, equal to or greater than]

Quadrangle	County	Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
		In beds 14-28 in. thick	In beds 28 in. thick	In beds 14-28 in.> thick	In beds 28 in. thick	In beds 14-28 in. thick	In beds 28 in. thick	In beds 14 in. thick	In beds 14 in. thick
Blaine------	Lawrence	36.5	4.2	0.7	0.2	35.8	4.0	2.9	42.7
Sitka-------	---do---	10.9	.3	N	N	10.9	.3	2.8	14.0
Do--------	Johnson	37.2	14.8	.5	2.6	36.7	12.2	14.8	63.7
Richardson-	---do---	4.0	.9	.1	.7	3.9	.2	1.4	5.5
Do--------	Lawrence	57.7	11.7	1.2	1.1	56.5	10.6	7.3	74.4
Adams-------	---do---	51.5	15.9	1.1	1.1	50.4	14.8	4.9	70.1
Louisa------	---do---	50.4	15.6	.3	.4	50.1	15.2	2.6	67.9
Do--------	Wayne---	6.8	3.6	.3	.1	6.5	3.5	1.8	31.8
Total------------		275.0	67.0	4.2	6.2	270.8	60.8	38.5	370.1

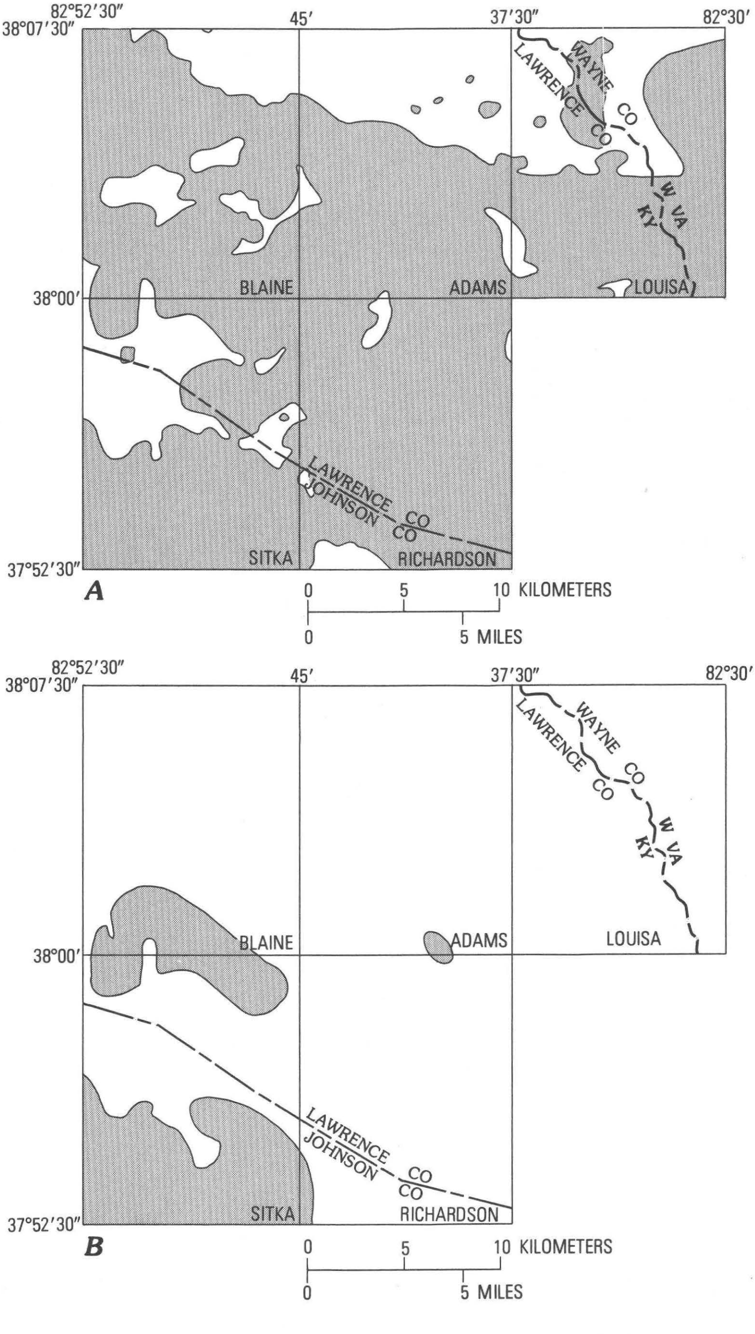


FIGURE 6.—Areas for which coal resources (patterned) were calculated, *A*, for all coal beds and zones; *B*, for the Van Lear coal bed.

UNNAMED COAL BED BELOW THE SANDSTONE OF THE LEE FORMATION

An unnamed coal bed was found 208 m below the surface in a core in the northeastern part of the Blaine quadrangle. It is 17 in. (43 cm) thick and lies 22 m below the base of the 52-m-thick sandstone of the Lee Formation (Connor, 1975, core K–3–75). Because of its depth beneath the surface, resources were not calculated for the bed.

The core sample of the bed was taken for analysis. It has the lowest ash content and highest heat of combustion of all the coal beds; sulfur content is about average. Zinc content is the highest of all beds (about 6 times the average), and arsenic is about one-sixth the average.

VAN LEAR COAL BED

The Van Lear coal bed, known locally as the Millers Creek bed and correlative with the Upper Elkhorn No. 3 bed of areas to the south and with the Tom Cooper bed of areas to the north (Huddle and others, 1963), is one of the three most important beds of the report area and has a total remaining calcualted resource of 54.5 million short tons (49.5 million metric tons (t)) (table 7). Nearly everywhere, the bed is free of partings.

By far the most important area of surface occurrence of the Van Lear coal bed is the southwestern and south-central part of the Sitka quadrangle (fig. 6*B*). In this area the bed crops out low in valley sides, where the bed is in most places 27–34 in. (69–86 cm) thick and is apparently nowhere less than 20 in. (51 cm) thick. In that area the bed has been entered by at least 83 adits, mainly those of small truck mines that operated in the 1940's. It has been contour stripped in five places along a total distance of about 1.4 km. An estimated 2.3 million short tons (2.1 million t) of coal has been mined or lost to future mining by these operations.

The next most important area of surface occurrence of the Van Lear coal bed is the northern part of the Sitka quadrangle and southern part of the Blaine quadrangle. In much of this area the Van Lear ranges in thickness between 13 and 22 in. (33 and 56 cm) and has been entered by at least 16 adits, mostly of home coal mines and small truck mines.

The only other area in which the Van Lear is more than 14 in. (36 cm) thick at the surface is a small area near the level of the Levisa Fork where the stream crosses the boundary of the Richardson and Adams quadrangles. The bed has not been mined there, but three isolated measurements of surface outcrops showed thicknesses of 11, 19, and 28 in. (28, 48, and 71 cm).

The Van Lear coal bed is beneath drainage level throughout most of the Richardson and Adams quadrangles, all of the Louisa quadrangle,

TABLE 3.—*Descriptions of 55 bituminous coal samples collected in or near the report area*

[Depth and elevation are for base of coal. 1 in.=2.54 cm; 1 ft = 0.3048 m. Leaders (---), not applicable]

Sample No.	Locality No.[1]	Coal bed or zone	Quadrangle	Lat N. Deg	Lat N. Min	Lat N. S	Long W. Deg	Long W. Min	Long W. S	Sample type	Depth (ft)	Elev. (ft)	Thickness (in)	Rock type above coal
D174712	21	Brush Creek-----	Louisa----	38	02	54	82	34	39	Core, USGS	36	1095	32	Coaly clay, then Fe nodules.
D174713	21	Princess No. 9 (upper bed).	---do-----	38	02	54	82	34	39	---do-----	75	1055	35	Carbonaceous shale.
D184662	18	Princess No. 9 (middle bed).	---do-----	38	05	45	82	30	47	Channel---	---	757	15	Carbonaceous clay.
D184663	18	------do-------	---do-----	38	05	45	82	30	47	---do-----	---	757	13	Do.
D184664	19	------do-------	---do-----	38	04	19	82	31	44	---do-----	---	903	11	Do.
D184665	19	------do-------	---do-----	38	04	19	82	31	44	---do-----	---	903	8	Do.
D184666	19	------do-------	---do-----	38	04	19	82	31	44	---do-----	---	903	11	Do.
D174714	21	------do-------	---do-----	38	02	54	82	34	39	Core, USGS	107	1023	16	Siltstone and sandstone.
D169557	22	------do-------	---do-----	38	01	54	82	34	49	Core------	50	1090	48	Coaly shale.
D168262	7	Unnamed bed (Princess No. 7?).	Blaine----	38	04	50	82	46	19	--do------	44	816	14	Do.
D168265	1	Richardson (Princess No. 5).	Mazie[2]----	38	05	27	82	54	12	Channel---	---	1050	18	Shale.
D168264	1	------do-------	---do-----	38	05	27	85	54	12	--do------	---	1050	12	Do.
D166260	5	------do-------	Blaine----	38	05	07	82	42	00	Core------	258	752	16	Silty shale, carbonaceous.
D168261	6	------do-------	---do-----	38	04	55	82	46	45	---do-----	185	735	16	Sandstone and siltstone.
D168263	7	------do-------	---do-----	38	04	50	82	46	19	---do-----	152	708	16	Sandstone and siltstone, coaly.
D174722	12	------do-------	Adams-----	38	02	54	82	42	23	Channel---	---	974	8	Unknown.
D174721	12	------do-------	---do-----	38	02	54	82	42	23	---do-----	---	974	20	Do.
D169555	20	------do-------	Louisa----	38	03	18	82	35	35	Core------	157	783	33	Carbonaceous claystone.
D169558	22	------do-------	---do-----	38	01	54	82	34	49	---do-----	233	907	35	Concretions.
D169556	23	------do-------	---do-----	38	01	40	82	34	49	---do-----	193	867	44	Sandstone.
D182463	42	------do-------	Richardson	37	53	58	82	39	07	Channel---	---	966	24	Do.
D182464	42	------do-------	---do-----	37	53	58	82	39	07	---do-----	---	966	46	Do.
D174725	11	Broas----------	Adams-----	38	02	59	82	42	18	---do-----	---	820	11	Siltstone.
D174723	11	------do-------	---do-----	38	02	59	82	42	18	---do-----	---	820	14	Do.
D171581	2	------do-------	Mazie-----	38	03	33	82	52	34	---do-----	---	900	36	Carbonaceous shale.

D168259	3	Peach Orchard--	Blaine----	38	06	29	82	46	02	Core------	321	654	8	Silty clay.
D182462	43	------do-------	Richardson	37	53	31	82	38	46	Channel---	---	849	25	Shale.
D174719	9	Hazard---------	Blaine----	38	00	56	82	46	23	Core, USGS	50	1000	20	Siltstone and sandstone.
D174715	4	Haddix---------	---do-----	38	05	17	82	45	53	---do-----	107	513	13	Shale, Fe streaks.
D168087	33	------do-------	Sitka-----	37	52	30	82	45	00	Run of mine (auger).	---	840	---	Silty shale.
D171600	13	Fire Clay rider	Adams-----	38	01	43	82	39	07	Core------	33	688	6	Shale.
D171599	14	------do-------	---do-----	38	00	42	82	39	45	---do-----	130+	718	7	Sandstone.
D171598	15	------do-------	---do-----	38	00	40	82	39	53	---do-----	70	728	9	Do.
D171591	16	------do-------	---do-----	38	00	22	82	39	56	---do-----	62	736	10	Do.
D171597	17	------do-------	---do-----	38	00	20	82	39	55	---do-----	34	734	10	Do.
D171596	34	------do-------	Richardson	37	59	20	82	39	55	---do-----	64	723	18	Carbonaceous shale.
D171595	35	------do-------	---do-----	37	56	35	82	40	30	---do-----	32	588	17	Sandstone.
D171594	39	------do-------	---do-----	37	55	05	82	43	35	---do-----	28	683	22	Do.
D171593	40	------do-------	---do-----	37	55	00	82	43	45	---do-----	74	682	26	Do.
D171592	29	------do-------	Sitka-----	37	54	25	82	46	10	---do-----	26	798	6	Shale.
D171590	16	Little Fire Clay	Adams-----	38	00	22	82	39	56	---do-----	103	695	7	Carbonaceous shale.
D171589	36	------do-------	Richardson	37	55	50	82	41	10	---do-----	24	580	18	Unknown.
D171588	37	------do-------	---do-----	37	55	40	82	41	40	---do-----	16	626	12	Carbonaceous shale.
D171587	38	------do-------	---do-----	37	55	35	82	41	55	---do-----	22	640	8	Do.
D171586	41	------do-------	---do-----	37	54	45	82	44	40	---do-----	35	688	18	Shale.
D171585	31	------do-------	Sitka-----	37	53	45	82	46	25	---do-----	33	771	7	Sandstone and siltstone.
D171584	8	------do-------	Blaine----	38	01	39	82	48	19	Channel---	---	860	9	Silty clay.
D171583	8	------do-------	---do-----	38	01	39	82	48	19	---do-----	---	860	6	Do.
D174720	9	------do-------	---do-----	38	00	56	82	46	23	Core, USGS	177	873	17	Carbonaceous shale.
D171582	8	Whitesburg-----	---do-----	38	01	38	82	48	18	Channel---	---	846	29	Do.
D171580	30	------do-------	Sitka-----	37	54	02	82	51	07	---do-----	---	928	28	Shale, black, fissile.
D174716	4	Williamson-----	Blaine----	38	05	17	82	45	53	Core, USGS	250	370	18	Shale with siltstone streaks.
D174717	4	Van Lear-------	---do-----	38	05	17	82	45	53	---do-----	294	326	10	Silty shale.
D171579	32	------do-------	Sitka-----	37	53	17	82	48	47	Channel---	---	756	28	Shale.
D174718	4	Unnamed bed below sandstone of Lee Formation.	Blaine----	38	05	17	82	45	53	Core, USGS	683	-63	17	Do.

[1]Shown in figure 5.

[2]Princess No. 6 at this locality according to Outerbridge (1977).

TABLE 4.—*Arithmetic mean, observed range, geometric mean, and geometric deviation of 36 elements in 45 coal samples from the report area, reported on whole-coal basis. Geometric means of 331 Appalachian region bituminous coal samples of Pennsylvanian age (Swanson and others, 1976, table 7C) are included for comparison*

[Values other than those in last column computed from data listed in table 26; values in table 26 followed by L were replaced by the number multiplied by 0.66 (standard procedure). As, F, Hg, Se, Th, and U values used to calculate the statistics were determined directly on whole coal. All other values calculated from determinations made on coal ash. L, less than value shown. Thirty-four of the 45 samples analyses summarized here were included in the 331 Appalachian samples. Si, Al, Ca, Sb, Mg, Na, K, Fe, Ti in percent; others in ppm. Leaders (---), not measurable]

Element	Arithmetic mean (abundance)	Observed range		Geometric mean (expected value)	Geometric deviation	Mean, Appalachian bituminous coal
		Minimum	Maximum			
Si	3.1	0.49	11.0	2.3	2.3	1.2
Al	2.0	.19	10	1.4	2.3	1.3
Ca	.11	.042	.51	.091	1.8	.093
Mg	.065	.012	.213	.045	2.3	.052
Na	.024	.005	.066	.020	1.9	.025
K	.25	.019	1.0	.15	2.7	.13
Fe	2.3	.070	8.0	1.1	4.2	1.0
Mn	68	3.9 L	1023	22	3.5	200
Ti	.12	.008	.49	.081	2.7	.074
As	43	1	300	20	4.3	11
Cd	---	.02 L	.5 L	.2 L[1]	---	.3
Cu	23	7.4	49	21	1.5	16
F	90	20 L	460	60	2.4	60
Hg	.27	.02	1.50	.16	3.0	.14
Li	24	1.8	120	16	2.7	18.8
Pb	17	3.2	72	13	2.1	10.9
Sb	2.0	.3	10.8	1.5	2.0	.8
Se	6.9	1.7	25	5.8	1.8	3.5
Th	6.7	2.7	47.8	4.9	2.1	2.8
U	2.4	.2 L	15	1.6	2.6	1.0
Zn	29	4.5	220	20	2.2	12.8
B	70	15	100	50	1.6	20
Ba	70	10	700	50	2.3	70
Be	3	1	7	3	1.7	2
Co	7	1.5	20	5	1.8	5
Cr	15	2	30	10	2.0	15
Ga[2]	7	2	10	7	1.5	7
Mo	3	.15	15	2	2.8	2
Nb	---	1.5 L	15	3[1]	---	3
Ni	15	5	50	15	1.7	15
Sc	5	1.5	10	5	1.7	3
Sr	50	15	150	30	1.9	70
V	20	2	70	20	2.0	20
Y	15	3	30	15	1.6	7
Yb[3]	1	.7	3	1	1.4	.7
Zr	30	2	300	20	2.7	30

[1] Median.
[2] 37 samples.
[3] 30 samples.

and the northern two-thirds of the Blaine quadrangle. The bed should be within 100 m of the surface, though, along the major drainage courses in the Richardson and southern part of the Adams quadrangle, and exploratory drilling could delineate areas within which the bed is of mineable thickness.

Two samples of the Van Lear coal bed were collected, one for the U.S. Bureau of Mines and one for U.S. Geological Survey chemical analysis. The ash content is a little higher than average, heat of combustion about average, and sulfur content about half the average of all the beds. Silica, lithium, and zinc contents are about one-fourth the average; manganese and cadmium contents are one-seventh the average; and arsenic and mercury contents are less than one-tenth the average.

