Geology and Coal Resources of Belmont County, Ohio

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GEOLOGY AND COAL RESOURCES OF BELMONT COUNTY, OHIO

By Henry L. Berryhill, Jr.

ABSTRACT

Belmont County, located in the east-central part of Ohio on the Ohio River, has long been a producer of high-grade bituminous coal, mostly from the well-known Pittsburgh bed. As a part of a program to appraise the nation's mineral resources, the U.S. Geological Survey with the cooperation of the Ohio Geological Survey has evaluated the coal reserves of the county. In addition to the investigation of coal, the stratigraphy was studied in detail.

The exposed strata of Belmont County, which covers an area of 535 square miles, were deposited during the Pennsylvanian and Permian periods in an uninterrupted sequence with an aggregate thickness of 1,100 feet. They consist of interbedded sheets of sandstone, siltstone, mudstone, clay, limestone, and coal, comprising the upper 350 feet of the Conemaugh formation of Middle Pennsylvanian age (late Des Moines to middle Missouri?), the Monongahela formation of Middle and Late Pennsylvanian age (late Missouri and Virgil?), and the lower 470 feet of the Dunkard group, Washington and Greene formations undifferentiated, of Late Pennsylvanian and early Permian age. Within these formations, 56 members and coal beds are recognized and named.

Outcrops and subsurface data indicate that marine limestone beds are the most extensive units in the Conemaugh formation. Coal beds are the most extensive of the various strata that occur in the Monongahela formation and in the lower part of the Dunkard group. Sandstone and siltstone are more persistent than other lithologic units in the upper part of the Dunkard group.

The Conemaugh formation crops out only in the western and eastern parts of the county, and it is characterized by thin, lenticular coal beds, red beds, and thin limestone beds. The Monongahela formation is more extensively exposed and contains thick, persistent coal beds, few red beds, and thick units of limestone. The Dunkard group, which crops out mainly in the eastern half of the county, is similar in the lower part to the Monongahela formation, but above the Washington coal bed it resembles the Conemaugh formation.

The vertical repetition of lithologic types is an outstanding feature of both the Pennsylvanian and Permian strata, which can be grouped into a number of sedimentary cycles. Basically the sedimentary cycle in Belmont County includes, in ascending order, coal, clay and shale, sandstone, siltstone and mudstone, limestone, and underclay, but because of facies changes the make-up of the cycles varies and 6 types were recognized. Each type is related either to a deltaic environment of deposition or to a neritic or basin environment. Individual types differ according to geographic position within one of these two environments. Shoreward, therefore, neritic-type cycles grade into deltaic types. Vertical variance in the types of cycles at a given locality are the result of many lateral shifts of the neritic and deltaic environments during Pennsylvanian and Permian time. Although some types of cycles are repeated many times vertically, other types are restricted to a particular formation. Thus, cycles in the lower part of the Conemaugh formation that are characterized by a limestone containing a diversified marine fauna have not been recognized higher in the section. Conditions necessary for a thriving benthonic fauna apparently did not exist after middle Conemaugh time.

Sediments deposited during Conemaugh and Monongehela times probably came from several source areas, but the principal source seems to have been to the north. During early Permian time, however, the pattern of sedimentation changed and most of the rocks above the Washington coal bed appear to be made up of sediments that came from a source to the southeast.

The strata dip to the southeast at an average rate of 18 feet per mile. Small local flexures cause slight variations in the dip, which in a few places is as much as 60–70 feet per mile. In the eastern part of the county, the dip is reversed around a small dome-shaped structure that is known locally as the Jacobsburg anticline.

The principal mineral resources of Belmont County are coal, oil, and gas. Of these, coal is the most important economically. The original reserves of coal in the seven thickest beds are estimated to total 5,668 million tons. Included in the original reserves is 884 million tons of coal mined out and lost in mining, leaving estimated remaining reserves of 4,784 million tons as of January 1, 1953. The Pittsburgh bed, which contains estimated remaining reserves of 1,929 million tons of coal, is the most important in terms of both reserves and quality. Production of oil and gas, which in the past has come principally from the Berea sandstone of Mississippian age, has been small in recent years.

INTRODUCTION

PURPOSE OF THE STUDY

Belmont County has long been Ohio's leading producer of high-grade bituminous coal, mostly from the well-known Pittsburgh bed. Its strategic location in the upper Ohio River valley near the industrial heart of the United States makes its large reserves of coal of vital importance to the national economy. As a part of a program to make an inventory of the nation's mineral resources, the U.S. Geological Survey with the cooperation of the Ohio Geological Survey has evaluated the coal reserves of the Pittsburgh bed, as well as other less well-known coal beds in Belmont County. Detailed stratigraphic studies were also made of the coal-bearing formations.

Information on the coal reserves of the Pittsburgh (No. 8) bed in Belmont County has been summarized in a circular published by the U.S. Geological Survey (Berryhill, 1955). Data on thickness and reserves of the Pittsburgh bed in Belmont County, based on that report, are included in a report on the Pittsburgh and Redstone coal beds in Ohio published by the Ohio Geological Survey (DeLong, 1955).