WILLIAMSON COAL ZONE

Neither of the coal beds of the Williamson coal zone is of much commercial importance. One or the other exceeds 14 in. (36 cm) in thickness at only a few scattered localities in the Blaine, Richardson, and Sitka quadrangles (fig. 7*A*). One is as much as 36 in. (91 cm) thick near a hilltop in the northwest part of the Sitka quadrangle. A bed of the zone has been entered by three adits for small truck mines in the southern and east-central parts of the Sitka quadrangle. A bed of the zone is 18 in. (46 cm) thick at a locality near the west edge of the Richardson quadrangle, and one is 20 in. (51 cm) thick at a locality in the southwestern part of the Blaine quadrangle. The total calculated remaining resource of the zone is 0.6 million short tons (0.54 million t) (table 8).

One sample from the Williamson coal zone was available for analysis. The ash content is about two-thirds the average, heat of combustion about average, and sulfur content about one-third the average of all the beds. It has unusually low concentration of more elements than any other bed: silica, potassium, fluorine, and selenium contents are about one-fourth the average; titanium, lithium, uranium, and zinc contents are about one-fifth the average; and arsenic and mercury contents are about one-tenth the average or less.

WHITESBURG COAL BED

The Whitesburg coal bed, called the Lower Whitesburg coal bed by Huddle and others (1963), is a very persistent bed without partings and is apparently more than 14 in. (36 cm) thick over extensive areas of the Sitka, Richardson, and Blaine quadrangles and locally in the Adams quadrangle (fig. 7*B*). It reaches thicknesses as great as 42 in. (107 cm) in the Sitka quadrangle, 36 in. (91 cm) in the Blaine quadrangle, 34 in. (86 cm) in the Adams quadrangle, and 29 in. (74 cm) in the Richardson quadrangle. The bed has been entered by at least 50 adits of small truck

TABLE 5.—*Arithmetic means, by coal bed, of proximate, ultimate, from the report area, reported*

[All values except heat of combustion in percent. Kcal/kg = 0.556

Coal bed or zone	No. of samples	Proximate analysis				Ultimate analysis				
		Moisture	Volatile matter	Fixed C	Ash	H	C	N	O	S
Brush Creek--------	1	4.3	40.0	42.0	13.7	5.0	64.8	1.2	11.2	4.1
Princess No. 9 (upper bed)------	1	3.4	41.6	41.4	13.6	5.0	66.3	1.4	11.7	2.0
Princess No. 9 (middle bed)-----	4	5.3	35.1	43.9	15.7	5.0	62.4	1.3	13.3	2.3
Richardson (Princess No. 5)-	8	5.8	36.2	47.2	10.7	5.2	66.5	1.3	13.5	2.8
Broas---------------	2	6.4	37.0	50.0	6.6	5.4	71.9	1.4	13.6	1.1
Peach Orchard------	1	12.3	27.7	46.3	13.7	4.8	56.3	1.1	23.5	.5
Hazard-------------	1	5.2	37.0	52.5	5.3	5.6	73.0	1.5	13.9	.7
Haddix-------------	2	5.4	35.5	54.6	9.4	5.1	69.6	1.4	13.6	.9
Fire Clay rider----	4	2.5	33.2	31.8	32.5	4.0	49.2	.98	8.0	5.2
Little Fire Clay---	4	3.4	36.4	47.5	12.7	5.0	68.8	1.4	11.5	.7
Whitesburg---------	1	2.9	37.0	53.2	6.9	5.3	74.3	1.5	11.2	.8
Williamson---------	1	5.1	35.9	52.3	6.7	5.4	72.5	1.5	13.3	.6
Van Lear-----------	1	3.9	41.2	39.3	15.6	4.9	64.3	1.3	13.1	.8
Unnamed bed below sandstone of Lee Formation--------	1	3.5	39.9	51.8	4.8	5.4	75.2	1.4	12.2	1.0
Average, all beds----------		5.0	36.7	46.7	11.2	5.1	66.8	1.3	13.1	1.7

heat of combustion, and forms-of-sulfur analyses of samples on as-received basis except as noted

(Btu/lb). Sulf = sulfate, Pyr = pyritic, Org = organic]

Forms of sulfur			Percent of total sulfur			Heat of combustion (Btu/lb)		Rank (All high-volatile)
Sulf	Pyr	Org	Sulf	Pyr	Org	As received	Moist, mineral-matter free	
0.14	2.97	0.94	4	73	23	11,540	13,650	B
.40	1.29	.27	20	66	14	11,950	14,090	A
.04	1.63	.60	2	72	26	11,170	13,540	B
.09	2.01	.66	3	73	24	11,920	13,560	B
.02	.43	.64	2	39	59	12,760	12,910	B
.02	.05	.47	4	9	87	9,490	13,780	C
.01	.18	.56	1	24	75	12,970	13,780	B
.005	.37	.51	1	42	57	12,330	13,780	B
.28	4.29	.62	5	83	12	8,900	13,970	A–B
.02	.14	.54	3	20	77	12,170	14,150	A
.02	.19	.63	2	23	75	13,090	14,180	A
.01	.05	.54	2	8	90	12,820	13,850	B
.01	.18	.66	1	21	78	11,480	13,870	B
.01	.46	.55	1	45	54	13,500	14,270	A
.08	1.02	.59	4	43	53	11,860	13,810	B

TABLE 6.—*Geometric means, by coal bed, of major-, minor-,*

[Si, Al, Ca, Mg, Na, K, Fe, Ti in percent; other elements

Coal bed or zone	No. of samples[1]	Si	Al	Ca	Mg	Na	K	Fe	Ti	Mn	As	Cd[2]	Cu	F	Hg
Brush Creek------	1	4	2.8	0.072	0.037	0.022	0.21	3.2	0.11	37	60	0.2	26	75	0.15
Princess No. 9 (upper bed)----	1	2.5	1.9	.081	.020	.021	.068	1.0	.18	10	45	.1 L	29	13	.45
Princess No. 9 (middle bed)---	4	2.9	2.1	.12	.047	.016	.16	2.1	.15	10	55	.2 L	16	45	.71
Unnamed bed (Princess No. 7?)--------	1	2.7	2.4	.062	.032	.015	.12	3.0	.086	26	140	.3	23	13	1.50
Richardson (Princess No. 5)---------	9	1.8	1.1	.075	.034	.012	.10	1.8	.041	20	20	.1 L	18	55	.20
Broas------------	2	1.4	1.0	.062	.021	.008	.069	.21	.055	11	9	.06L	12	30	.12
Peach Orchard----	2	1.4	.80	.14	.046	.009	.074	.46	.057	8.5	6	.1 L	18	20	.15
Hazard-----------	1	.76	.64	.058	.028	.009	.12	.15	.031	10	5	.4	23	55	.02
Haddix-----------	1	4.3	2.1	.060	.079	.023	.26	.77	.22	16	35	.2 L	27	90	.18
Fire Clay rider--	10	3.2	1.6	.15	.099	.038	.39	5.4	.099	83	65	.3 L	25	155	.28
Little Fire Clay-----------	8	4.1	2.5	.069	.055	.027	.22	.30	.18	25	5	.1 L	28	75	.05
Whitesburg-------	2	1.3	1.0	.058	.023	.019	.079	.49	.054	6.2	10	.07L	18	40	.08
Williamson-------	1	.55	.46	.086	.015	.024	.037	.084	.019	7.7	2	.2	15	13	.03
Van Lear---------	1	.53	.39	.051	.015	.016	.038	.070	.026	2.6	2	.02L	12	24	.02
Unnamed bed below sandstone of Lee Formation------	1	.92	.76	.19	.019	.032	.065	.82	.033	14	5	.42	19	30	.22
Average, all beds-----------		2.2	1.4	.089	.038	.019	.13	1.3	.089	19	31	.2 L	21	46	.28

[1] Except where otherwise footnoted.

[2] Median values.

[3] n=3

[4] n=5

[5] n=4

[6] n=1

[7] n=9

[8] n=2

and trace-element composition of samples from the report area

in ppm. L, less than value shown; B, not determined]

Li	Pb	Sb	Se	Th	U	Zn	B	Ba	Be	Co	Cr	Ga	Mo	Ni	Sc	Sr	V	Y	Yb	Zr
34	8.9	1.0	2.8	5.5	1.3	62	100	100	5	20	20	27	10	30	10	150	30	20	1.5	30
28	7.1	.9	14	8.1	1.2	13	30	70	1.5	3	15	10	7	7	10	30	30	10	1	30
32	10.2	2.4	10	3.5	1.4	32	30	100	2	5	15	5	7	15	5	50	30	15	[3]1	30
39	72.2	10.8	18	14.5	15.0	77	50	30	3	10	20	B	10	20	7	20	30	15	B	20
11	9.2	1.2	5.3	3.3	1.0	23	50	70	2	5	10	[4]5	3	15	3	30	20	10	[5]1	10
8.1	5.5	.8	5.5	2.8	.7	5.6	70	15	5	5	10	5	1.5	10	2	15	15	10	.7	10
8.8	12.4	1.1	4.5	2.0	.4	28	30	20	5	7	10	[6]5	2	30	7	20	15	10	1	15
5.1	5.7	1.5	2.0	2.0	.4	18	70	30	7	7	7	5	3	7	3	30	10	10	.7	7
24	19.0	1.5	11	6.5	2.0	9.7	20	70	1.5	3	20	B	1.5	10	5	50	30	10	1	30
16	22.3	1.8	6.6	6.4	3.3	26	70	70	5	5	15	[7]7	2	15	3	50	20	15	[8]1.5	20
32	16.5	1.6	5.4	9.9	2.6	14	50	50	5	7	15	10	1.5	15	5	30	30	15	1.5	50
11	11.1	1.3	5.3	5.4	1.3	11	70	20	5	5	10	7	1.5	15	5	20	15	10	1	15
3.2	6.0	1.7	1.7	2.0	.4	7.3	100	20	5	5	5	5	.5	10	3	20	10	15	1	5
4.0	6.5	.8	4.3	2.0	.8	7.5	30	15	5	3	3	2	.2	7	1.5	15	5	7	.7	5
9.0	11.1	1.6	3.5	5.7	1.3	220	100	30	2	7	10	7	3	20	5	50	10	10	1	10
18	14.9	2.0	6.7	5.3	2.2	37	70	50	5	7	15	7	3	15	5	50	20	15	1	20

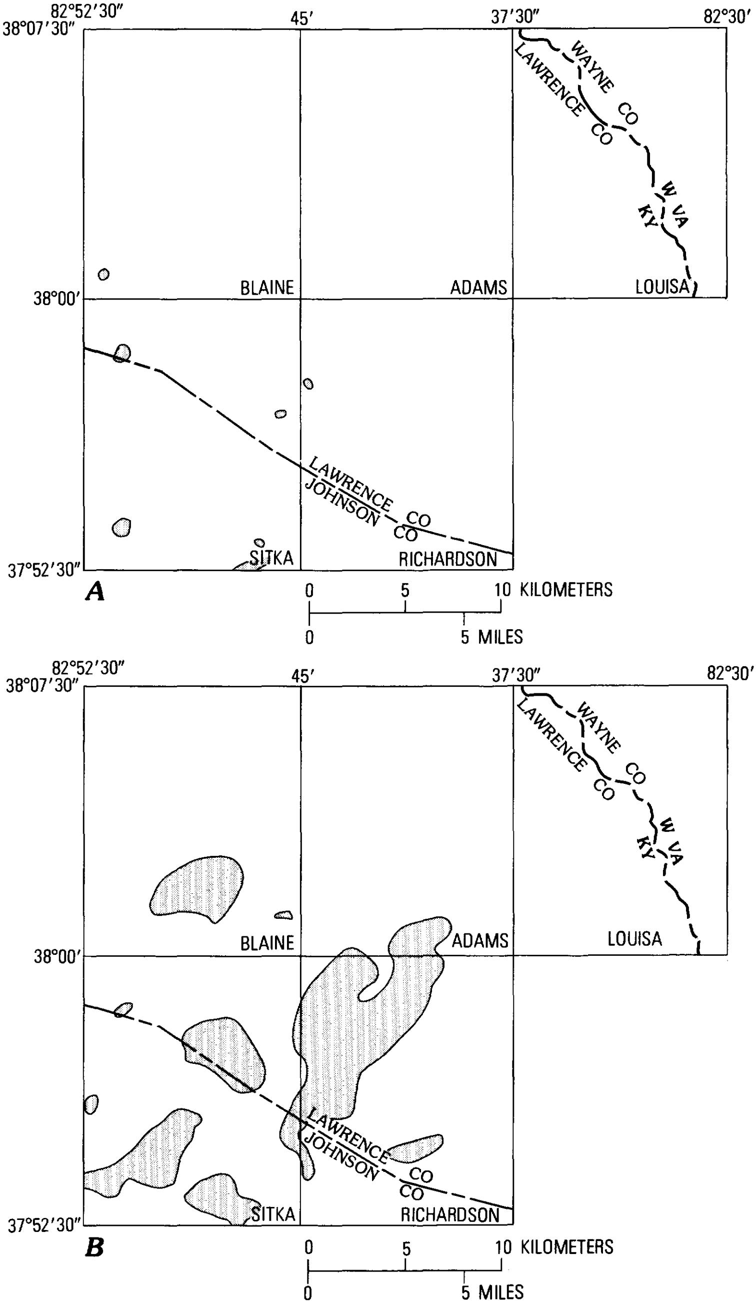


FIGURE 7.—Areas for which coal resources (patterned) were calculated, *A*, for the Williamson zone; *B*, for the Whitesburg coal bed.

TABLE 7.—*Coal resources of Van Lear coal bed in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. >, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource: In beds 14-28 in. thick	Original demonstrated resource: In beds >28 in. thick	Mined and lost in mining: In beds 14-28 in. thick	Mined and lost in mining: In beds >28 in. thick	Remaining demonstrated resource: In beds 14-28 in. thick	Remaining demonstrated resource: In beds >28 in. thick	Inferred resource: In beds >14 in. thick	Total remaining: In beds >14 in. thick
Blaine-----	Lawrence	5.5	---	0.1	---	5.4	---	0.3	5.7
Sitka------	---do---	5.0	---	N	---	5.0	---	1.7	6.7
Do-------	Johnson	17.4	10.6	.2	2.1	17.2	8.5	14.2	39.9
Richardson-	---do---	---	---	---	---	---	---	1.3	1.3
Do-------	Lawrence	.1	---	---	---	.1	---	---	.1
Adams------	---do---	.8	---	N	---	.8	---	---	.8
Total----------		28.8	10.6	0.3	2.1	28.5	8.5	17.5	54.5

TABLE 8.—*Coal resources of Williamson coal zone in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. >, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource: In beds 14-28 in. thick	Original demonstrated resource: In beds >28 in. thick	Mined and lost in mining: In beds 14-28 in. thick	Mined and lost in mining: In beds >28 in. thick	Remaining demonstrated resource: In beds 14-28 in. thick	Remaining demonstrated resource: In beds >28 in. thick	Inferred resource: In beds >14 in. thick	Total remaining: In beds >14 in. thick
Blaine-----	Lawrence	0.1	---	---	---	0.1	---	---	0.1
Sitka------	---do---	.1	---	---	---	.1	---	---	.1
Do-------	Johnson	.3	0.1	---	N	.3	0.1	---	.4
Richardson-	Lawrence	N	---	---	---	N	---	---	N
Total------------		.5	.1	---	N	.5	.1	---	.6

TABLE 9.—*Coal resources of Whitesburg coal bed in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. >, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource: In beds 14-28 in. thick	Original demonstrated resource: In beds >28 in. thick	Mined and lost in mining: In beds 14-28 in. thick	Mined and lost in mining: In beds >28 in. thick	Remaining demonstrated resource: In beds 14-28 in. thick	Remaining demonstrated resource: In beds >28 in. thick	Inferred resource: In beds >14 in. thick	Total remaining: In beds >14 in. thick
Blaine-----	Lawrence	4.0	1.5	0.1	0.1	3.9	1.4	N	5.3
Sitka------	---do---	2.9	.3	---	N	2.9	.3	0.7	3.9
Do-------	Johnson	6.5	2.2	.1	.1	6.4	2.1	.2	8.7
Richardson	---do---	.4	N	---	---	.4	N	---	.4
Do-------	Lawrence	16.9	1.1	.2	---	16.7	1.1	1.8	19.6
Adams------	---do---	2.8	.1	---	N	2.8	.1	.1	3.0
Total-----------		33.5	5.2	.4	.2	33.1	5.0	2.8	40.9

and home coal mines with at least 21 of those adits in the Richardson quadrangle. In addition, the bed has been bench stripped along a total of about 4.9 km of outcrop in the Sitka and Blaine quadrangles. The total calculated remaining resource of the Whitesburg is 40.9 million short tons (37.1 million t) (table 9), at least 25 million more tons than were reported for the zone in the area by Huddle and others (1963).

Two samples of the Whitesburg coal bed were available for analysis; one of these was sent to the U.S. Bureau of Mines. The ash content is about two-thirds the average of all the beds, heat of combustion a little higher than average, and sulfur content about one-half the average. Managnese, arsenic, and zinc contents are about one-third the average.