The present report describes the structure, stratigraphy, economic geology, and sedimentation of Belmont County.

PREPARATION OF THE REPORT

The field investigations preliminary to the preparation of this report were made during the summers of 1951–53. The coal beds and other readily recognizable stratigraphic units were traced across the county, and the elevations of these key beds were determined at many outcrops by means of an aneroid barometer, tape, or hand level. Outcrops of key beds, strip mines, and openings to underground mines were plotted in the field on aerial photographs (scale 1:20,000) and on topographic maps. The writer measured 1,041 sections of coal beds at outcrops and in mines during the field investigations, and in addition measured in detail 326 stratigraphic sections that were used to gain adequate vertical control for the correlation of the key beds.

The field data were transferred in the office to a topographic base map of the county (scale 1:48,000). This map was prepared by combining parts of the Flushing, Woodfield, Clarington, St. Clairsville, Ohio, and the Wheeling and Cameron, W. Va.-Ohio, 15-minute quadrangle topographic maps. The formation contacts and the lines of outcrop of the main coal beds were plotted on this base map, from which the individual coal bed maps were then prepared. Plates showing diagrammatic coal sections were also prepared to supplement the coal bed maps. On the plates showing the coal sections the diagrams are located by township, and the townships are arranged in their geographic position within the county so that trends in the character of a coal bed across the county can be easily visualized.

Many figures containing graphic sections that show the stratigraphic position and association of the various strata have been included so that the stratigraphy of the many relatively thin members and beds can be more easily seen and understood.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation for the cooperation of the members of the Ohio Geological Survey, particularly John H. Melvin, State Geologist, William H. Smith, chief of the Coal Resources Section, who gave freely of his knowledge of the geology of Belmont County, and Russell A. Brant, J. A. Fagerstrom, and Russell Lehman, who compiled the map of the areas from which the Pittsburgh coal has been largely mined out. Most of the elevations of the mine openings used in preparing the structure contour map of the Pittsburgh coal bed were surveyed by Fagerstrom and Lehman with the use of a telescopic alidade. Many of the coal sections from the files of the Ohio Geological Survey were measured by Wilbur Stout, former State geologist of Ohio. Acknowledgment is hereby extended to Dr. Stout and others for the use of their data. Thanks are also due to the officers and representatives of the various coal companies in Belmont County for permitting the collection of data from their mines and for the use of their mine maps. Many other individuals kindly contributed data which materially aided in preparing this report.

PREVIOUS WORKERS

The first recorded study of the geology of Belmont County was that of Andrews (1874). He gave local names to some of the coal beds, but did not name the strata between the coal beds. His report included only the southern half of the county.

Stevenson (1878) made a study of the northern part of Belmont County and tentatively correlated the coal beds, which he designated by numbers, with coal beds in Pennsylvania. Like Andrews, he did not name the strata between the coal beds.

White (1891), in his report on the stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia, listed several stratigraphic sections from eastern Ohio. He stated that the rocks above the Waynesburg coal bed are Permian in age and that they occur in Belmont County as well as in other counties in eastern Ohio. He also correlated the coal beds of the "Upper coal measures" of Belmont County with the coal beds of the "Monongahela River series" of Pennsylvania.

Condit (1912), in a report on the Conemaugh formation in Ohio, classified the strata below the Pittsburgh coal bed in Belmont County as Conemaugh in age.

Stauffer and Schroyer (1920) made a study of the "Dunkard series" in Ohio, and measured a number of stratigraphic sections in Belmont County. Following White's original interpretation, they classified the strata above the Waynesburg coal bed as Permian in age, and, in addition, they subdivided the rocks of Permian age into two formations which they correlated with the Washington and Greene formations of Pennsylvania.

Condit (1923) made a study of the economic geology of the Summerfield and Woodsfield quadrangles, Ohio. This study included the southwestern quarter of Belmont County.

White (1947) mapped the Waynesburg coal bed in the northwestern and north-central parts of the county.

Stout (1953), in a report on the Monongahela series in Ohio, listed a large number of stratigraphic sections from Belmont County.

GEOGRAPHY

Belmont County is on the eastern edge of Ohio midway between the northern and southern boundaries of the State. It comprises an area of 535 square miles distributed over 16 townships (fig. 1). The dimensions of the county are roughly 24 miles from east to west and 21 miles from north to south. This county, which is almost rectangular in shape, is bounded on the east by the Ohio River, which separates it from West Virginia; on the west by Guernsey and Noble Counties; on the north by Harrison and Jefferson Counties; and on the south by Monroe County.

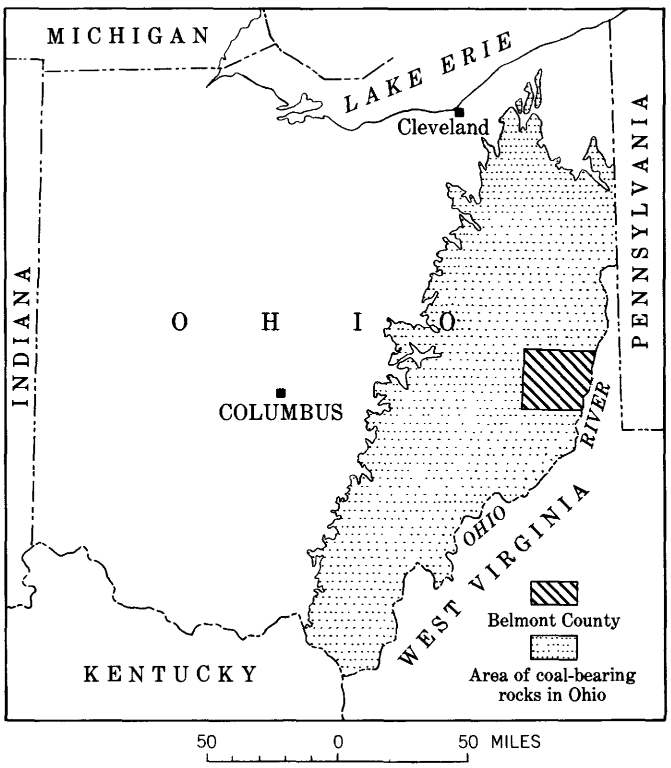

FIGURE 1.—Index map of Ohio showing the location of Belmont County and the area of coal-bearing rocks.

St. Clairsville, the county seat, is near the center of the northeastern quarter of the county. By highway it is 70 miles southwest of Pittsburgh, Pa.; 10 miles west of Wheeling, W. Va.; 137 miles southeast of Cleveland, which is the closest point on Lake Erie; and 117 miles east of Columbus.

A network of Federal, State, and county highways makes all parts of Belmont County accessible. U.S. Highways 40 and 250 and State Highways 7 and 8 are the main roads. Rail service to most of the northern half of Belmont County and to all of the eastern part of the county along the Ohio River is provided by the Baltimore and Ohio, Pennsylvania, and New York Central and St. Louis Railroads (fig. 2). Coal is shipped by barge to many cities on the Ohio River.

In 1950, Belmont County had 87,740 inhabitants. The principal towns in the county in order of size are Martins Ferry, Bellaire, Barnesville, Bridgeport, Shadyside, and St. Clairsville.

The economy of Belmont County is based principally on agriculture, coal mining, and manufacturing. Agriculture is the leading activity in terms of persons engaged, but coal mining exceeds both manufacturing and agriculture combined in terms of income from sales.

TOPOGRAPHY AND DRAINAGE

Belmont County is a part of the Appalachian Plateau physiographic province (Fenneman, 1938, p. 279), which is a broad dissected upland underlain by essentially horizontal sedimentary rocks.

The surface of the county is hilly. Streams have dissected the area so that, except for the uniformly level ridge summits, most of its plateau surface is no longer evident. The present surface consists chiefly of broad, rounded ridges and intervening V-shaped valleys. The valleys are deep and narrow along the Ohio River and its main tributaries, but are shallower and broader headward near the drainage divides.

The highest elevation is slightly more than 1,400 feet above sea level. Two hills rise to this level: one is near the western edge of sec. 11, Goshen Township; the other is Galloway Knob near the eastern edge of sec. 29, Smith Township. The lowest elevation is at the extreme southeastern corner of the county where the Ohio River is 615 feet above sea level. Maximum relief is about 800 feet. Along the Ohio River, the ridge tops are as much as 680 feet above river level. In the central one-third of the county, relief along the main streams ranges from 530 feet on Captina Creek to 360 feet on Wheeling Creek. West of the Flushing escarpment (fig. 2), the relief along the larger streams is about 300 feet.

Most of the higher ridges reach a rather uniform altitude of about 1,260–1,300 feet. The uniform level of the ridge crests is most apparent along the Flushing escarpment, along the broad ridges that extend eastward from the escarpment to the Ohio River, and along the ridge that extends northwestward from Barnesville to Fairview, Guernsey County.