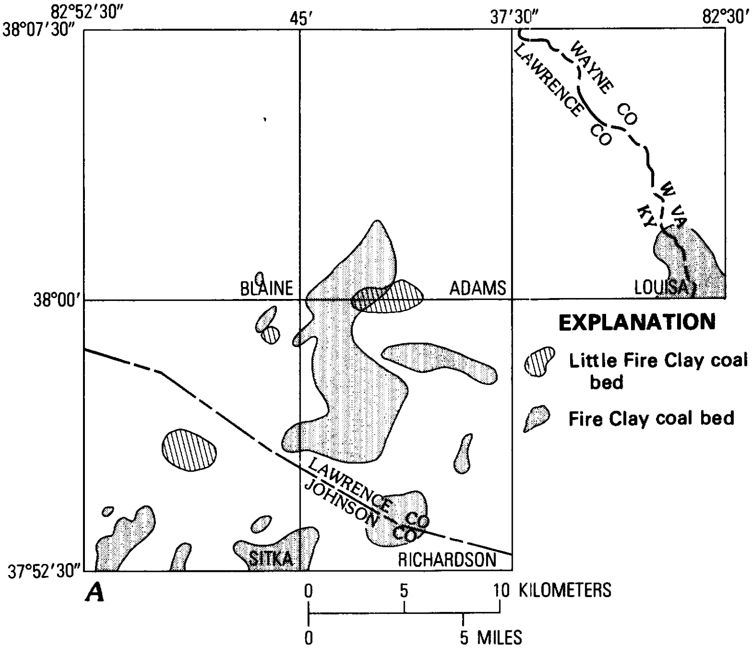
LITTLE FIRE CLAY COAL BED

The Little Fire Clay coal bed (considered as the upper bed of the Whitesburg coal zone in the Blaine quadrangle and called the Upper Whitesburg coal bed by Huddle, Lyons, Smith, and Ferm (1963)) is a very persistent bed, but it is less than 14 in. (36 cm) thick throughout most of the report area, except for two small areas in the Sitka quadrangle and one along the boundary of the Adams and Richardson quadrangles (fig. 8*A*). The larger of these exceptions in the Sitka quadrangle is near the center of the quadrangle, where the bed is locally as much as 26 in. (66 cm) thick; it has been bench stripped along about 100 m of outcrop in conjunction with some more extensive stripping of the Whitesburg bed. The other area in the Sitka quadrangle is in the northeastern part, where the bed was entered by an adit of a very small truck mine. The bed is as much as 24 in. (61 cm) thick locally near the south edge of the Adams quadrangle. It has a total remaining calculated resource of 3.6 million short tons (3.27 million t) (table 10).

TABLE 10.—*Coal resources of Little Fire Clay coal bed in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. >, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource: In beds 14-28 in. thick	Original demonstrated resource: In beds >28 in. thick	Mined and lost in mining: In beds 14-28 in. thick	Mined and lost in mining: In beds >28 in. thick	Remaining demonstrated resource: In beds 14-28 in. thick	Remaining demonstrated resource: In beds >28 in. thick	Inferred resource: In beds >14 in. thick	Total remaining: In beds >14 in. thick
Sitka------	Lawrence	0.4	---	N	---	0.4	---	---	0.4
Do-------	Johnson	1.3	---	N	---	1.3	---	---	1.3
Richardson-	Lawrence	.6	---	---	---	.6	---	N	.6
Adams------	---do---	1.3	---	---	---	1.3	---	---	1.3
Total-----------		3.6	---	N	---	3.6	---	N	3.6



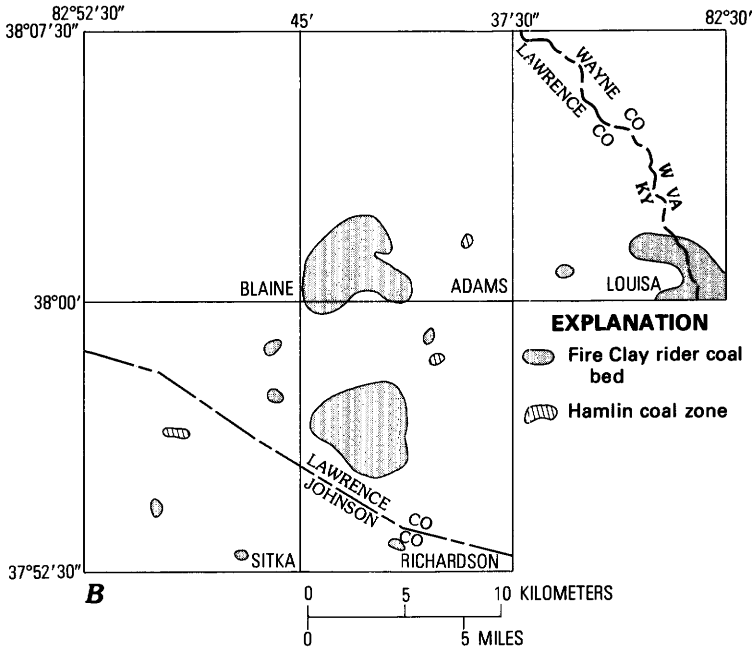


FIGURE 8.—Areas for which coal resources (patterned) were calculated for *A*, Little Fire Clay and Fire Clay coal beds; *B*, Fire Clay rider coal bed and Hamlin coal zone.

Eight samples of the Little Fire Clay coal bed were available for analysis. Four of these were also sent to the U.S. Bureau of Mines. The ash content and heat of combustion are a little higher than the average of all beds, and sulfur content less than half the average. Iron and zinc contents are less than one-fourth the average, and arsenic and mercury contents about one-sixth the average.

FIRE CLAY COAL BED

The Fire Clay coal bed, locally called the Springfield coal bed in the Sitka quadrangle, is very persistent and, with its distinctive flint-clay parting, is a useful marker bed. It is not of great economic importance. The bed exceeds 14 in. (36 cm) in thickness in many places but rarely exceeds 28 in. (71 cm). It is more than 14 in. (36 cm) thick at some point in all of the quadrangles, most extensively in the Richardson quadrangle (fig. 8*A*). The greatest observed thicknesses of the bed in the several quadrangles are 34 in. (86 cm) in the Sitka quadrangle, 27 in. (69 cm) in the Adams, Richardson, and Louisa quadrangles, and 17 in. (43 cm) in the Blaine quadrangle. The bed has been entered by at least 42 adits of very small truck mines and home coal mines, chiefly in the Richardson and Adams quadrangles, and has been contour stripped along about 3.5 km of outcrop in the southwestern part of the Sitka quadrangle. The bed has a total remaining calculated resource of 28.5 million short tons (25.9 million t) (table 11).

No samples of the Fire Clay coal bed were available for analysis.

TABLE 11.—*Coal resources of Fire Clay coal bed in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
		In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Blaine-----	Lawrence	0.1	---	---	---	0.1	---	---	0.1
Sitka------	---do---	.5	---	---	---	.5	---	---	.5
Do-------	Johnson	3.1	0.5	N	0.2	3.1	0.3	---	3.4
Richardson-	---do---	2.2	---	N	---	2.2	---	0.1	2.3
Do-------	Lawrence	10.3	---	N	---	10.3	---	2.7	13.0
Adams------	---do---	4.9	---	0.1	---	4.8	---	N	4.8
Louisa-----	---do---	1.5	---	---	---	1.5	---	.1	1.6
Do-------	Wayne---	2.0	---	---	---	2.0	---	.8	2.8
Total----------		24.6	0.5	0.1	0.2	24.5	0.3	3.7	28.5

FIRE CLAY RIDER COAL BED

The Fire Clay rider coal bed is a persistent bed that nearly everywhere is canneloid in its upper part. Though of little commercial value, it is a useful marker bed. It is more than 14 in. (36 cm) thick locally in all but the Blaine quadrangle (fig. 8*B*) and reaches maximum thicknesses of 37 in. (94 cm) in the Adams quadrangle, 32 in. (81 cm) in the Louisa quadrangle, 30 in. (76 cm) in the Richardson quadrangle, and 22 in. (56 cm) in the Sitka quadrangle. The bed has been entered by at least 18 adits, mostly of home coal mines and small truck mines. It was mined commercially near the turn of the century for home use near Whitehouse on the southern boundary of the Richardson quadrangle, where it may be of better grade (Crandall, 1905) than indicated by the analyses reported in table 25. Its total remaining calculated resource is 22.9 million short tons (20.6 million t) (table 12), at least 9 million more tons in the Kentucky part of the area than were reported by Huddle, Lyons, Smith, and Ferm (1963).

TABLE 12.—*Coal resources of Fire Clay rider coal bed in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. $\geq$, equal to or greater than. Leaders (---), no resources]

		Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
Quadrangle	County	In beds 14-28 in. thick	In beds $\geq$28 in. thick	In beds 14-28 in. thick	In beds $\geq$28 in. thick	In beds 14-28 in. thick	In beds $\geq$28 in. thick	In beds $\geq$14 in. thick	In beds $\geq$14 in. thick
Sitka------	Lawrence	0.4	---	---	---	0.4	---	---	0.4
Do-------	Johnson	.1	---	---	---	.1	---	---	.1
Richardson-	---do---	.1	---	---	---	.1	---	N	.1
Do-------	Lawrence	8.0	0.3	N	N	8.0	0.3	1.6	9.9
Adams------	---do---	7.1	1.0	0.1	0.1	7.0	.9	N	7.9
Louisa-----	---do---	2.6	N	N	---	2.6	N	---	2.6
Do-------	Wayne---	1.9	---	---	---	1.9	---	N	1.9
Total----------		20.2	1.3	0.1	0.1	20.1	1.2	1.6	22.9

Ten samples of the Fire Clay rider coal bed were available for chemical analysis. Four of these were also sent to the U.S. Bureau of Mines. The ash and sulfur contents are the highest of all the beds, almost three times the average. The heat of combustion, on a moist, mineral-matter-free basis, is about average, but on an as-received basis the heating value is well below average because of the high ash content. Potassium, iron, manganese, and fluorine contents are three to four times the average. Only the sample from the probable Princess No. 7 coal bed has a greater number of elements in unusually high concentration.

HAMLIN COAL ZONE

The Hamlin coal zone is a persistent zone that generally contains two beds. It possesses virtually no commercial value. At one place near the center of the Sitka quadrangle, one bed of the zone is 17 in. (43 cm) thick in a drill hole (fig. 8*B*). A bed of the zone is locally 19 in. (48 cm) thick in a highway cut in the Richardson quadrangle and 17 in. (43 cm) thick in a highway cut in the Adams quadrangle. There has been no known mining of beds in the zone, and its total calculated resource is only about 0.1 million short tons (table 13).

No samples of beds in the Hamlin coal zone were available for analysis.

TABLE 13.—*Coal resources of Hamlin coal zone in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. >, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
		In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Sitka------	Johnson	0.1	---	---	---	0.1	---	---	0.1
Richardson-	Lawrence	N	---	---	---	N	---	---	N
Adams------	---do---	N	---	---	---	N	---	---	N
Total-----------		0.1	---	---	---	0.1	---	---	0.1

HADDIX COAL BED

The Haddix coal bed is somewhat erratic in distribution in the area (fig. 9*A*). It is locally as thick as 34 in. (86 cm) in the Blaine quadrangle, 32 in. (81 cm) in the Sitka quadrangle, and 30 in. (76 cm) in the Richardson quadrangle. It apparently is everywhere less than 14 in. (36 cm) thick in the Adams quadrangle and only locally thicker than that in the Louisa quadrangle, where it is 16 in. (41 cm) thick at one place. The bed has been bench stripped along about 4.3 km of outcrop in the southeastern part of the Sitka quadrangle and has been entered by at least 34 adits in the Blaine, Richardson, and Sitka quadrangles. This bed has been locally misidentified by coal operators as the Springfield or Fire Clay coal bed. The total remaining calculated resource of the Haddix is 11.7 million short tons (10.6 million t) (table 14), at least twice as much as reported by Huddle, Lyons, Smith, and Ferm (1963).

Two samples of the Haddix coal bed were available for analysis. Both were sent to the U.S. Bureau of Mines; one was chemically analyzed by

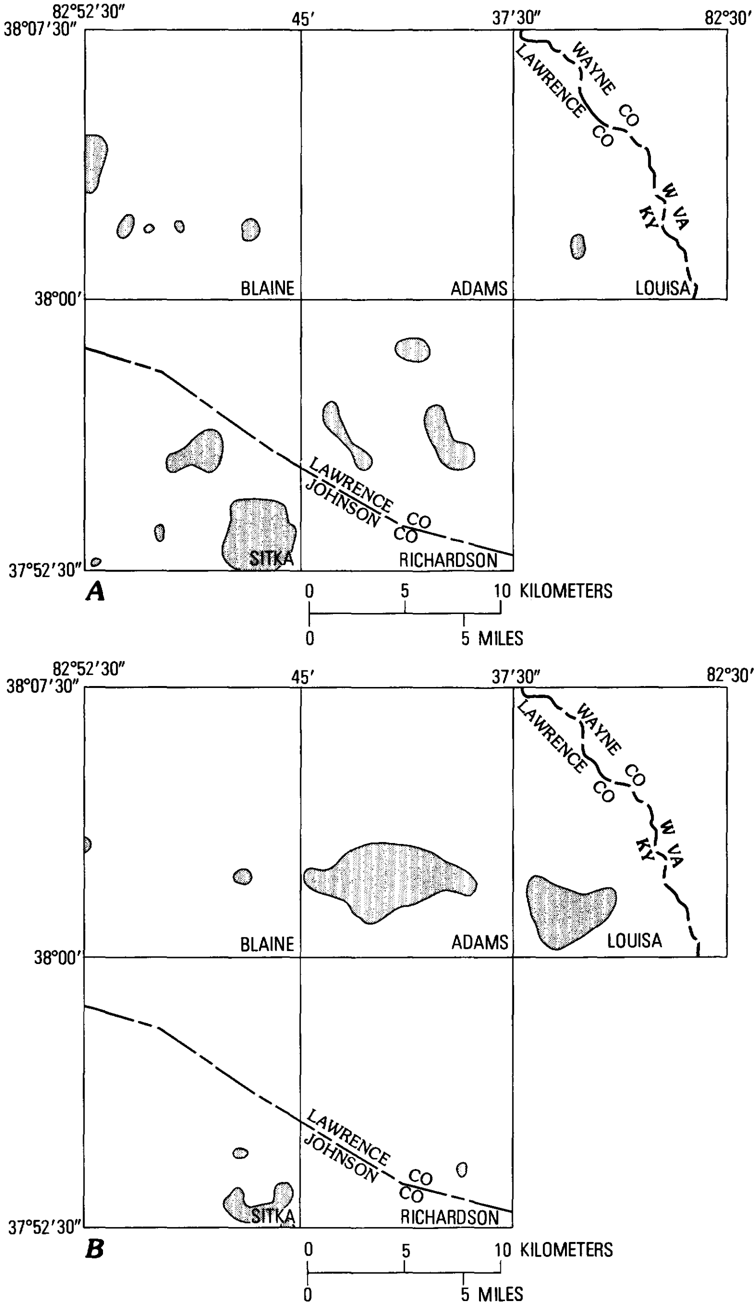


FIGURE 9.—Areas for which coal resources (patterned) were calculated for *A*, Haddix coal bed; *B*, Hazard coal zone.

TABLE 14.—*Coal resources of Haddix coal bed in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource: In beds 14–28 in. thick	Original demonstrated resource: In beds ≥28 in. thick	Mined and lost in mining: In beds 14–28 in. thick	Mined and lost in mining: In beds ≥28 in. thick	Remaining demonstrated resource: In beds 14–28 in. thick	Remaining demonstrated resource: In beds ≥28 in. thick	Inferred resource: In beds ≥14 in. thick	Total remaining: In beds ≥14 in. thick
Blaine-----	Lawrence	3.0	N	0.1	---	2.9	N	---	2.9
Sitka------	---do---	N	---	---	---	N	---	---	N
Do-------	Johnson	4.4	1.3	.1	0.1	4.3	1.2	0.1	5.6
Richardson-	Lawrence	2.9	N	.1	N	2.8	N	.1	2.9
Louisa-----	---do---	.3	---	---	---	.3	---	---	.3
Total-----------		10.6	1.3	0.3	0.1	10.3	1.2	0.2	11.7

the U.S. Geological Survey. The ash content is about four-fifths the average of all beds, heat of combustion is about average, and sulfur content is about half the average. Zinc and boron contents are about one-fourth the average.

HAZARD COAL ZONE

Coal beds of the Hazard coal zone are somewhat erratic in distribution and variable in thickness. All beds are less than 14 in. (36 cm) thick over a large part of the area (fig. 9*B*), but locally some bed of the zone is 28 in. (71 cm) or more thick in all but the Richardson and Sitka quadrangles, where the maximum measured thicknesses of a bed in the zone are 18 in. (46 cm) and 20 in. (51 cm), respectively. One bed of the zone is as thick as 51 in. (130 cm) at one point in the Adams quadrangle and as thick as 36 in. (91 cm) in a drill hole in the Louisa quadrangle. About 1.9 km of outcrop of one bed have been bench stripped in the Adams quadrangle and about 0.3 km in the Sitka quadrangle. The bed has been entered by at least 14 adits in the Adams quadrangle and by at least 1 adit in the Sitka quadrangle. The Hazard coal zone has a total calculated remaining resource of 16.9 million short tons (15.3 million t) (table 15). Huddle, Lyons, Smith, and Ferm (1963) did not calculate resources for the zone in the area.

A single sample from the Hazard coal zone, from the Blaine quadrangle, was available for analysis. The ash content is about twice the average of all the beds, heat of combustion is near average, and sulfur content is less than half the average. Lithium content is about one-third the average, uranium and arsenic contents about one-sixth, and mercury less than one-tenth the average.

TABLE 15.—*Coal resources of Hazard coal zone in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
		In beds 14–28 in. thick	In beds ≥28 in. thick	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Blaine-----	Lawrence	0.4	---	---	---	0.4	---	---	0.4
Sitka------	Johnson	1.1	---	0.1	---	1.0	---	---	1.0
Richardson-	Lawrence	N	---	---	---	N	---	---	N
Adams------	---do---	8.5	2.0	.6	0.2	7.9	1.8	0.7	10.4
Louisa-----	---do---	4.1	.1	---	---	4.1	.1	.9	5.1
Total----------		14.1	2.1	0.7	0.2	13.4	1.9	1.6	16.9

PEACH ORCHARD COAL ZONE

The Peach Orchard coal zone, represented by the Mudseam coal bed in quadrangles to the west (Rice, 1968; Outerbridge, 1977) and by the Princess No. 3 coal zone to the north (Huddle and others, 1963), contains greater coal resources than any other coal bed or zone in the area. The value of the bed, however, is diminished by the presence of shale partings.