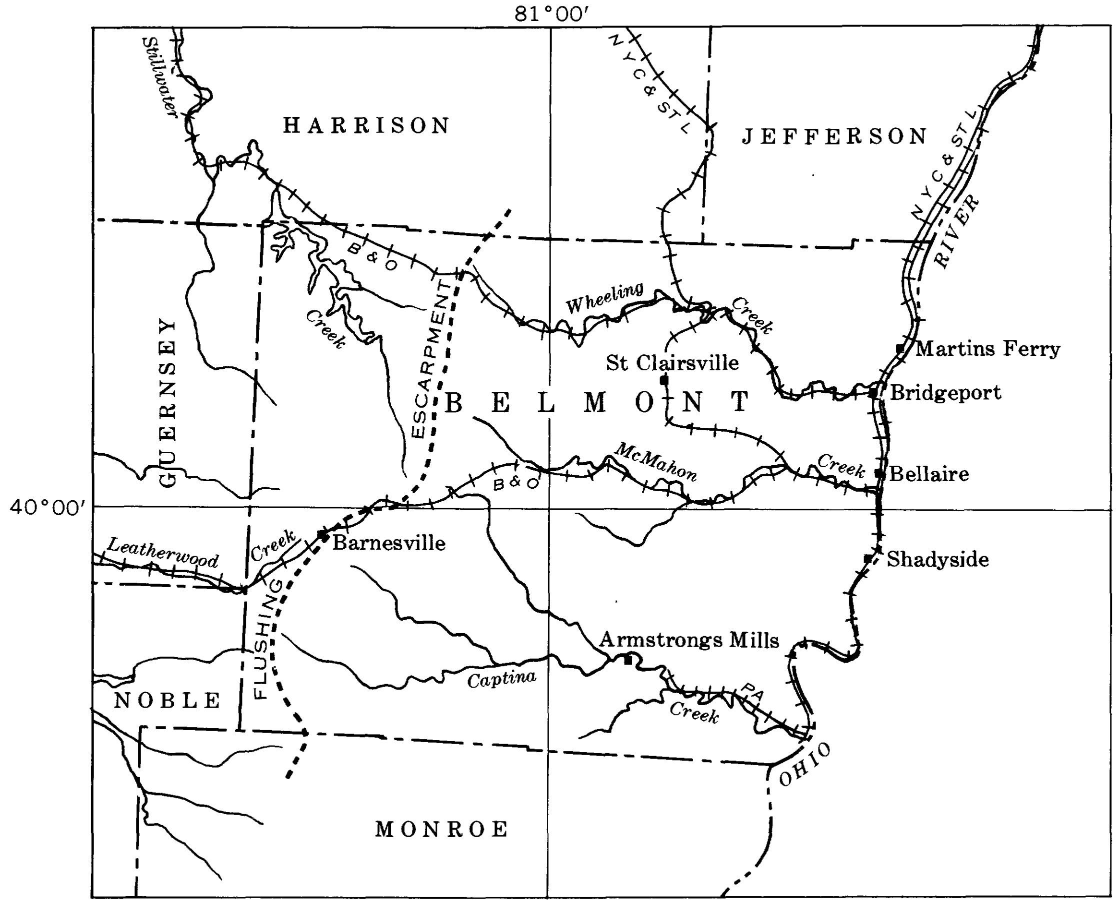

FIGURE 2.—Index map of Belmont County, Ohio, showing the location of main towns, streams, and railroads, and the main drainage divide, the Flushing escarpment.

A drainage divide, the Flushing escarpment (Stout and Lamb, 1939, p. 4–5), which trends slightly northeastward across the western one-fourth of the county, is an outstanding physiographic feature of eastern Ohio (fig. 2). This divide follows a sinuous course from southwestern Columbiana County southward across Carroll, Harrison, and Belmont Counties into northwestern Monroe County. It crosses Monroe County in a southeastward direction and reaches the Ohio River at a point near New Martinsville, W. Va. In Belmont County this divide separates the drainage of the area into two separate systems. The eastern system, which is made up of Wheeling, McMahon, and Captina Creeks and their tributaries, flows directly into the Ohio River. The western system is made up of Stillwater Creek and Wills Creek and their tributaries, which flow westward and northwestward into the Tuscarawas and Muskingum Rivers before entering the Ohio River at Marietta.

A conspicuous feature of the drainage pattern of the Ohio River in this area is the relatively short lengths of its tributaries. From Marietta, Ohio, north to Pittsburgh, Pa., a distance of approximately 100 miles, not a single tributary of the Ohio River has been called a river. Elsewhere, however, the Ohio River drainage system includes several large rivers—the northern part is made up of the Monongahela, Allegheny, Conemaugh, and Youghioheny Rivers and their tributaries, and the southern part includes the Kanawha, Kentucky, Wabash, Cumberland, and Tennessee Rivers.

The well-developed tributaries in the northern and southern parts of the present Ohio River drainage system and the lack of well-developed tributaries between Marietta, Ohio, and Pittsburgh, Pa., plus the divergent orientation of the tributaries north and south of New Martinsville, W. Va., led Leverett (1902, p. 88–94) to the conclusion that the area now drained by the Ohio River was, prior to the Pleistocene ice age, two systems separated by an eastward-trending drainage divide that crossed the present Ohio River somewhere between Bellaire, Ohio, and New Martinsville, W. Va. The streams making up the northern system, which included the streams of eastern Belmont County, flowed to the Atlantic Ocean via the northern Ohio, Allegheny, and St. Lawrence Rivers, and the streams making up the southern system, which included the streams of western Belmont County, flowed to the Gulf of Mexico via the southern Ohio and Mississippi Rivers. The reversal in direction of flow of the northern system occurred during a late stage of the glacial period and was a result of damming by glaciers and glacial debris. Being unable to flow northward, the water ponded, eventually broke over a col on the drainage divide near New Martinsville, and flowed southward into the southern Ohio River system. A large continuous supply of water from the melting glaciers quickly cut a gorge through the narrow col and drainage of the northern Ohio River system was permanently incorporated with the southern Ohio River system to form the present drainage pattern.