The Peach Orchard coal zone generally contains three coal beds in the eastern part of the area, two or three in the central part, and one or two in the western part. Any of the beds may be locally thick, but in areas where two beds are present it is most commonly the upper that is thicker.

Coal beds of the Peach Orchard zone are thickest and most persistent in a large area covering the southern parts of the Louisa and Adams quadrangles and the northern part of the Richardson quadrangle (fig. 10*A*). In that area, bed thicknesses of 42 in. (107 cm) or more are not uncommon, and beds may locally be 72–84 in. (183–213 cm) thick in the Louisa quadrangle. About 18 km of outcrop have been bench stripped, the most in the Richardson quadrangle and the least in the Louisa quadrangle; and coal beds of the zone have been entered by at least 146 adits, also mostly in the Richardson quadrangle.

In the southern part of the Richardson quadrangle, most of the Sitka quadrangle, and the southern part of the Blaine quadrangle, beds of the zone are rarely as thick as 28 in. (71 cm) and in many places are all less than 14 in. (36 cm). In this large area one bed of the zone has been bench stripped along about 0.4 km of outcrop and entered by at least 24 adits.

The Peach Orchard coal zone has been removed by erosion from the highest hills in most of the northwestern parts of the Sitka quadrangle. It is below drainage level in the northern parts of the Louisa, Adams, and Blaine quadrangles, where very little is known about it. The total remaining calculated resource of the zone is 90.6 million short tons (82.2 million t) of coal (table 16).

Two samples from the Peach Orchard coal zone were available for chemical analysis, one of which was also sent to the U.S. Bureau of Mines. The ash content is a little higher than the average of all beds, heat of combustion about average, and the sulfur content less than one-third the average, lowest of all the beds. Arsenic and uranium contents are about one-fifth the average.

TABLE 16.—*Coal resources of Peach Orchard coal zone in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

		Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
Quadrangle	County	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Blaine-----	Lawrence	2.8	---	0.1	---	2.7	---	1.3	4.0
Sitka------	---do---	1.6	---	N	---	1.6	---	.4	2.0
Do-------	Johnson	2.7	---	N	---	2.7	---	.3	3.0
Richardson-	---do---	1.1	---	N	---	1.1	---	N	1.1
Do-------	Lawrence	18.0	7.2	.8	.7	17.2	6.5	.2	23.9
Adams------	---do---	9.1	2.1	.2	.1	8.9	2.0	2.7	13.6
Louisa-----	---do---	25.2	6.1	.2	.1	25.0	6.0	.1	31.1
Do-------	Wayne---	11.1	.9	.1	---	11.0	.9	N	11.9
Total-----------		71.6	16.3	1.4	0.9	70.2	15.4	5.0	90.6

BROAS COAL ZONE

The term Broas coal zone is used here to include most coal beds between the Peach Orchard and Richardson coal zones. The beds in the interval are generally thin. In most areas not more than two beds are found, although in excellent roadcut exposures in the eastern part of the Adams quadrangle as many as seven beds are present. For the most part the beds in the zone are less than 14 in. (36 cm) thick; but, locally, one or another may be moderately thick and commercially important in the three northern quadrangles—as thick as 63 in. (160 cm) in the Louisa quadrangle, 44 in. (112 cm) in the Adams quadrangle, and 38 in. (97 cm) in the Blaine quadrangle. At no point in the Richardson quadrangle was a bed of the zone found to be more than 14 in. (36 cm) thick and, except for two localities where beds 24 in. (61 cm) and 15 in. (38 cm) thick were found, the same is true of the Sitka quadrangle (fig. 10*B*). Beds of the zone have been entered by at least 44 adits in the

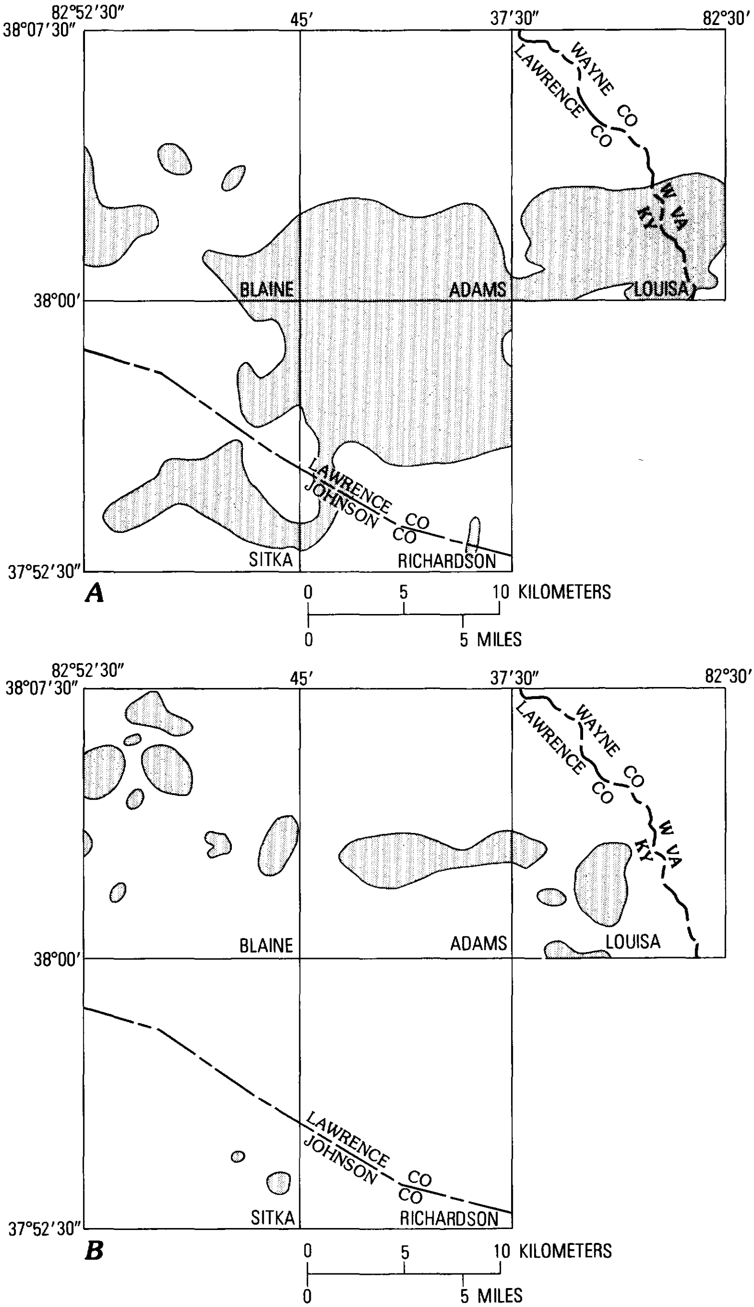


FIGURE 10.—Areas for which coal resources (patterned) were calculated for *A*, Peach Orchard coal zone; *B*, Broas coal zone.

Adams and Blaine quadrangles, and about 4.0 km of bed outcrop have been bench stripped in those quadrangles and the Louisa quadrangle. Where mined in the Adams and Louisa quadrangles, a bed of the zone has been referred to as the Torchlight coal bed and correlated with the Princess No. 4 coal bed of areas to the north (Huddle and others, 1963). The total calculated remaining coal resource of the Broas zone is 22.7 million short tons (20.6 million t) (table 17).

A bed of the Broas coal zone was sampled in the Adams quadrangle and just west of the Blaine quadrangle in the Mazie quadrangle. The ash content of the three samples is about half the average of all the beds, heat of combustion the lowest of all the beds, and the sulfur content a little lower than the average. Arsenic, uranium, barium, and strontium contents are about one-third the average, zinc content one-fourth, and iron content one-sixth the average.

TABLE 17.—*Coal resources of Broas coal zone in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

		Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
Quadrangle	County	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Blaine-----	Lawrence	7.2	0.1	0.1	N	7.1	0.1	---	7.2
Sitka------	Johnson	.2	---	---	---	.2	---	---	.2
Adams------	Lawrence	3.9	4.4	N	.4	3.9	4.0	0.9	8.8
Louisa-----	---do---	5.5	.9	---	.1	5.5	.8	.2	6.5
Total-----------		16.8	5.4	0.1	0.5	16.7	4.9	1.1	22.7

RICHARDSON COAL ZONE

The Richardson coal zone, correlated with the Princess No. 5 coal zone of areas to the north and locally referred to as the No. 5 Block (a West Virginia name), contains the thickest and most persistently thick coal beds of the area, and contains the largest percentage of the most accessible coal. The zone may contain as many as five coal beds, but generally only one, at or near the base, is thicker than 14 in. (36 cm).

The major resources of the zone are in a broad belt that extends across the Blaine, Adams, and Louisa quadrangles (fig. 11*A*). The greatest amount of mining of the zone, however, has been in the south half of the Richardson quadrangle, where the zone generally occurs high on the ridges and is particularly amenable to contour or hilltop stripping. Maximum measured thicknesses of beds in the zone are 93 in. (236 cm) in the Adams quadrangle, 84 in. (213 cm) in the Richardson quadrangle, 63 in. (160 cm) in the Louisa quadrangle, and 50 in. (127

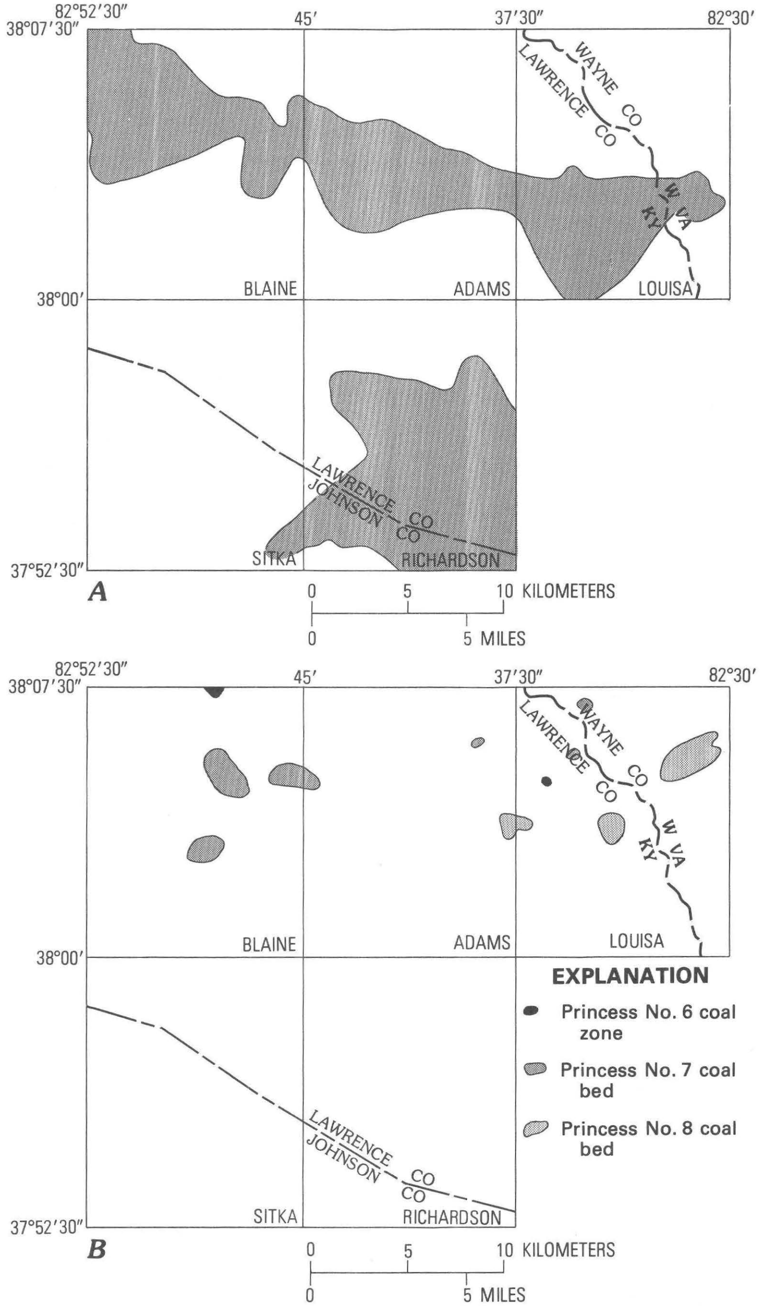


FIGURE 11.—Areas for which coal resources (patterned) were calculated for *A*, Richardson coal zone; *B*, Princess No. 6 coal zone and the Princess Nos. 7 and 8 coal beds.

cm) in the Blaine quadrangle. Altogether, beds of the zone have been stripped along about 33 km of outcrop, about 19 km of which is in the Richardson quadrangle. In addition, the bed has been entered by at least 56 adits, chiefly in the Adams, Blaine, and Louisa quadrangles.

Beds of the Richardson zone are thin or missing in most of the Sitka quadrangle, the southern parts of the Blaine and Adams quadrangles, and the northern part of the Richardson quadrangle. They are also thin or missing in the northeastern part of the Blaine quadrangle. The position of the zone is beneath drainage level in the northern part of the Louisa quadrangle and in much of the northern part of the Adams quadrangle, where little is known of it. The total calculated remaining resource of the Richardson coal zone is 59.0 million short tons (53.6 million t) (table 18).

Twelve samples of coal from the Richardson coal zone were collected at nine localities. All were chemically analyzed by the U.S. Geological Survey; 10 also were sent to the U.S. Bureau of Mines. The ash content and heat of combustion are about average, and sulfur content is about one and one-half times the average of all the beds. None of the other element contents are unusually high or low.

TABLE 18.—*Coal resources of Richardson coal zone in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource: In beds 14-28 in. thick	Original demonstrated resource: In beds ≥28 in. thick	Mined and lost in mining: In beds 14-28 in. thick	Mined and lost in mining: In beds ≥28 in. thick	Remaining demonstrated resource: In beds 14-28 in. thick	Remaining demonstrated resource: In beds ≥28 in. thick	Inferred resource: In beds ≥14 in. thick	Total remaining: In beds ≥14 in. thick
Blaine-----	Lawrence	12.0	2.5	0.2	0.1	11.8	2.4	1.3	15.5
Sitka------	Johnson	N	.1	N	.1	N	N	---	N
Richardson-	---do---	.2	.9	.1	.7	.1	.2	---	.3
Do-------	Lawrence	.9	3.1	.1	.4	.8	2.7	.9	4.4
Adams------	---do---	12.7	6.3	.1	.3	12.6	6.0	.5	19.1
Louisa-----	---do---	9.8	8.1	.1	.2	9.7	7.9	1.3	18.9
Do-------	Wayne---	.6	.2	N	---	.6	.2	N	.8
Total-----------		36.2	21.2	0.6	1.8	35.6	19.4	4.0	59.0

PRINCESS NO. 6 COAL ZONE

The Princess No. 6 coal zone is found only in the Blaine, Adams, and Louisa quadrangles, where it is fairly persistent and is generally made up of three or four very thin coal beds separated by rooted clay. At no place were any of the beds observed to be more than 14 in. (36 cm) thick, but at least two adits enter one of the beds: one in the northwest quarter of the Louisa quadrangle and one on the north edge of the Blaine quadrangle (fig. 11*B*). In the Mazie quadrangle, just west of the

Blaine quadrangle, the single bed of the zone is as thick as about 3 ft (0.9 m) and has been locally stripped (Outerbridge, 1977). The calculated remaining resource of the Princess No. 6 coal zone is negligible (table 19).

No samples from the Princess No. 6 coal zone were available for analysis.

TABLE 19.—*Coal resources of Princess No. 6 coal bed in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
		In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Blaine-----	Lawrence	N	---	N	---	N	---	---	N
Louisa-----	---do---	N	---	N	---	N	---	---	N
Total-----------		N	---	N	---	N	---	---	N

PRINCESS NO. 7 COAL BED

The Princess No. 7 coal bed occurs only in the northern two-thirds of the Blaine, Adams, and Louisa quadrangles. It is generally less than 14 in. (36 cm) thick although it locally exceeds that thickness in all three quadrangles (fig. 11*B*). It reaches a maximum measured thickness of 36 in. (91 cm) in the Blaine quadrangle, where it has been entered by at least two adits. It is locally 30 in. (76 cm) thick in the Louisa quadrangle and 22 in. (56 cm) thick in the Adams quadrangle. The total remaining calculated resource of the bed is 1.7 million short tons (1.54 million t) (table 20).

One sample was available of a coal at the approximate position of the Princess No. 7 coal bed. It was not submitted for U.S. Bureau of Mines

TABLE 20.—*Coal resources of Princess No. 7 coal bed in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
		In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Blaine----	Lawrence	1.4	0.1	N	N	1.4	0.1	---	1.5
Adams-----	---do---	.1	---	N	---	.1	---	---	.1
Louisa----	---do---	.1	N	---	---	.1	N	---	.1
Total-----------		1.6	0.1	N	N	1.6	0.1	---	1.7

analysis. It has unusually high contents of more elements than any other bed: uranium content is about seven times the average of all beds, and arsenic, mercury, lead, and antimony contents are about five times the average. Only fluorine content is considerably lower than (one-fourth) the average.

PRINCESS NO. 8 COAL BED

The Princess No. 8 coal bed is found only in the Louisa and Adams quadrangles (fig. 11*B*). Although generally less than 14 in. (36 cm) thick, it reaches maximum measured thicknesses of 26 in. (66 cm) in the Louisa quadrangle and 19 in. (48 cm) in the Adams quadrangle. The largest area of occurrence of the bed where it is thicker than 14 in. (36 cm) is in the northeastern part of the Louisa quadrangle. The bed was stripped along about 2 km of outcrop near the boundary between the Louisa and Adams quadrangles. It has a total calculated remaining resource of 3.0 million short tons (2.72 million t) (table 21). No samples of Princess No. 8 coal bed were available for analysis.

TABLE 21.—*Coal resources of Princess No. 8 coal bed in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
		In beds 14–28 in. thick	In beds ≥28 in. thick	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Adams------	Lawrence	0.1	N	N	N	0.1	---	---	0.1
Louisa-----	---do---	0.5	---	---	---	0.5	---	---	0.5
Do-------	Wayne---	2.2	---	---	---	2.2	---	0.2	2.4
Total------------		2.8	N	N	N	2.8	---	0.2	3.0

PRINCESS NO. 9 COAL ZONE

The main (middle) bed of the Princess No. 9 coal zone is sporadically present at the top of the Breathitt Formation in the northern three quadrangles. It is most persistent and most commonly thicker than 14 in. (36 cm) in the Louisa quadrangle (fig. 12*A*) and is thinnest and least persistent in the Blaine quadrangle, where its only measured thickness is 9 in. (23 cm). The bed has been bench stripped along about 5 km of outcrop in the Louisa and Adams quadrangles and has been entered by at least 12 adits, mostly in the eastern part of the Louisa quadrangle. An upper bed, 35 in. (89 cm) thick, was found in a core in the central part of the Louisa quadrangle; and a thin lower bed is exposed locally in

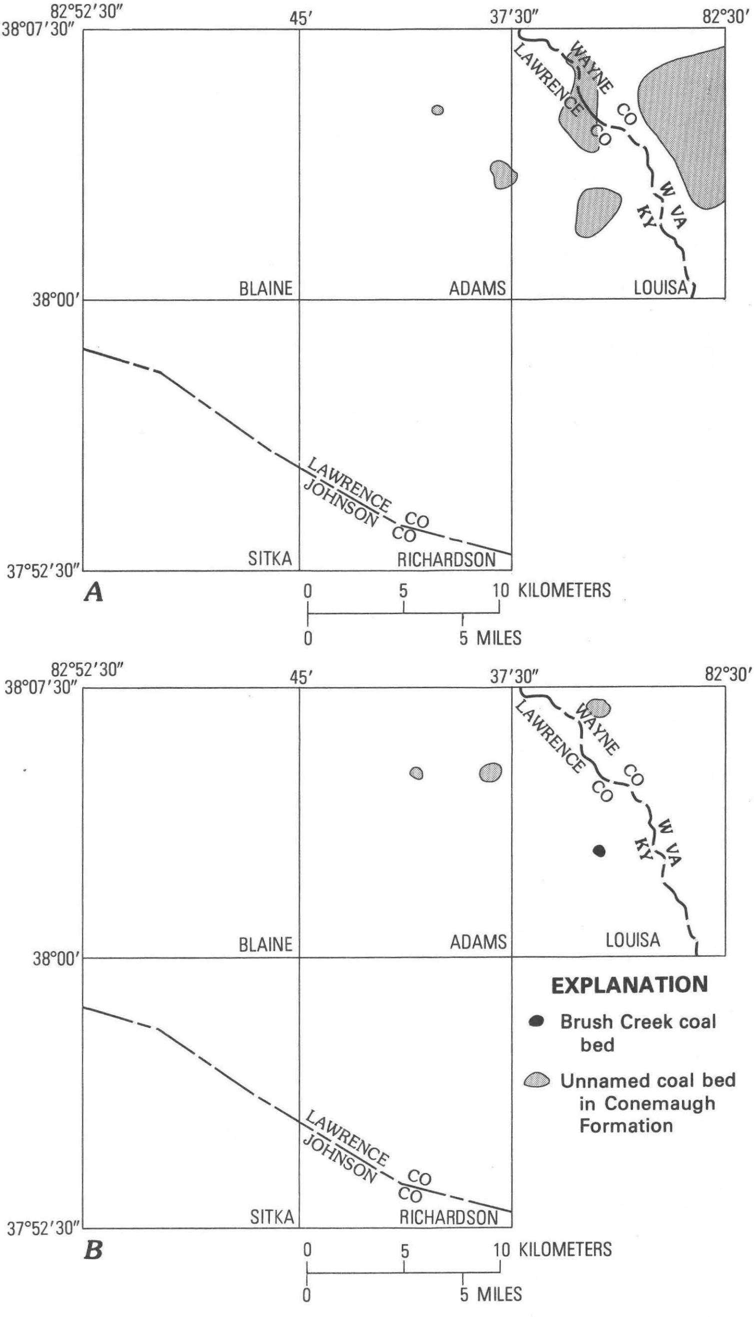


FIGURE 12.—Area for which coal resources (patterned) were calculated for *A*, Princess No. 9 coal zone; *B*, Brush Creek coal bed and an unnamed coal bed in the Conemaugh Formation.

the east-central part of that quadrangle. The zone has a total calculated remaining resource of 13.2 million short tons (12.0 million t) (table 22).

The lowermost bed in the zone was not sampled. Seven samples of the main (middle) bed were collected at four localities. Four composite samples representing the four localities were sent to the U.S. Bureau of Mines. The ash content is about $1\frac{1}{2}$ times the average of all the beds, heat of combustion is about average, and sulfur content is about $1\frac{1}{3}$ times the average. None of the other element contents are unusually high or low. The single sample of the uppermost bed showed ash content, heat of combustion, and sulfur content all a little higher than the average; only fluorine content is considerably lower (one-fourth) than the average.

TABLE 22.—*Coal resources of Princess No. 9 coal zone in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

		Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
Quadrangle	County	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Adams------	Lawrence	0.1	N	N	N	0.1	N	---	0.1
Louisa-----	---do---	.8	0.4	N	N	.8	.4	N	1.2
Do-------	Wayne---	8.8	2.5	0.1	0.1	8.7	2.4	0.8	11.9
Total-----------		9.7	2.9	0.1	0.1	9.6	2.8	0.8	13.2

BRUSH CREEK COAL BED

The Brush Creek coal bed occurs only in the Adams and Louisa quadrangles where it is nearly everywhere less than 14 in. (36 cm) thick. It is, however, about 32 in. (81 cm) thick in a drill hole in the central part of the Louisa quadrangle (fig. 12*B*). The bed has apparently not been mined at any place in the area. Its total resource is negligible (table 23).

TABLE 23.—*Coal resources of Brush Creek coal bed in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

		Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
Quadrangle	County	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds 14–28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Louisa-----	Lawrence	---	N	---	---	---	N	---	N
Total-----------		---	N	---	---	---	N	---	N

A single sample of the Brush Creek coal bed was available for analysis. Ash content is a little higher than the average for all the beds, heat of combustion about average, and sulfur content about 2½ times the average. Strontium content, highest of all the beds, three times the average, is the only element in unusual concentration.

UNNAMED COAL BED OF CONEMAUGH FORMATION

An unnamed coal bed a few meters above the Brush Creek Limestone Member occurs locally in the Adams and Louisa quadrangles. Only locally is it thicker than 14 in. (36 cm). In the Adams quadrangle, where it has been entered by at least three adits, it is up to 24 in. (61 cm) thick; in the Louisa quadrangle it is up to 20 in. (51 cm) thick (fig. 12*B*). The bed occurs high on the ridges and is of very little economic importance. It has a calculated total remaining resource of only 0.2 million short tons (0.18 million t) (table 24). No samples of this bed were taken for analysis.

TABLE 24.—*Coal resources of unnamed coal bed in Conemaugh Formation in millions of short tons*

[N, less than 0.05 million short tons. Data in inch-pound units; 1 ton=0.907 t; 1 in.=2.54 cm. ≥, equal to or greater than. Leaders (---), no resources]

Quadrangle	County	Original demonstrated resource		Mined and lost in mining		Remaining demonstrated resource		Inferred resource	Total remaining
		In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds 14-28 in. thick	In beds ≥28 in. thick	In beds ≥14 in. thick	In beds ≥14 in. thick
Adams------	Lawrence	0.1	---	---	---	0.1	---	---	0.1
Louisa-----	Wayne---	.2	---	0.1	---	.1	---	---	.1
Total------------		0.3	---	0.1	---	0.2	---	---	0.2

GENERAL OBSERVATIONS ON ANALYTICAL DATA

The 55 coal samples from the report area are chemically similar to Appalachian Pennsylvanian bituminous coals as reported by Swanson and others (1976, table 7*C*). Because the mean Appalachian coal values of Swanson and others are biased toward the values of the northern Appalachian coals (half of the samples are from Pennsylvania and Ohio), a rigorous statistical comparison of our values with those values is not appropriate. The only elements that are considered here as probably different in abundance are those for which the geometric mean is less than one-third (manganese) or more than three times (no elements) the geometric mean of the Appalachian coals (table 4). Proximate and ultimate analyses, heat of combustion, and forms of sulfur for 32 coal samples in the report area are similar to those reported by Swanson and others (1976, table 7*A*).

Sampling limitations were discussed in the previous section, "Coal Beds and Zones." For the report area, analytical data were examined and, where the distribution was considered adequate, statistically tested for stratigraphic and geographic trends.

Detailed analytical data are given in tables 25, 26, and 27 of this report, on pages 58–69 following "References Cited."

STRATIGRAPHIC TRENDS

Coal beds in the upper and lower parts of the stratigraphic section were compared for differences in trace-element contents and U.S. Bureau of Mines analyses by means of the statistical "t-test." The division between the upper and lower parts is placed at the base of the Peach Orchard coal zone, which is approximately at the boundary between the upper and lower delta plain environments. (See "Interpretation of Depositional History.") All the trace-element contents were tested using coal-bed geometric means (table 6). The Bureau of Mines analyses were tested using coal-bed arithmetic means (table 5). The tests were made both including and excluding the Fire Clay rider coal bed, the extremely high ash content (32.5 percent) of which could strongly influence the abundance of some elements.

The results show that the stratigraphically higher coal beds taken as a whole (with the Fire Clay rider coal bed excluded from the test) have higher contents of total and pyritic sulfur, as percent of total sulfur, of iron (at the 95 percent probability level), and of arsenic and mercury (at the 90 percent probability level) than do the lower coal beds. Ash content, although not significantly higher in the upper beds at the levels considered (90 and 95 percent), is significantly higher at the 80 percent level. With the Fire Clay rider coal bed included in the test, only moisture and mercury have significantly higher values (90 percent probability level).

The lower coal beds taken as a whole, with the Fire Clay rider coal bed excluded from the test, have higher organic sulfur contents, a higher heat of combustion, and more nitrogen and carbon (at the 95 percent probability level) and greater moisture and sodium contents (90 percent probability level). With the Fire Clay rider coal bed included in the test, heat of combustion is higher in the lower part of the section at the same probability level (95 percent), organic sulfur content at a lower level (90 percent), and sodium content at a higher level (95 percent).

It was observed that with the boundary between the upper and lower parts of the stratigraphic sequence placed higher, between the Broas and Richardson coal zones, the differences in forms of sulfur (as percent of total sulfur) are even more significant (99.9 percent probability level). From the Richardson zone upward, without exception, the coal beds have more pyritic sulfur. From below the Richardson, excepting the unusual Fire Clay rider coal bed, the beds have more organic sulfur. (See table 5.)

Heat of combustion may be higher in beds in the lower part of the sequence because of the greater depth of burial, and sodium content may be higher because the lower delta plain would have had greater marine influence than the upper delta plain. The reason for the greater amount of organic sulfur in coal beds interpreted to have been deposited in the lower delta plain environment is not known, nor is it known why more total sulfur and pyritic sulfur occur in beds interpreted to have been deposited in the upper delta and alluvial plain. The greater amount of iron, arsenic, and mercury in the upper coal beds is related to the higher percentages of pyrite (as indicated by pyritic sulfur) in those beds.

The significantly higher percentages of pyritic sulfur in the interpreted upper delta plain coal beds than in the lower delta plain coal beds, is in contradiction to the findings of Caruccio and others (1977). For their larger study area they stated (p. 61) that "in general * * * greater percentages of framboidal pyrite, combined with a greater percentage of pyritic sulfur, occur in lower delta plain sequences * * *." Although we have no direct data on framboidal pyrite for our area, the above statement on the association of pyritic sulfur and framboidal pyrite suggests that more framboidal pyrite may be present in the upper delta plain coal beds in our area. A correlation coefficient run on Caruccio and others' raw data (1977, table A–2, cols. 7 and 9) shows that a high correlation, 99 percent probability level, does indeed occur between the percentage of pyritic sulfur and the percentage of framboidal pyrite. It is possible, however, that the relatively high percentage of pyrite in the upper beds in this report area is postdiagenetic and has no relation to depositional environments. If so, the percentages of framboidal pyrite in the upper beds would probably be relatively low.

GEOGRAPHIC TRENDS

The number of samples and their distribution were considered amenable to testing for geographic trends only for the Richardson coal zone and the Fire Clay rider coal bed.

Eight of the nine Richardson samples occur fortuitously in a linear pattern about 29 km long across the northern part of the report area (fig. 5, locs. 1, 5–7, 12, 20, 22, 23) in a generally land to sea (southeast to northwest) orientation. Correlation coefficients were determined for the analytical data (tables 25, 26) versus distance along the line. For the U.S. Bureau of Mines analyses, correlation coefficients were significant at the 95 percent probability level only for ash (as-received basis, raw data), which, as might be expected, increases in the source direction.

For the element data (whole-coal basis, log transformed), correlation coefficients were significant at the 95 percent level for more than one-third of the elements tested. Increasing in the source direction are silicon, magnesium, sodium, potassium, and copper contents. Increasing in the seaward direction are calcium, iron, titanium, mercury, boron, germanium, and molybdenum contents. Sulfur and arsenic contents exhibit a tendency to increase in the seaward direction, but at lower levels of probability.

The 10 Fire Clay rider coal bed samples occur in a linear pattern about 23 km long almost perpendicular to the line of Richardson coal zone samples and therefore generally paralleling the paleoshoreline (fig. 5, locs. 13–17, 34, 35, 39, 40, 29). Because of this orientation, few significant correlations of analytical data versus distance along the line were expected. As only four of the samples were analyzed by the U.S. Bureau of Mines, correlation coefficients for those data were not determined. For the element data (whole-coal basis, log transformed) only manganese showed a correlation at the 95 percent probability level, increasing northeastward, for an unknown reason.

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TABLE 25.—*Proximate, ultimate, and forms-of-sulfur analyses, air-dry loss, heat of samples from*

[All analyses except heat of combustion, apparent rank, free-swelling index, and fusibility of ash were collected and transported in plastic bags to avoid metal contamination. Form of analyses: Section, U.S. Bureau of Mines, Pittsburgh, Pa. ND, not determined. Bracketed values are locality. Kcal/kg = 0.556 (Btu/lb) Leaders (---), not applicable]

Coal bed or zone	Sample No.	Form of analysis	Proximate analyses: Moisture	Proximate analyses: Volatile matter	Proximate analyses: Fixed C	Proximate analyses: Ash	Ultimate analysis: H	Ultimate analysis: C	Ultimate analysis: N	Ultimate analysis: O	Ultimate analysis: S
Brush Creek	D174712	1	14.3	40.0	42.0	13.7	5.0	64.8	1.2	11.2	4.1
		2	---	41.8	43.9	14.3	4.7	67.7	1.2	7.8	4.2
		3	---	48.8	51.2	---	5.5	79.0	1.4	9.2	4.9
Princess No. 9 (upper bed).	D174713	1	3.4	41.6	41.4	13.6	5.0	66.3	1.4	11.7	2.0
		2	---	43.0	43.0	14.0	4.8	68.6	1.5	9.1	2.0
		3	---	50.0	50.0	---	5.6	79.8	1.7	10.5	2.4
Princess No. 9 (middle bed).	D184662-3	1	6.8	33.3	45.5	14.4	5.1	62.4	1.3	15.9	.8
		2	---	35.7	48.9	15.4	4.7	67.0	1.4	10.6	.9
		3	---	42.2	57.8	---	5.5	79.2	1.7	12.5	1.0
Do----	D184664-6	1	5.2	35.1	45.1	14.6	5.0	64.1	1.4	13.0	1.9
		2	---	37.0	47.6	15.4	4.7	67.6	1.4	8.9	2.0
		3	---	43.8	56.2	---	5.5	79.9	1.7	10.5	2.4
Do----	D174714	1	4.9	34.3	42.7	18.2	4.9	59.7	1.2	11.5	4.5
		2	---	36.0	44.9	19.1	4.6	62.8	1.2	7.6	4.7
		3	---	44.5	55.5	---	5.6	77.7	1.5	9.4	5.8
Do----	D169557	1	4.2	37.8	42.4	15.6	5.0	63.4	1.4	12.8	1.8
		2	---	39.4	44.3	16.3	4.8	66.2	1.5	9.3	1.9
		3	---	47.1	52.9	---	5.7	79.1	1.7	11.2	2.3
Richardson (Princess No. 5).	D168265	1	7.2	36.0	49.6	7.2	5.5	68.7	1.4	15.2	2.0
		2	---	38.8	53.4	7.8	5.1	74.0	1.5	9.5	2.1
		3	---	42.1	57.9	---	5.5	80.3	1.7	10.2	2.3
			7.2	36.0	49.1	7.7	5.4	68.0	1.4	15.0	2.5
Do----	D168264	1	7.2	36.0	48.4	8.4	5.3	67.0	1.4	14.7	3.2
		2	---	38.8	52.1	9.1	4.9	72.2	1.5	8.8	3.5
		3	---	42.7	57.3	---	5.4	79.4	1.6	9.8	3.8
Do----	D168260	1	4.7	41.6	47.3	6.4	5.5	70.6	1.4	11.8	4.3
		2	---	43.6	49.7	6.7	5.2	74.1	1.5	7.9	4.6
		3	---	46.8	53.2	---	5.5	79.4	1.6	8.6	4.9
Do----	D168261	1	4.6	39.1	48.8	7.5	5.3	70.0	1.4	12.2	3.6
		2	---	41.0	51.1	7.9	5.0	73.4	1.5	8.4	3.8
		3	---	44.5	55.5	---	5.5	79.7	1.6	9.1	4.1
Do----	D168263	1	6.6	36.2	48.3	8.9	5.2	67.1	1.4	14.1	3.3
		2	---	38.8	51.7	9.5	4.8	71.9	1.5	8.8	3.5
		3	---	42.9	57.1	---	5.3	79.5	1.7	9.6	3.9
Do----	D174722	1	14.7	34.5	46.1	4.7	5.7	62.2	1.0	25.1	1.3
		2	---	40.5	54.0	5.5	4.8	72.9	1.2	14.1	1.5
		3	---	42.8	57.2	---	5.1	77.1	1.3	14.9	1.6
			8.0	37.4	41.3	13.3	4.8	61.0	1.0	15.0	4.9
Do----	D174721	1	5.3	38.6	39.4	16.7	4.5	60.5	1.0	11.0	6.3
		2	---	40.8	41.6	17.6	4.1	63.9	1.0	6.8	6.6
		3	---	49.5	50.5	---	5.0	77.6	1.3	8.0	8.1
Do----	D169558	1	5.1	32.7	45.2	17.0	4.9	61.8	1.3	14.1	.9
		2	---	34.5	47.6	17.9	4.6	65.2	1.3	10.0	1.0
		3	---	42.0	58.0	---	5.6	79.4	1.6	12.2	1.2
Do----	D169556	1	5.5	38.3	44.7	11.5	5.3	67.3	1.3	12.8	1.8
		2	---	40.5	47.4	12.1	4.9	71.3	1.4	8.4	1.9
		3	---	46.1	53.9	---	5.6	81.1	1.6	9.5	2.2
Do----	D182463-4	1	4.9	28.6	52.9	13.6	4.8	66.4	1.3	13.1	.8
		2	---	30.1	55.6	14.3	4.5	69.8	1.4	9.1	.8
		3	---	35.1	64.9	---	5.2	81.5	1.6	10.7	1.0

combustion, apparent rank, free-swelling index, and fusibility of ash of 35 coal
the report area

are in percent. Original moisture content may be slightly more than shown because samples
1, as received; 2, moisture free; 3, moisture and ash free. All analyses by Coal Analysis
weighted average, as-received basis, for upper and lower parts of a coal bed at a single