Stout and Lamb (1939) also discussed the effects of the glacial period on the drainage of southeastern Ohio. They believed that the Tuscarawas River system, which includes the westward-flowing tributaries draining Belmont County, flowed northwestward to the Great Lakes area prior to the glacial period and was, therefore, a part of the St. Lawrence River system. The course of the Tuscarawas was subsequently dammed by glaciers and its flow diverted southward into the southern Ohio system.

Cutoff meanders and perched alluvial terraces in places along Captina, McMahon, and Wheeling Creeks indicate that the eastward-flowing drainage system was once more mature than at the present time. Stream loading occurred during the late glacial period. Subsequent alteration of the drainage pattern, as described above, caused a lowering of base level and the streams became incised. The present relief is a result of this rejuvenation.

STRUCTURE

The rocks in Belmont County form a gentle monocline that dips to the southeast at an average rate of 18 feet per mile. Locally, the dip increases to as much as 70 feet per mile where small flexures cause slight variations in the southeastward dip. (See pl. 4 which includes structure contours drawn on the base of the Pittsburgh coal bed.) Two small dome-shaped anticlines lie in the eastern part of the county, one in eastern Richland Township at Claremont and the other in northwestern Mead and eastern Smith Townships near Jacobsburg. Several structural noses and terraces occur in the mapped area. The most prominent structural noses are in southwestern Warren Township near Barnesville and in the southeastern corner of Wayne Township.

A narrow northeastward-trending syncline, whose position was plotted from mine maps of the Pittsburgh coal bed, extends from west-central Pultney Township to the northeastern part of Pease Township (pl. 4). The width of the structure is reported to range from a few hundred feet to about 1,000 feet, and the elevation of the base of the coal bed across the syncline is reported to vary as much as 40 feet in about 200 feet of lateral distance. Locally the syncline is cut by a normal fault along its western side, adjacent to the deepest part of the trough. The beds on the west side of the fault have moved up about 5 feet relative to those on the east side. Mine operators report very little, if any, abnormal fracturing of the coal adjacent to the fault. The lower bench of the Pittsburgh coal bed increases from an average thickness of about 60 inches to 84 inches or more in a narrow belt along the central part of the syncline. The thicker coal in the lower bench of the Pittsburgh coal bed suggests that the trough may have been present at least in an incipient stage during accumulation of the plant debris.

In the north-central part of sec. 31, Union Township, at the McConnaugh mine, a small graben is outlined by faults in the Pittsburgh coal bed. The downfaulted block is approximately 800 feet wide and is reported by the mine owner to be bounded on the southeast and northwest by northeast-trending faults. The elevation of the base of the Pittsburgh coal bed at the portal of the McConnaugh mine, which is located at the low point of the graben, is 960 feet. The elevation is 998 feet at points about 400 feet north of the portal and 500 feet east-southeast of the portal. The elevation of the coal bed also increases northeastward along the center of the graben, suggesting that the structure plunges to the southwest. In the center of the graben, the total thickness of the coal is more than 96 inches, which is well above average for the area. Local faulting of the Pittsburgh coal bed is also reported by mine operators in other parts of the county.

STRATIGRAPHY

GENERAL FEATURES

The exposed strata of Belmont County were deposited during the Pennsylvanian and Permian periods. They comprise, in ascending order, the Conemaugh and Monongahela formations of Pennsylvanian age, and the lower part of the Dunkard group, Washington and Greene formations, undifferentiated, of Pennsylvanian and Permian age. (See pl. 1.) In its type area along Dunkard Creek in southwestern Pennsylvania, the Dunkard group includes the Washington and Greene formations. In Belmont County, Ohio, neither a lithologic nor a faunal basis exists for subdividing Dunkard strata. Furthermore, the Jollytown coal, basal unit of the Greene formation in Pennsylvania, cannot be positively identified in Belmont County. Consequently, Dunkard strata are referred to in this report as Dunkard group, Washington and Greene formations undifferentiated. Group rather than formation is used because of traditional usage of either group or series to designate the Dunkard in the northern Appalachian basin and also because of the proximity of Belmont County to the type area. Reasoning followed in redefining the Dunkard of Belmont County is discussed in detail in the section on Dunkard stratigraphy, pages 46–47.

The exposed rocks in Belmont County have a combined thickness of about 1,100 feet, of which the Conemaugh formation makes up approximately 360 feet, the Monongahela formation 230 to 265 feet, and the Dunkard group approximately 470 feet. The lower part of the Conemaugh formation is covered, and the upper part of the Dunkard group has been removed by erosion. The thickness of each of the three units is remarkably uniform; thinning is slight and very gradual. Drill-hole data indicate that the Conemaugh formation thins toward the southwest at the rate of 2 to 3 feet per mile, the Monongahela formation thins toward the northwest at the rate of 1 foot per mile, and the Dunkard group thins toward the north at the rate of 1 foot per mile.

The Conemaugh and Monongahela formations and the Dunkard group have each been subdivided into several members, many of which can be correlated with members in other parts of the Appalachian basin. Units that could not be readily correlated either have been given new names or have been designated as "undifferentiated" strata in this report. For some of the members, the same geographic name has been used for two members, for example, Redstone limestone member, Redstone sandstone member. Such duplication of a single geographic name for two members does not accord with the stratigraphic code of the U.S. Geological Survey, but inasmuch as these duplicated names have been widely used for more than 50 years, and also because 9 of them have been previously adopted by the U.S. Geological Survey, retention of the duplicated but well-established names is more practical than replacing them with new ones. However, in introducing new names for previously unnamed units, no geographic names have been duplicated. The stratigraphic units and their relations are shown in the generalized columnar sections in plate 2. Most of the clay beds beneath coal beds have not been previously named in the Appalachian coal basin. Following this precedent, these beds in Belmont County are designated simply as "underclays."

All the formations are composed of relatively thin layers of interbedded and intertongued sandstone, siltstone, mudstone, clay, limestone, and coal. Most of the beds of coal and their underclays and two of the units of limestone are persistent throughout the county, but the other units grade laterally into different types of rocks. The distribution of sandstone, siltstone, and limestone within each formation varies from one part of the county to another. In the Conemaugh formation sandstone and siltstone seem to be concentrated mainly in the northern half of the county, but because of insufficient drill-hole data for the southern half where the formation does not crop out, this conclusion is in part conjectural. The sandstone and siltstone beds of the Monongahela formation occur mainly in the western part of the county, and those of the Dunkard group chiefly in the southern part. The vertical repetition of the various rock units in a rhythmic pattern is characteristic of both the Pennsylvanian and the Permian rocks and is a characteristic that is modified laterally across the county by facies changes.

Most of these strata have been probably deposited in either a fresh- or brackish-water environment. Several thin units of limestone containing marine fossils are interbedded with the nonmarine strata in the lower half of the Conemaugh formation.

The formations differ in the number of coal beds and red beds and in the ratio of sandstone, siltstone, and shale to limestone. The Monongahela formation contains several thick and persistent coal beds of commercial quality, a large amount of limestone, but virtually no red beds. The Conemaugh formation contains no exposed coal but thin coal beds have been recorded in drill holes. The Dunkard group contains several thin lenticular coal beds but only one is thick and persistent. Both the Conemaugh formation and the Dunkard group contain red beds and in both formations the clastic rocks are predominant over limestone. The Dunkard group, however, contains more limestone locally than the Conemaugh formation, especially in the northeastern part of the county.

PENNSYLVANIAN ROCKS

CONEMAUGH FORMATION

HISTORY OF NAME

The name "Conemaugh" was first used by Platt (1875, p. 8) to designate the strata that occupy the interval between the Upper Freeport and Pittsburgh coal beds along the Conemaugh River in Pennsylvania. In Ohio, however, the older "Lower Productive," "Lower Barren," "Upper Productive," "Upper Barren" classification of Rogers (1839) was used for that part of the "Coal Measures" above the "Conglomerate Group" until Prosser (1901, p. 199) substituted the formation names Pottsville ("Conglomerate Group"), Allegheny ("Lower Productive"), Conemaugh ("Lower Barren"), Monongahela ("Upper Productive"), and Dunkard ("Upper Barren"). The name "Conemaugh" is in general use today throughout the Appalachian basin to designate the strata between the top of the Upper Freeport coal bed and the base of the Pittsburgh coal bed. The Conemaugh formation ranges in age from late Middle to Late Pennsylvanian and includes strata that are probably equivalent to strata of late Des Moines, Missouri, and early Virgil age in the Midcontinent region (Moore and others, 1944, chart 6).

DISTRIBUTION

The Conemaugh formation crops out mainly in the westernmost and northeastern parts of Belmont County but is largely concealed in all of the central and southern parts. The largest area of outcrop is in western Flushing and Kirkwood Townships, where approximately the upper three-fourths of the formation is exposed. In western Warren and western Somerset Townships, less of the formation is exposed, and in the extreme southwestern corner of the county only the upper 15 to 20 feet are exposed.

Near the northeastern corner of the county the upper part of the Conemaugh formation crops out along the valley slopes adjacent to the Ohio River. Outcrops of the uppermost strata extend westward for several miles along the valleys of Wheeling and McMahon Creeks. South of east-central Pultney Township, the Conemaugh formation is concealed except for a small area along Captina Creek in secs. 21 and 27, York Township, where the upper few feet lie above creek level.