Air dry loss	Heat of combustion (Btu/lb)	Heat of combustion (Btu/lb), moist, mineral-matter free	Apparent rank (high volatile	Forms of sulfur: Sulfate	Forms of sulfur: Pyritic	Forms of sulfur: Organic	Free-Swelling Index	Fusibility of ash (°F)[1]
0.61	11,540	13,650	B	0.14	2.97	0.94	3	2060
---	12,060	---	---	.15	3.11	.99	---	2110
---	14,070	---	---	.17	3.62	1.15	---	2300
3.32	11,950	14,090	A	.40	1.29	.27	2	2510
---	12,370	---	---	.41	1.33	.28	---	2560
---	14,390	---	---	.48	1.55	.32	---	2620
1.9	11,070	13,170	B	.03	.14	.63	ND	2800+
---	11,880	---	---	.03	.15	.67	---	2800+
---	14,040	---	---	.04	.17	.80	---	2800+
1.4	11,480	13,710	B	.02	1.40	.50	1	2655
---	12,110	---	---	.02	1.48	.53	---	2755
---	14,320	---	---	.02	1.74	.63	---	2800+
.30	10,700	13,450	B	.04	3.66	.80	1.5	2080
---	11,220	---	---	.04	3.85	.84	---	2130
---	13,910	---	---	.05	4.76	1.04	---	2290
1.02	11,440	13,840	B	.04	1.32	.46	ND	ND
---	11,940	---	---	.04	1.37	.48	---	ND
---	14,270	---	---	.05	1.64	.57	---	ND
1.5	12,240	13,320	B	.08	1.42	.47	ND	ND
---	13,200	---	---	.09	1.53	.51	---	ND
---	14,310	---	---	.09	1.66	.55	---	ND
	12,170	13,320		.10	1.86	.51		
1.4	12,060	13,330	B	.13	2.53	.57	ND	ND
---	12,990	---	---	.14	2.73	.62	---	ND
---	14,290	---	---	.15	3.00	.68	---	ND
.2	12,820	13,850	B	.00	3.46	.88	ND	ND
---	13,450	---	---	.00	3.64	.92	---	ND
---	14,420	---	---	.00	3.90	.99	---	ND
.6	12,660	13,850	B	.11	2.95	.53	ND	ND
---	13,270	---	---	.11	3.09	.55	---	ND
---	14,400	---	---	.12	3.36	.60	---	ND
1.1	12,030	13,380	B	.11	2.60	.57	ND	ND
---	12,880	---	---	.12	2.79	.61	---	ND
---	14,240	---	---	.13	3.08	.68	---	ND
7.56	10,650	11,250	C	.12	.03	1.16	0.5	2140
---	12,480	---	---	.14	.03	1.36	---	2230
---	13,210	---	---	.15	.03	1.44	---	2320
	10,860	12,860		.22	3.07	1.57		
1.57	10,940	13,510	B	.26	4.29	1.73	3	2030
---	11,550	---	---	.27	4.53	1.83	---	2090
---	14,030	---	---	.33	5.50	2.22	---	2180
1.89	11,060	13,620	B	.04	.40	.49	ND	ND
---	11,650	---	---	.04	.42	.52	---	ND
---	14,200	---	---	.05	.52	.63	---	ND
1.84	12,100	13,880	B	.03	1.45	.33	ND	ND
---	12,810	---	---	.03	1.54	.35	---	ND
---	14,580	---	---	.04	1.75	.40	---	ND
1.9	11,670	13,740	B	.10	.27	.40	0	2800+
---	12,270	---	---	.10	.29	.42	---	2800+
---	14,330	---	---	.12	.34	.49	---	2800+

TABLE 25.—*Proximate, ultimate, and forms-of-sulfur analyses, air-dry loss, heat of samples from the*

Coal bed or zone	Sample no.	Form of analysis	Proximate analyses: Moisture	Volatile matter	Fixed C	Ash	Ultimate analyses: H	C	N	O	S
Broas-----	D174725	1	6.6	35.2	53.1	5.1	5.2	71.9	1.4	15.7	.7
		2	—	37.7	56.8	5.5	4.8	76.9	1.5	10.6	.7
		3	—	39.9	60.1	—	5.1	81.4	1.6	11.1	.8
			6.5	37.4	50.9	5.2	5.3	71.6	1.5	15.5	0.9
Do-----	D174723	1	6.4	39.1	49.2	5.3	5.4	71.3	1.6	15.3	1.1
		2	—	41.8	52.5	5.7	5.0	76.1	1.7	10.3	1.2
		3	—	44.3	55.7	—	5.3	80.8	1.8	10.9	1.2
Do-----	D171581	1	6.3	36.6	49.1	8.0	5.4	72.2	1.4	11.7	1.3
		2	—	39.1	52.4	8.5	5.0	77.1	1.5	6.6	1.3
		3	—	42.7	57.3	—	5.4	84.2	1.6	7.3	1.5
Peach Orchard.	D182462	1	12.3	27.7	46.3	13.7	4.8	56.3	1.1	23.5	.5
		2	—	31.5	52.8	15.7	3.9	64.1	1.3	14.4	.6
		3	—	37.4	62.6	—	4.7	76.1	1.5	17.0	.7
Hazard----	D174719	1	5.2	37.0	52.5	5.3	5.6	73.0	1.5	13.9	.7
		2	—	39.0	55.4	5.6	5.3	77.0	1.6	9.7	.8
		3	—	41.3	58.7	—	5.6	81.6	1.6	10.4	.8
Haddix----	D174715	1	6.4	38.5	51.6	3.5	5.5	73.8	1.4	15.2	.6
		2	—	41.2	55.0	3.8	5.2	78.9	1.5	10.0	.6
		3	—	42.8	57.2	—	5.4	82.0	1.5	10.4	.7
Do-----	D168087	1	4.4	32.5	57.7	15.4	4.7	65.3	1.4	12.0	1.2
		2	—	34.0	59.9	16.1	4.4	68.3	1.4	8.6	1.2
		3	—	40.5	59.5	—	5.3	81.5	1.7	10.0	1.5
Fire Clay Rider.	D171596	1	2.8	35.9	33.9	27.4	4.4	53.6	1.1	8.3	5.2
		2	—	37.0	34.8	28.2	4.2	55.1	1.1	6.1	5.3
		3	—	51.5	48.5	—	5.8	76.7	1.6	8.5	7.4
Do-----	D171595	1	2.4	33.1	31.6	32.9	4.0	49.2	.9	7.8	5.2
		2	—	33.9	32.4	33.7	3.8	50.4	1.0	5.8	5.3
		3	—	51.1	48.9	—	5.8	76.1	1.5	8.6	8.0
Do-----	D171594	1	2.6	31.5	31.4	34.5	3.9	48.4	1.0	8.2	4.0
		2	—	32.4	32.2	35.4	3.7	49.7	1.0	6.1	4.1
		3	—	50.1	49.9	—	5.7	76.9	1.5	9.5	6.4
Do-----	D171593	1	2.3	32.2	30.2	35.3	3.7	45.8	.9	7.9	6.4
		2	—	33.0	30.9	36.1	3.5	46.9	.9	6.1	6.5
		3	—	51.6	48.4	—	5.5	73.4	1.4	9.5	10.2
Little Fire Clay.	D171589	1	2.9	36.4	49.6	11.1	5.0	70.7	1.4	11.1	.7
		2	—	37.5	51.1	11.4	4.8	72.8	1.5	8.8	.7
		3	—	42.3	57.7	—	5.4	82.2	1.7	9.9	.8
Do-----	D171586	1	3.1	36.2	46.8	13.9	4.9	67.8	1.4	11.3	.7
		2	—	37.3	48.3	14.4	4.7	70.0	1.4	8.8	.7
		3	—	43.6	56.4	—	5.5	81.7	1.7	10.2	.9
Do-----	D171584	1	4.4	36.3	46.4	12.9	5.2	68.0	1.5	11.8	.6
		2	—	38.0	48.5	13.5	4.9	71.1	1.5	8.3	.7
		3	—	43.9	56.1	—	5.6	82.2	1.8	9.6	.8
Do-----	D174720	1	3.3	36.8	47.1	12.8	4.9	68.6	1.3	11.7	.7
		2	—	38.1	48.6	13.3	4.6	71.0	1.4	9.0	.7
		3	—	43.9	56.1	—	5.4	81.9	1.6	10.2	.9
Whitesburg	D171582	1	2.9	37.0	53.2	6.9	5.3	74.3	1.5	11.2	.8
		2	—	38.1	54.8	7.1	5.1	76.6	1.6	8.7	.9
		3	—	41.0	59.0	—	5.5	82.4	1.7	9.5	.9
Williamson	D174716	1	5.1	35.9	52.3	6.7	5.4	72.5	1.5	13.3	.6
		2	—	37.8	55.2	7.0	5.0	76.4	1.6	9.4	.6
		3	—	40.7	59.3	—	5.4	82.2	1.7	10.0	.7
Van Lear---	D174717	1	3.9	41.2	39.3	15.6	4.9	64.3	1.3	13.1	.8
		2	—	42.9	40.8	16.3	4.7	66.9	1.4	9.8	.9
		3	—	51.2	48.8	—	5.6	79.9	1.6	11.9	1.0
Unnamed bed below Lee Formation.	D174718	1	3.5	39.9	51.8	4.8	5.4	75.2	1.4	12.2	1.0
		2	—	41.4	53.6	5.0	5.2	78.0	1.4	9.3	1.1
		3	—	43.5	56.5	—	5.5	82.1	1.5	9.8	1.1

[1] $^{\circ}F = ^{9}/_{5}\ ^{\circ}C+32.$

combustion, apparent rank, free-swelling index, and fusibility of ash of 35 coal report area—Continued

Air dry loss	Heat of combustion (Btu/lb)	Heat of combustion (Btu/lb), moist, mineral-matter free	Apparent rank (high volatile)	Forms of sulfur			Free-swelling index	Fusibility of ash (°F)[1]
				Sulfate	Pyritic	Organic		
1.87	12,700	13,460	B	.01	.03	.64	ND	2910+
—	13,580	—	—	.01	.03	.68	—	ND
—	14,360	—	—	.01	.03	.72	—	ND
	12,660	13,440		.02	.14	.75		
1.15	12,620	13,420	B	.02	.23	.83	1.5	2910+
—	13,480	—	—	.02	.24	.89	—	ND
—	14,300	—	—	.02	.26	.94	—	ND
ND	12,860	14,120	A	.02	.72	.52	ND	ND
—	13,720	—	—	.02	.76	.55	—	ND
—	15,000	—	—	.02	.84	.60	—	ND
7.0	9,490	11,180	C	.02	.05	.47	0	2800+
—	10,820	—	—	.02	.05	.53	—	2800+
—	12,820	—	—	.03	.06	.63	—	2800+
.56	12,970	13,780	B	.01	.18	.56	1.5	2680
—	13,680	—	—	.01	.19	.59	—	2730
—	14,490	—	—	.01	.20	.62	—	2780
1.72	13,080	13,610	B	.01	.06	.52	1.5	2620
—	13,980	—	—	.01	.06	.56	—	2680
—	14,520	—	—	.01	.07	.58	—	2740
1.1	11,580	13,960	B	.00	.68	.50	ND	ND
—	12,110	—	—	.00	.71	.53	—	ND
—	14,430	—	—	.00	.85	.63	—	ND
ND	9,740	14,050	A	.26	4.21	.71	ND	ND
—	10,020	—	—	.27	4.33	.73	—	ND
—	13,960	—	—	.37	6.04	1.01	—	ND
ND	8,860	14,000	A	.27	4.20	.72	ND	ND
—	9,070	—	—	.28	4.31	.74	—	ND
—	13,690	—	—	.42	6.50	1.11	—	ND
ND	8,620	13,980	B	.24	3.41	.38	ND	ND
—	8,850	—	—	.25	3.50	.39	—	ND
—	13,700	—	—	.38	5.42	.60	—	ND
ND	8,390	13,860	B	.36	5.33	.66	ND	ND
—	8,590	—	—	.37	5.46	.67	—	ND
—	13,440	—	—	.58	8.54	1.06	—	ND
ND	12,470	14,220	A	.01	.12	.58	ND	ND
—	12,840	—	—	.01	.12	.59	—	ND
—	14,500	—	—	.01	.14	.67	—	ND
ND	11,980	14,150	A	.02	.14	.57	ND	ND
—	12,370	—	—	.02	.14	.58	—	ND
—	14,450	—	—	.02	.17	.68	—	ND
ND	12,110	14,120	A	.03	.10	.49	ND	ND
—	12,670	—	—	.03	.10	.52	—	ND
—	14,640	—	—	.04	.12	.60	—	ND
.34	12,120	14,120	A	.01	.21	.50	1.5	2910+
—	12,540	—	—	.01	.22	.52	—	ND
—	14,460	—	—	.01	.25	.59	—	ND
ND	13,090	14,180	A	.02	.19	.63	ND	ND
—	13,480	—	—	.02	.19	.65	—	ND
—	14,500	—	—	.02	.21	.69	—	ND
.51	12,820	13,850	B	.01	.05	.54	2	2570
—	13,510	—	—	.01	.05	.56	—	2620
—	14,530	—	—	.01	.06	.61	—	2730
.68	11,480	13,870	B	.01	.18	.66	1.5	1990
—	11,940	—	—	.01	.19	.68	—	2040
—	14,260	—	—	.01	.22	.81	—	2090
.35	13,500	14,270	A	.01	.46	.55	2	2250
—	13,990	—	—	.01	.48	.57	—	2300
—	14,730	—	—	.01	.50	.60	—	2350

TABLE 26.—*Content of 42 elements in 53 coal samples*

[Si, Al, Ca, Mg, Na, K, Fe, Ti in percent; rest in ppm (parts per million). As, F, Hg, Sb, analyses calculated from determinations on ash. –S, content determined by emission determined. Bracketed values are weighted averages for parts of a coal bed at a single