THICKNESS

The lower part of the Conemaugh formation is not exposed in Belmont County. Approximately the upper 350 feet is exposed in the northwestern corner of the county, and approximately the upper 200 feet is exposed near the northeastern corner. The lower 70 feet of the exposure near the northeastern corner is obscured in part by weathering and in part by terrace deposits along the Ohio River so that the maximum vertical section exposed is about 130 feet. The formation is less exposed toward the south and southeast because of the regional dip; and in the southern and southeastern parts of Belmont County, it is completely covered by younger rocks. Drill holes penetrated 412 feet of the Conemaugh formation in Union Township and approximately 468 feet near Wheeling, W. Va. The formation is about 425 feet thick to the west in Guernsey County (Condit, 1912), about 422 feet thick to the southwest in Noble County, and from 473 to 505 feet thick to the north in Jefferson County. Data on the thickness of the Conemaugh formation in Monroe County are not available.

GENERAL CHARACTER

The Conemaugh formation consists of sandstone, siltstone, mudstone, and small amounts of shale, clay, and limestone. Coal beds have not been found in outcrops of the Conemaugh in Belmont County, but they have been reported in drill holes.

The sandstone members of the formation are lenticular. Crossbedding is common, and, because of an abundance of mica, the sandstone beds tend to break into flaggy and platy fragments along irregular bedding planes. Locally the sandstone is massive and has an undulatory base with thin lenses of conglomerate in a few places. The sandstone beds are poorly sorted; grain size ranges from fine to coarse but is predominantly fine to medium. The siltstone beds are generally shaly, more evenly bedded than the sandstone, and commonly grade laterally into sandstone.

Unweathered sandstone and siltstone beds are light to medium gray, but weathered sandstone generally is tan to rusty brown and weathered siltstone is olive gray.

The sandstone and siltstone are similar in mineralogic composition. Quartz is the most abundant mineral, and the grains are clear, unetched, and vary from angular to subrounded. Grains of feldspar, muscovite, biotite, and chlorite are in most of these rocks and make up approximately 5 to 10 percent of the total mass. The interstitial material is made up of very finely ground feldspar, mica, and clay minerals, and this material, together with secondary quartz, forms the cement. The sandstone is generally friable on the weathered surface.

Both iron concretions, consisting principally of iron oxide and clay ironstone nodules, occur locally in the sandstone but are more common in the siltstone. Calcareous nodules also occur in places in the siltstone. Most of the nodules and concretions lie in either the lower or the upper part of the sandstone and siltstone members, but locally they may occur in both the lower and the upper parts. There are some limy nodules in the beds of mudstone.

The mudstone beds of the Conemaugh formation in Belmont County are variable in thickness and locally grade into either shale, siltstone, or limestone. The term "mudstone" is used in this report to designate virtually nonbedded rocks composed principally of clay-sized particles but containing, in addition, various amounts of silt-sized particles and nonclay minerals. The color of the mudstone is predominantly grayish red, but greenish-gray bands and blotches are common. The red and green colors are imparted to the mudstone by iron compounds, and the variegation in color occurs because some of the iron compounds have been oxidized but some have been reduced chemically.

Both marine and nonmarine limestone beds are found in the Conemaugh formation in Belmont County. The marine limestone, which occurs only in the lower part of the formation, contains a diversified fauna including brachiopods, crinoids, bryozoa, pelecypods, gastropods, and corals. The nonmarine limestone contains a relatively nondiversified and diminutive fauna consisting mainly of forms such as ostracodes, *Spirorbis*, pelecypods, gastropods, and fish remains. The limestone beds are the best stratigraphic markers in the Conemaugh formation in Belmont County because of their greater lateral persistence. On a regional basis the marine limestone beds are the more persistent.

Clay, containing carbonaceous material in many places, occurs in layers generally a foot or less in thickness. These layers commonly overlie the nonmarine limestone beds and underlie the marine limestone, but locally clay is absent.

The geographic distribution of the types of rock making up the Conemaugh formation varies from north to south across Belmont County. In the northern part the strata contain considerable sandstone, but in the west-central and southwestern parts, the strata consist largely of siltstone, shale, and mudstone. Red beds seem to be more numerous in the western part of the county.

DESCRIPTION OF MEMBERS

Condit (1912, p. 20) divided the Conemaugh formation in Ohio into 23 members. Exposures in Belmont County are generally poor, however, and identification and correlation of some of the named members is difficult. The following members, as recognized by Condit (1912), are present in the county: Upper Pittsburgh limestone, Bellaire sandstone, Lower Pittsburgh limestone, Connellsville sandstone, Morgantown sandstone, Ames limestone, Portersville limestone, Anderson coal bed, and Cambridge limestone.

The stratigraphic positions of these members and of the undifferentiated strata are shown in the generalized section for the Conemaugh formation in plate 2.

With the exception of a few of the uppermost members, correlation within the formation from one part of the county to the other is uncertain because of the scarcity and poor condition of the outcrops. The members of the formation, therefore, are described separately for the two areas of outcrop, under the headings "Western Belmont County" and "Eastern Belmont County."