Sample No.	Si	Al	Ca	Mg	Na	K	Fe	Mn	Ti
D174712	3.7	2.8	0.072	0.037	0.022	0.21	3.2	37	0.11
D174713	2.5	1.9	.081	.020	.021	.053	1.0	10	.18
D184662	4.0 } 3.5	3.1 } 2.4	.46 } .34	.059 } .041	.019 } .019	.22 } .16	1.6 } 1.2	7.6 } 7.3	.11 } .18
D184663	2.9	1.7	.19	.020	.019	.084	.65	7.0	.26
D184664	5.1 } 3.3	3.4 } 2.3	.19 } .17	.070 } .035	.022 } .016	.34 } .17	2.0 } 1.7	14 } 8.1	.16 } .15
D184665	2.3	1.7	.18	.012	.012	.040	1.8	5.9	.14
D184666	2.2	1.6	.15	.017	.014	.087	1.2	3.7	.14
D174714	1.8	1.4	.045	.035	.010	.13	4.1	10	.083
D169557	3.4	2.4	.085	.101	.020	.19	2.3	26 L	.25
D168262	2.7	2.4	.062	.032	.015	.12	3.0	26	.086
D168265	1.3 } 1.3	1.3 } 1.3	.12 } .091	.020 } .020	.006 } .006	.040 } .049	1.6 } 2.0	15 } 17	.019 } .020
D168264	1.4	1.2	.048	.021	.007	.062	2.5	21	.022
D168260	.61	.24	.070	.012	.008	.019	3.0	30	.008
D168261	.53	.34	.090	.020	.009	.044	3.8	50	.012
D168263	1.5	.70	.071	.025	.012	.083	2.5	21	.033
D174722	1.1 } 2.0	.49 } 1.7	.091 } .088	.012 } .022	.009 } .013	.030 } .094	.50 } 2.9	4.8 } 12	.014 } .043
D174721	2.3	2.2	.086	.026	.015	.12	3.8	15	.055
D169555	4.8	3.0	.069	.17	.019	.26	.48	27 L	.17
D169558	4.6	3.4	.063	.086	.031	.48	.56	28 L	.12
D169556	1.8	1.4	.051	.046	.014	.18	1.7	56	.048
D182463	1.6 } 3.3	1.3 } 1.8	.089 } .096	.019 } .033	.007 } .010	.097 } .16	.51 } 2.1	3.1 } 5.1	.051 } .12
D182464	4.2	2.1	.099	.040	.012	.20	2.9	6.1	.16
D174725	.87 } 1.0	.74 } .77	.050 } .054	.013 } .017	.005 } .007	.045 } .065	.055 } .14	3.9 } 5.6	.028 } .030
D174723	1.1	.79	.058	.020	.008	.080	.20	7.0	.031
D171581	1.9	1.3	.070	.026	.009	.074	.30	22	.10
D168259	.49	.31	.056	.024	.005	.029	1.1	12	.017
D182462	3.8	2.1	.34	.088	.015	.19	.19	6.0	.19
D174719	.76	.64	.058	.028	.009	.12	.15	10	.031
D168087	4.3	2.1	.060	.079	.023	.26	.77	24 L	.22
D171600	4.5	1.9	.29	.11	.066	.51	8.0	360	.11
D171599	1.9	1.1	.16	.088	.025	.28	6.1	550	.063
D171598	.94	.59	.15	.041	.020	.14	4.0	200	.037
D171591	2.8	1.6	.51	.13	.049	.47	7.0	1000	.10
D171597	3.0	1.6	.11	.083	.025	.34	4.4	28 L	.083
D171596	6.2	3.3	.11	.17	.047	.76	4.4	46 L	.16
D171595	7.0	4.1	.13	.19	.062	.93	4.3	50 L	.17
D171594	8.2	4.9	.11	.21	.064	1.0	3.8	55 L	.28
D171593	8.4	3.9	.11	.16	.053	.78	6.2	59 L	.36
D171592	.51	.19	.092	.018	.015	.045	7.9	23 L	.016
D171590	4.2	2.7	.067	.093	.033	.35	.46	84	.17
D171589	3.3	1.7	.061	.030	.019	.12	.17	18 L	.17
D171588	11.	10.	.13	.14	.044	.43	.63	89	.49
D171587	7.1	3.7	.12	.21	.062	.93	4.0	51 L	.18
D171586	4.0	2.3	.064	.036	.022	.17	.22	45	.20
D171585	1.6	1.0	.052	.019	.017	.076	.088	9.9L	.057
D171584	3.4 } 3.6	2.0 } 2.3	.049 } .050	.047 } .060	.022 } .024	.23 } .28	.17 } .21	31 } 36	.31 } .24
D171583	3.9	2.7	.051	.080	.026	.36	.26	43	.14
D174720	3.4	1.7	.048	.024	.018	.10	.096	5.0	.17
D171582	1.4	1.0	.081	.021	.016	.092	.45	10 L	.057
D171580	1.2	1.0	.042	.026	.022	.068	.54	9.0L	.051
D174716	.55	.46	.086	.015	.024	.037	.084	7.7	.019
D171579	.53	.39	.051	.015	.016	.038	.070	3.9L	.026
D174718	.92	.76	.19	.019	.032	.065	.82	14	.033

from the report area, reported on whole-coal basis

Se, Th, and U values are from direct determinations on air-dried (32°C) coal. Remaining spectrography. L, less than the value shown; N, not detected; leaders (---), not locality]

P	As	Cd	Cu	F	Hg	Li	Pb	Sb	Se
110	60	0.20	26.0	75	0.15	33.5	8.9	1.0	2.8
51 L	45	.12L	28.8	20L	.45	27.8	7.1	.9	14
830 L	73 }47	.19L }.16L	11.3 }14.6	65 }46	.88 }.62	46.9 }37.5	7.6 }7.3	1.6 }1.0	8.5 }9.2
510 L	16	.12L	18.3	25	.31	26.6	7.0	.28	10
980 L	22 }25	.23L }.16L	20.2 }18.8	85 }48	.43 }.41	66.6 }41.0	5.6L }6.5L	.56 }3.6	6.9 }25
510 L	42	.12L	16.4	30	.49	21.3	3.5	.29	14
460 L	16	.11L	19.2	25	.32	29.6	9.5	9.1	52
63 L	150	.29	15.9	35	1.30	22.2	28.3	8.8	3.9
73 L	50	.17L	17.1	60	.80	29.9	9.2	1.0	12
66 L	140	.30	22.8	20L	1.50	38.9	72.2	10.8	18
300	45 }55	.08L }.08L	9.0 }11.8	120 }100	.45 }.41	15.7 }16.6	13.1 }17.4	2.8 }2.6	8.5 }6.4
41 L	70	.09L	15.9	70	.36	18.0	23.9	2.4	3.3
30 L	50	.07L	15.2	40	.20	1.8	12.2	2.2	5.0
36 L	40	.08L	16.7	40	.22	2.2	7.9	1.9	5.3
40	35	.09L	17.4	20	.23	9.7	8.0	1.9	6.0
64	20 }30	.10 }.14L	4.5 }19.2	50 }55	.19 }.18	6.3 }18.8	3.1 }3.8	.3 }.3	13 }9.5
72 L	35	.16L	25.1	55	.18	23.8	4.1	.3	8.1
77 L	5	.18L	23.2	100	.11	35.2	11.4	.8	5.2
80 L	10	.18L	26.7	115	.17	26.0	12.8	1.7	3.1
42 L	40	.10L	20.0	50	.23	9.4	7.2	.9	5.9
340 L	4 }3	.08L }.13L	9.4 }13.2	50 }55	.21 }.17	15.8 }18.5	3.9 }8.3	.6 }.5	.1 }3.3
660 L	3	.15L	15.2	55	.15	19.9	10.6	.5	5.0
17 L	2 }6	.04L }.05L	16.1 }11.1	20L }25L	.04 }.07	5.5 }5.1	1.6 }3.8	.3 }.7	3.9 }4.3
21 L	10	.05L	7.2	25	.09	4.7	5.5	1.1	4.6
69	12	.08L	12.8	55	.20	12.8	8.0	1.0	7.1
16 L	35	.04L	13.0	20L	.39	2.5	13.8	3.0	2.9
650 L	1	.15L	24.3	40	.06	30.7	11.2	.4	7.1
17 L	5	.35	22.8	55	.02	5.1	5.7	1.5	2.0
66 L	35	.15L	26.8	90	.18	23.7	19.0	1.5	11
1400	90	.29L	40.0	330	.26	14.3	28.6	2.1	13
120	50	.18L	17.9	80	.28	10.7	35.8	1.6	4.9
96	35	.11L	13.7	60	.17	4.2	6.3	1.5	4.1
2000	130	.23L	23.3	460	.42	11.6	69.9	2.2	12
108	70	.45	32.4	120	.15	11.7	22.5	1.3	4.5
160	40	.30L	29.6	200	.20	29.6	14.8	2.0	3.9
140 L	35	.32L	32.4	220	.14	48.6	13.0	1.6	4.5
160 L	50	.35L	42.6	250	.30	63.9	21.3	2.2	7.5
160 L	100	.38L	49.3	210	.57	53.1	30.3	2.6	11
120	300	.15L	7.4	40	.72	2.9	25.0	1.9	7.4
120	8	.17L	27.5	100	.05	32.7	17.2	2.7	4.5
87	5	.12L	33.3	50	.05	21.4	15.5	.7	8.2
370	3	.49L	34.2	155	.04	122	58.6	.9	13
180	100	.33L	29.5	235	.26	59.0	26.2	2.9	5.0
99	3	.15L	34.3	60	.03	29.8	17.9	.7	9.0
32	2	.06L	16.0	35	.03	12.8	3.2	3.8	2.6
102	2 }3	.13L }.14L	13.0 }20.6	75 }85	.04 }.04	20.8 }25.3	22.1 }19.0	3.0 }2.9	4.5 }4.8
97	5	.16L	32.0	100	.05	32.0	14.4	2.8	5.3
55 L	3	.12L	33.3	35	.03	24.7	11.9	1.4	2.7
28 L	12	.07L	18.2	40	.05	13.0	12.4	1.1	6.3
34	8	.06L	17.4	40	.12	9.3	9.9	1.5	4.5
12 L	2	.20	14.6	20L	.03	3.2	6.0	1.7	1.7
16	2	.02L	12.5	24	.02	4.0	6.5	.8	4.3
34	5	.42	18.7	30	.22	9.0	11.1	1.6	3.5

TABLE 26.—*Content of 42 elements in 53 coal samples from*

Sample No.	Th	U	Zn	Ag-S	B-S	Ba-S	Be-S	Ce-S	Co-S	Cr-S
D174712	5.5	1.3	61.5	N	100	100	5	100L	20	20
D174713	8.1	1.2	13.2	N	30	70	1.5	70L	3	15
D184662	3.0L [4.7L]	1.0 [1.1]	30.6 [21.1]	N	30 [30]	70 [50]	2 [1.5]	100L [100L]	---	15 [15]
D184663	6.6	1.3	10.2	N	30	30	.7	70	---	15
D184664	6.5 [4.3L]	1.5 [1.7]	20.7 [15.3]	N	30 [30]	70 [50]	1.5 [1.5]	100L [70L]	---	15 [15]
D184665	3.0L	1.3	12.3	N	30	30	1	70	---	15
D184666	3.0L	2.3	12.0	N	50	20	1.5	50L	---	20
D174714	3.0L	1.0	45.2	N	70	700	5	N	15	20
D169557	6.8	2.0	68.9	N	30	30	1	100L	10	20
D168262	14.5	15.0	76.6	N	50	30	3	N	10	20
D168265	4.7 [4.4]	1.6 [2.0]	21.2 [26.0]	N	70 [70]	70 [50]	1.5 [1.5]	50L	7 [5]	15 [10]
D168264	3.9	2.7	33.3	N	70	10	2	N	3	7
D168260	3.0L	1.2	17.0	N	70	70	3	N	2	2
D168261	2.7	1.1	17.4	N	100	100	5	N	1.5	2
D168263	3.0L	.7	34.0	N	100	50	5	N	10	5
D174722	3.0L [4.1L]	.4 [.8]	21.4 [17.4]	N	50 [70]	15 [20]	1 [1.5]	30 [70]	2 [10]	5 [10]
D174721	4.5	1.0	15.8	N	70	30	2	70	15	10
D169555	6.4	1.7	9.9	N	50	50	3	N	3	30
D169558	7.1	1.9	36.6	N	30	150	3	N	10	30
D169556	2.8	1.4	15.4	N	30	100	3	N	7	10
D182463	3.0L [3.0L]	.2L [.2L]	33.3 [70.4]	N	50 [30]	20 [30]	1.5 [—]	50L [70L]	7 [5]	10 [15]
D182464	3.0L	.2L	89.8	N	30	30	1	70L	5	20
D174725	3.0L [3.0L]	.4 [.5]	4.1 [4.9]	N	70 [70]	10 [15]	.7 [3]	20 [20L]	5 [3]	7 [7]
D174723	3.0L	.6	5.6	N	70	15	5	20L	2	7
D171581	3.9	1.1	6.4	N	50	15	5	50L	5	10
D168259	3.0L	1.3	39.8	N	70	10	7	N	10	7
D182462	3.0L	.2L	20.6	N	15	50	3	70L	5	20
D174719	3.0L	.4	18.1	0.05	70	30	7	20L	7	7
D168087	6.5	2.0	9.7	N	20	70	1.5	70L	3	20
D171600	10.3	8.3	22.9	N	50	70	5	N	7	20
D171599	5.5	3.3	28.6	N	100	30	5	N	5	15
D171598	3.8	2.1	25.2	N	100	30	7	N	3	5
D171591	3.0L	8.6	30.3	N	70	70	7	100L	7	15
D171597	5.2	1.6	45.0	N	100	50	5	100L	5	15
D171596	9.0	2.5	29.6	N	70	100	2	150L	7	20
D171595	11.9	3.0	32.4	N	70	150	2	150L	5	20
D171594	15.2	4.4	31.9	N	70	100	2	150L	7	20
D171593	14.7	4.2	22.7	N	70	100	3	200L	7	30
D171592	3.0L	1.4	8.8	N	50	15	5	N	2	2
D171590	7.2	2.6	49.9	N	50	100	5	100L	10	15
D171589	11.3	2.2	11.9	.1	70	20	3	20	7	20
D171588	47.8	10.5	24.4	N	30	70	5	150	5 L	30
D171587	6.6	3.1	26.2	N	70	100	2	150L	5	20
D171586	10.6	2.1	7.5	.15L	50	70	3	50	3	15
D171585	4.8	1.5	5.8	N	50	20	7	30L	5	5
D171584	10.5 [10.1]	1.6 [1.9]	13.0 [16.8]	N	50 [50]	50 [50]	5 [5]	50 [50L]	7 [10]	15 [15]
D171583	9.5	2.4	22.4	.15L	70	50	5	70L	15	20
D174720	7.1	1.8	4.5	N	70	20	3	70L	7	20
D171582	4.9	1.5	10.4	N	50	15	3	30L	2	10
D171580	5.9	1.1	11.6	.1	70	30	7	15	15	10
D174716	3.0L	.4	7.3	N	100	20	5	15L	5	5
D171579	3.0L	.8	7.5	.02	30	15	5	7	3	3
D174718	5.7	1.3	216	.07	100	30	2	50	7	10

the report area, reported on whole-coal basis—Continued

Ga-S	Ge-S	La-S	Mo-S	Nb-S	Nd-S	Ni-S	Sc-S	Sr-S	V-S	Y-S	Yb-S	Zr-S
7	N	30	10	5	30	30	10	150	30	20	1.5	30
10	10	15	7	7	15	7	10	30	30	10	1	30
7 }5	7	20L }20L	7 }5	7 }7	30L }30L	7 }5	3 }5	100 }70	30 }30	20 }20	1.5 }1.5	30 }50
3	N	15	2	7	20	3	7	30	30	15	1.5	70
7 }5	5	20L }15L	3 }3	7 }7	30L }20L	7 }7	7 }5	70 }70	30 }30	20 }15	1.5 }–	30 }30
3	N	20	3	7	15	7	3	100	20	10	1	20
5	N	10	5	7	15	10	3	20	30	15	1	30
7	30	15L	15	3	N	50	7	30	30	20	---	15
5	3	15	5	5	20	15	5	50	30	10	1	50
---	30	N	10	N	---	20	7	20	30	15	---	20
---	15	15	7 }7	N }N	15	15 }15	5 }5	150 }100	20 }20	7 }7	---	7 }7
---	7	N	5	N	---	15	3	15	20	7	---	7
---	10	N	3	N	---	10	1	15	7	3	---	N
---	10	N	7	N	---	10	1.5	20	15	7	---	2
---	7	7	5	1.5L	N	15	3	50	15	10	---	10
1.5 }5	3	15 }20	10 }7	1 L }2L	15 }20	3 }15	1.5 }5	100 }150	10 }15	10 }15	.7	5 }15
7	N	20	5	3	20	20	5	150	20	15	---	15
5	3	15	1.5	5	30L	10	5	30	30	15	1.5	30
10	N	20	2	3	30	20	5	30	50	15	1.5	30
3	3	7	2	2	15L	10	3	30	20	7	.7	10
5 }5	1.5	7 }15	2 }1.5	2 }5	10 }15	15 }10	2 }3	20 }20	20 }20	10 }10	.7 }1	10 }30
5	N	15	1.5	7	20	10	3	20	20	10	1	50
5 }3	1	7 }5	2 }2	1 }1.5	7 }7	7 }7	2 }3	20 }15	10 }10	7 }10	.7 }.7	7 }10
3	3	5	2	1.5	7	7	3	15	10	15	.7	10
5	2	7L	1.5	2	10	10	2	20	15	7	.7	10
---	20	N	3	N	---	50	7	20	10	5	.7	5
5	N	15	1.5	7	20	15	5	20	20	15	1	30
5	7	7	3	1	7	7	3	30	10	10	.7	7
---	N	15	1.5	3	20	10	5	50	30	10	1	30
---	N	30L	.2	7 L	N	20	5	100	50	20	---	30
10	10	20L	3	3 L	30L	15	3	50	20	20	---	15
5	5	10L	.7	2 L	N	7	1.5	50	7	15	---	7
7	N	20	3	5 L	30L	30	3	50	20	20	---	20
5	N	20L	1.5	3 L	N	15	3	30	20	15	---	20
7	N	30L	3	7 L	50L	15	5	70	30	10	1	30
10	N	30L	3	7 L	50L	15	7	70	50	10	---	30
10	N	30L	5	7	50L	15	7	50	50	15	1.5	50
10	N	30L	3	7	70L	20	7	70	70	20	---	70
7	N	N	N	3 L	---	5	1.5	20	2	7	---	3
10	N	15	2	5	20	20	5	20	30	15	1	50
7	N	10	2	7	20	10	3	20	30	10	1	30
15	N	70	N	15	70	15	10	50	50	30	3	300
10	N	30L	3	7	N	15	5	50	50	10	1	30
7	N	20	1	5	20	5	5	50	20	15	1.5	50
7	7	7L	1	2	10	10	3	15	10	10	1	15
7 }7	10	20 }20	1 }1.5	10 }7	20 }20	20 }20	5 }5	20 }20	20 }30	15 }15	1.5 }1.5	70 }50
10	10	15	2	5	20	20	7	20	50	15	2	30
10	3	20	2	10	20	15	7	20	20	20	2	30
5	2	7	1	2	10	5	3	20	20	10	1	20
7	10	10	3	1.5	10	30	5	30	10	10	1	15
5	15	3L	.5	1	5	10	3	20	10	15	1	5
2	3	2L	.2	1.5	5	7	1.5	15	5	7	.7	5
7	10	20	3	2	20	20	5	50	10	10	1	10

TABLE 27.—*Major- and minor-oxide and trace-element composition*

[Ash, SiO_2, CaO, MgO, Na_2O, K_2O, Fe_2O_3, TiO_2, P_2O_5, SO_3, Cl in percent; rest in ppm (parts per (---), not determined; -S, values listed were determined by semiquantitative spectrographic are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as midpoints is approximately one bracket at 68-percent, or two brackets at 95-percent confidence]

Sample No.	Ash	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3	Mn	TiO_2	P_2O_5	SO_3	Cl	Cd
D174712	19.7	40	27	0.51	0.32	0.15	1.3	23	190	0.93	1.0 L	0.68	0.20L	1.0
D174713	11.8	45	30	.96	.28	.24	.69	12	85	2.5	1.0 L	1.2	.20L	1.0L
D184662	18.9	45	31	3.4	.51	.14	1.4	12	39	1.00	1.0 L	---	.20L	1.0L
D184663	11.7	53	27	2.3	.28	.22	.86	7.9	62	3.7	1.0 L	---	.20L	1.0L
D184664	22.5	49	29	1.2	.51	.14	1.8	13	62	1.2	1.0 L	---	.20L	1.0L
D184665	11.7	43	27	2.1	.17	.14	.41	22	46	2.0	1.0 L	---	.20L	1.0L
D184666	10.5	46	29	2.0	.27	.18	1.0	16	39	2.3	1.0 L	---	.20L	1.0L
D174714	14.5	27	19	.43	.40	.09	1.1	40	70	.95	1.0 L	1.1	.20L	2.0
D169557	16.8	43	27	.71	1.00	.16	1.3	19	150L	2.5	.10L	.90	.10L	1.0L
D168262	15.2	38	29	.58	.35	.14	.92	28	170	.94	.10L	.59	.10L	2.0
D168265	8.2	35	29	2.0	.40	.09	.59	27	180	.39	.83	1.3	.10L	1.0L
D168264	9.4	31	25	.72	.37	.09	.79	39	220	.39	.10L	.83	.10L	1.0L
D168260	7.0	19	6.6	1.4	.28	.15	.34	62	430	.19	.10L	1.7	.10L	1.0L
D168261	8.4	13	7.6	1.5	.40	.15	.63	65	590	.24	.10L	2.3	.10L	1.0L
D168263	8.9	36	15	1.1	.46	.18	1.1	41	240	.62	.10	1.4	.10L	1.0L
D174722	5.1	48	18	2.5	.40	.23	.71	14	93	.47	1.0 L	3.5	.20L	2.0
D174721	16.5	30	25	.73	.27	.12	.86	33	93	.56	1.0 L	1.2	.20L	1.0L
D169555	17.6	59	32	.55	1.59	.15	1.8	3.9	150L	1.6	.10L	.60	.10L	1.0L
D169558	18.3	54	35	.49	.78	.23	3.2	4.4	150L	1.1	.10L	.52	.10L	1.0L
D169556	9.6	40	28	.75	.80	.20	2.3	25	590	.84	.10L	1.3	.10L	1.0L
D182463	7.8	45	31	1.6	.40	.12	1.5	9.4	39	1.1	1.0 L	---	.20L	1.0L
D182464	15.2	59	26	.91	.43	.11	1.6	2.7	39	1.7	1.0 L	---	.20L	1.0L
D174725	3.9	48	36	1.8	.56	.18	1.4	2.0	100	1.2	1.0 L	1.9	.20L	1.0L
D174723	4.8	48	31	1.7	.70	.22	2.0	5.9	150	1.1	1.0 L	2.9	.20L	1.0L
D171581	8.0	51	31	1.2	.55	.15	1.1	5.3	270	2.1	.20	2.0	.10L	1.0L
D168259	3.6	29	16	2.2	1.10	.19	.95	42	330	.78	.10L	2.8	.10L	1.0L
D182462	14.9	54	27	3.2	.98	.14	1.5	1.8	39	2.1	1.0 L	---	.20L	1.0L
D174719	3.9	42	31	2.1	1.21	.32	3.7	5.4	260	1.3	1.0 L	3.2	.20L	9.0
D168087	15.2	60	26	.55	.86	.20	2.0	7.3	150L	2.4	.10L	.32	.10L	1.0L
D171600	28.6	34	13	1.4	.65	.31	2.2	40	1200	.62	1.1	1.3	.10L	1.0L
D171599	17.9	23	11	1.2	.81	.19	1.9	49	3100	.59	.15	2.1	.10L	1.0L
D171598	10.5	19	11	2.0	.65	.26	1.6	54	1900	.59	.21	2.4	.10L	1.0L
D171591	23.3	26	13	3.1	.95	.28	2.4	43	4400	.74	1.9	2.3	.10L	1.0L
D171597	18.0	36	17	.87	.76	.19	2.3	35	150L	.77	.14	1.5	.10L	2.5
D171596	29.6	44	21	.54	.95	.22	3.1	21	150L	.90	.13	1.2	.10L	1.0L
D171595	32.4	46	24	.56	1.00	.26	3.5	19	150L	.87	.10L	1.1	.10L	1.0L
D171594	35.5	49	26	.43	1.00	.24	3.4	15	150L	1.3	.10L	.98	.10L	1.0L
D171593	37.9	47	20	.41	.68	.19	2.5	23	150L	1.6	.10L	1.1	.10L	1.0L
D171592	14.7	7.5	2.4	.87	.20	.14	.36	77	150L	.18	.18	.82	.10L	1.0L
D171590	17.2	53	30	.55	.90	.26	2.5	3.9	490	1.6	.16	.89	.10L	1.0L
D171589	11.9	59	27	.72	.41	.22	1.2	2.1	150L	2.4	.17	1.1	.10L	1.0L
D171588	48.8	49	41	.36	.46	.12	1.1	1.9	190	1.7	.17	.36	.10L	1.0L
D171587	32.8	47	22	.53	1.05	.26	3.4	17	150L	.89	.12	1.2	.15	1.0L
D171586	14.9	57	29	.61	.40	.20	1.3	2.1	300	2.3	.15	1.1	.10L	1.0L
D171585	6.4	54	30	1.1	.50	.35	1.4	2.0	150L	1.5	.11	1.6	.10L	1.0L
D171584	13.0	56	29	.53	.60	.23	2.1	1.9	240	3.9	.18	1.2	.10L	1.0L
D171583	16.0	52	32	.44	.83	.22	2.7	2.3	260	1.4	.14	.62	.10L	1.0L
D174720	12.5	59	26	.54	.32	.19	1.0	1.1	39	2.3	1.0 L	.36	.20L	1.0L
D171582	6.5	46	30	1.7	.53	.32	1.7	9.9	150L	1.5	.10L	2.1	.10L	1.0L
D171580	5.8	44	33	1.0	.73	.51	1.4	13	150L	1.5	.13	1.3	.10L	1.0L
D174716	2.8	42	31	4.3	.90	1.17	1.6	4.3	270	1.1	1.0 L	4.3	.20L	7.0
D171579	2.5	46	30	2.8	.98	.89	1.8	4.0	150L	1.8	.15	3.7	.10L	1.0L
D174718	6.0	33	24	4.4	.53	.73	1.3	20	230	.92	1.0 L	4.5	.20L	7.0

of the laboratory ash of 53 coal samples from the report area

million). The coals were ashed at 525°C. L, less than the value shown; N, not detected; leaders
analysis. The spectrographic results are to be identified with geometric brackets whose boundaries
of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of the spectrographic data

Cu	Li	Pb	Zn	Ag-S	B-S	Ba-S	Be-S	Ce-S	Co-S	Cr-S	Ga-S	Ge-S	La-S	Mo-S	Nb-S	Nd-S
132	170	45	312	N	500	500	20	500L	100	100	30	N	150	50	20	150
244	236	60	112	N	300	500	15	500L	30	150	70	70	150	50	50	150
60	248	40	162	N	150	300	10	500L	15	70	30	30	100L	30	30	150L
156	227	60	87	N	300	300	7	500	15	150	30	N	150	20	70	200
90	296	25L	92	N	150	300	7	500L	10	70	30	20	100L	15	30	150L
140	182	30	105	N	300	300	10	500	20	150	30	N	200	30	50	150
183	282	90	114	N	500	200	15	500L	50	200	50	N	100	50	70	150
110	153	195	312	N	500	5000	30	N	100	150	50	200	100L	100	20	N
102	178	55	410	N	200	200	7	500L	70	150	30	20	100	30	30	150
150	256	475	504	N	300	200	20	N	70	150	---	200	N	70	N	---
110	192	160	260	N	700	700	15	500L	70	150	---	200	150	70	N	150
170	192	255	356	N	700	100	20	N	30	70	---	70	N	50	N	---
218	26	175	244	N	1000	1000	50	N	30	30	---	150	N	50	N	---
200	26	95	208	N	1000	1000	50	N	20	30	---	100	N	70	N	---
196	110	90	384	N	1000	500	50	N	100	50	---	70	70	50	20L	N
88	123	60	420	N	1000	300	20	700	50	100	30	70	300	200	20L	300
152	144	25	96	N	500	200	15	500	100	70	50	N	150	30	20	150
132	200	65	56	N	300	300	15	N	20	150	30	20	70	10	30	150L
146	142	70	200	N	200	700	20	N	50	150	50	N	100	10	20	150
208	98	75	160	N	300	1000	30	N	70	100	30	30	70	20	20	150L
121	203	50	427	N	700	300	20	500L	100	150	50	20	100	30	30	150
100	131	70	591	N	200	200	7	500L	30	150	30	N	100	10	50	150
412	140	40	106	N	2000	300	20	500	100	150	100	30	150	50	30	200
150	98	115	116	N	1500	300	100	500L	50	150	70	70	100	50	30	150
160	160	100	80	N	700	200	70	500L	70	150	70	30	100L	20	30	150
360	70	380	1100	N	2000	300	200	N	300	200	---	500	N	100	N	---
163	206	75	138	N	100	300	20	500L	30	150	30	N	100	10	50	150
584	132	145	464	1	2000	700	200	500L	150	150	100	150	150	70	30	150
176	156	125	64	N	150	500	10	500L	20	150	---	N	100	10	20	150
140	50	100	80	N	150	200	15	N	20	70	---	N	100L	7	20L	N
100	60	200	160	N	500	150	30	N	30	70	50	50	100L	15	20L	150L
130	40	60	240	N	1000	300	70	N	30	50	50	50	100L	7	20L	N
100	50	300	130	N	300	300	30	500L	30	70	30	N	100	15	20L	150L
180	65	125	250	N	500	300	30	500L	30	70	30	N	100L	7	20L	N
100	100	50	100	N	200	300	7	500L	20	70	20	N	100L	10	20L	150L
100	150	40	100	N	200	500	7	500L	15	70	30	N	100L	10	20L	150L
120	180	60	90	N	200	300	7	500L	20	70	30	N	100L	15	20	150L
130	140	60	90	N	200	300	7	500L	20	100	30	N	100L	10	20	150L
50	20	170	60	N	300	100	30	N	15	15	50	N	N	N	20L	---
160	190	100	290	N	300	500	30	500L	50	100	50	N	100	15	30	150
280	180	130	100	1	500	200	30	200	50	150	50	N	100	15	50	150
70	250	120	50	N	70	150	10	300	10L	70	30	N	150	N	30	150
90	180	80	80	N	200	300	7	500L	15	70	30	N	100L	10	20	N
230	200	120	50	1 L	300	500	20	300	20	100	50	N	150	7	30	150
250	200	50	90	N	700	300	100	500L	70	70	100	100	100L	15	30	150
100	160	170	100	N	300	300	30	300	50	100	50	70	150	7	70	200
200	200	90	140	1 L	500	300	30	500L	100	150	70	70	100	15	30	150
266	198	95	36	N	500	200	30	500L	50	150	70	30	150	20	70	150
280	200	190	160	N	700	200	50	500L	30	150	70	30	100	15	30	150
300	160	170	200	1.5	1000	500	100	300	300	150	100	150	150	50	30	150
520	113	215	260	N	3000	700	150	500L	150	150	200	500	100L	20	30	150
500	160	260	300	1	1500	500	200	300	150	150	100	150	100L	10	50	200
312	150	185	3600	1	1500	500	30	700	100	150	100	200	300	50	30	300

TABLE 27.—*Major- and minor-oxide and trace-element composition of the laboratory ash of 53 coal samples from the report area*—Continued

Sample No.	Ni-S	Sc-S	Sr-S	V-S	Y-S	Yb-S	Zr-S	As	F	Hg	Sb	Se	Th	U
D174712	150	50	700	150	100	7	150	60	75	0.15	1.0	2.8	5.5	1.3
D174713	50	70	300	300	100	7	300	45	20L	.45	.9	14	8.1	1.2
D184662	30	20	500	150	100	7	150	---	65	.88	---	---	3.0L	1.0
D184663	30	50	300	300	150	15	500	---	25	.31	---	---	6.6	1.3
D184664	30	30	300	150	100	7	150	---	85	.43	---	---	6.5	1.5
D184665	50	30	1000	200	100	10	200	---	30	.49	---	---	3.0L	1.3
D184666	100	30	200	300	150	10	300	---	25	.32	---	---	3.0L	2.3
D174714	300	50	200	200	150	---	100	150	35	1.30	8.8	3.9	3.0L	1.0
D169557	100	30	300	200	70	7	300	50	60	.80	1.0	12	6.8	2.0
D168262	150	50	150	200	100	---	150	140	20L	1.50	10.8	18	14.5	15.0
D168265	150	50	2000	300	70	---	70	45	120	.45	2.8	8.5	4.7	1.6
D168264	150	30	150	200	70	---	70	70	70	.36	2.4	3.3	3.9	2.7
D168260	150	15	200	100	50	---	N	50	40	.20	2.2	5.0	3.0L	1.2
D168261	100	20	300	150	70	---	30	40	40	.22	1.9	5.3	2.7	1.1
D168263	150	30	500	150	100	---	100	35	20	.23	1.9	6.0	3.0L	.7
D174722	70	30	2000	200	200	15	100	20	50	.19	.3	13	3.0L	.4
D174721	150	30	1000	150	100	---	100	35	55	.18	.3	8.1	4.5	1.0
D169555	50	30	150	150	70	7	200	5	100	.11	.8	5.2	6.4	1.7
D169558	100	30	200	300	70	7	150	10	115	.17	1.7	3.1	7.1	1.9
D169556	100	30	300	200	70	7	100	40	50	.23	.9	5.9	2.8	1.4
D182463	200	30	300	300	150	10	150	4	50	.21	.6	.1	3.0L	.2L
D182464	70	20	150	150	70	7	300	3	55	.15	.5	5.0	3.0L	.2L
D174725	150	50	500	300	150	15	200	2	20L	.04	.3	3.9	3.0L	.4
D174723	150	70	300	200	300	15	200	10	25	.09	1.1	4.6	3.0L	.6
D171581	150	30	300	200	100	10	150	12	55	.20	1.0	7.1	3.9	1.1
D168259	1500	200	700	300	150	20	150	35	20L	.39	3.0	2.9	3.0L	1.3
D182462	100	30	150	150	100	7	200	1	40	.06	.4	7.1	3.0L	.2L
D174719	200	70	700	300	300	20	200	5	55	.02	1.5	2.0	3.0L	.4
D168087	70	30	300	200	70	7	200	35	90	.18	---	11	6.5	2.0
D171600	70	15	300	150	70	---	100	90	330	.26	2.1	13	10.3	8.3
D171599	70	15	300	100	100	---	70	50	80	.28	1.6	4.9	5.5	3.3
D171598	70	15	500	70	150	---	70	35	60	.17	1.5	4.1	3.8	2.1
D171591	150	15	200	100	100	---	100	130	460	.42	2.2	12	3.0L	8.6
D171597	70	15	200	100	70	---	100	70	120	.15	1.3	4.5	5.2	1.6
D171596	50	15	200	100	30	3	100	40	200	.20	2.0	3.9	9.0	2.5
D171595	50	20	200	150	30	---	100	35	220	.14	1.6	4.5	11.9	3.0
D171594	50	20	150	150	50	5	150	50	250	.30	2.2	7.5	15.2	4.4
D171593	50	20	150	150	50	---	150	100	210	.57	2.6	11	14.7	4.2
D171592	30	10	150	15	50	---	20	300	40	.72	1.9	7.4	3.0L	1.4
D171590	150	30	150	200	100	7	300	8	100	.05	2.7	4.5	7.2	2.6
D171589	70	30	150	300	100	10	300	5	50	.05	.7	8.2	11.3	2.2
D171588	30	20	100	100	70	7	700	3	155	.04	.9	13	47.8	10.5
D171587	50	15	150	150	30	3	100	100	235	.26	2.9	5.0	6.6	3.1
D171586	30	30	300	150	100	10	300	3	60	.03	.7	9.0	10.6	2.1
D171585	150	50	200	150	150	15	200	2	35	.03	3.8	2.6	4.8	1.5
D171584	150	30	200	200	100	10	500	2	75	.04	3.0	4.5	10.5	1.6
D171583	150	50	150	300	100	15	200	5	100	.05	2.8	5.3	9.5	2.4
D174720	100	50	150	200	150	15	300	3	35	.03	1.4	2.7	7.1	1.8
D171582	70	50	300	300	150	15	300	12	40	.05	1.1	6.3	4.9	1.5
D171580	500	70	500	200	200	20	300	8	40	.12	1.5	4.5	5.9	1.1
D174716	300	100	700	300	500	30	200	2	20L	.03	1.7	1.7	3.0L	.4
D171579	300	70	700	200	300	30	200	2	24	.02	.8	4.3	3.0L	.8
D174718	300	70	700	200	200	15	150	5	30	.22	1.6	3.5	5.7	1.3