WESTERN BELMONT COUNTY

CAMBRIDGE LIMESTONE MEMBER

The Cambridge limestone was named by Andrews (1874, p. 262) for exposures at Cambridge in Guernsey County, where it lies 138 feet above the base of the Conemaugh formation. This unit, now considered a member of the Conemaugh, is the oldest exposed member in Belmont County that can be correlated with Condit's section (1912, p. 183). It crops out only near the northwestern corner of the county. (See pl. 1.) The best outcrop is in the east road bank a short distance northeast of the Piedmont Lake concession house (west edge of the NW¼ sec. 33 W., Flushing Township) about 23 feet above the surface of the lake. Here the member consists of about 5 feet of weathered yellowish-gray clay and nodular dusky-yellow to dull black highly ferruginous limestone. The Cambridge limestone member is 130 feet below the Ames limestone member at this locality. The following detailed section measured in the road bank just northeast of the concession house shows the character of the Cambridge and its relation to associated strata.

	Thickness Ft.	In.
Conemaugh formation:		
Undifferentiated strata:		
Siltstone, shaly to poorly bedded and nodular, dusky-yellow	5	0
Mudstone, shaly, variegated grayish-red to dusky-yellow	2	5
Cambridge limestone member:		
Limestone, shaly to nodular, silty; partly conglomeratic; interbedded with yellowish-gray clay; contains crinoid stems, brachiopods, and horn corals; weathers to rubble	3	0
Limestone, nodular; contains dull black iron concretions; yielded brachiopods (*Spirifer* sp. or *Neospirifer* sp.(?) and *Chonetes* sp.) and one pelecypod; weathers to rusty-brown rubble	1	10
Wilgus coal bed of Condit (1912)?:		
Sandstone, laminated, fine-grained, sugary; contains shrinkage cracks and carbonized plant remains		4
Clay, light-gray; weathers distinctive white; contains carbonaceous streaks		4
Buffalo sandstone member of Condit (1912)?:		
Siltstone, shaly, micaceous; nodular fracture; iron oxide encrusts upper 3 ft	23	0
Level of Piedmont Lake.		

The weathered condition of the fossils at this outcrop made specific identification of individual fossils impossible, but crinoid stems, *Spirifer* sp. or *Neospirifer* sp.(?), *Chonetes* sp., one pelecypod, and one coral were found. The coral and crinoid remains seemed to be limited to the upper part of the limestone. Mark (1912 *in* Condit, p. 296) states that *Chonetes verneuilanus* Norwood and Pratten and *Productus longispinus* Sowerby are characteristic fossils found in the Cambridge limestone member in eastern Ohio.

ANDERSON COAL BED

The Anderson coal bed was named by Andrews (1874, p. 639) for exposures at the Anderson mine near Lore City in Guernsey County, where the coal lies 12 feet above the Cambridge limestone member.

Overlying the Cambridge in the section exposed near the Piedmont Lake concession house in sec. 33 W., Flushing Township, is a sequence of undifferentiated strata consisting of grayish-red mudstone, shaly siltstone, and olive-gray calcareous mudstone, totaling 14 feet in thickness. At the top of this sequence is a layer of clay, 1 foot thick, containing traces of carbonaceous material (pl. 3*A*, section 1). This clay probably is the lateral correlative of the Anderson coal bed.

PORTERSVILLE LIMESTONE MEMBER OF CONDIT

Condit (1912, p. 41) named the Portersville limestone member for its outcrops near Portersville, Perry County, where it lies 3 feet above the Anderson coal bed.

Directly above the clay that marks the position of the Anderson coal bed is a ferruginous coquina of diminutive brachiopods, gastropods, and bryozoa, 1 inch thick. This coquina probably is the lateral correlative of the Portersville. Its stratigraphic position is shown in section 1 of plate 3*A*.

UNDIFFERENTIATED STRATA OVERLYING THE PORTERSVILLE LIMESTONE MEMBER AND UNDERLYING THE AMES LIMESTONE MEMBER

The strata described in the following paragraphs include beds that are probably equivalent to the Cowrun sandstone member, Barton coal bed, Ewing limestone member, Saltsburg sandstone member, and "Round Knob horizon" (Pittsburgh red beds) of other areas.

The Portersville limestone member is overlain by 115 feet of siltstone and mudstone along the road to the Piedmont Lake concession house in sec. 33 W., Flushing Township (pl. 3*A*, section 1). At this locality the basal 105 feet of the section is a monotonous sequence of shaly siltstone containing some flaggy to massive layers, and the upper 10 feet is grayish-red mudstone. Interbedded with the siltstone are two thin bands of reddish-brown shale, 62 and 82 feet respectively above the Portersville limestone. Although the rocks in this sequence are poorly exposed in most places, the siltstone that crops out in sec. 33 W., Flushing Township, appears to be typical. The lower 30–40 feet of this siltstone may be equivalent to the Cowrun sandstone member of Condit (1912, p. 39).

The reddish mudstone just beneath the Ames limestone member is a persistent unit, 10 to 15 feet thick at most places, and may be the "Round Knob horizon" (Pittsburgh red beds) of Condit (1912, p. 35).

Along the road southwest of Golda in sec. 19 W., Flushing Township, however, approximately the upper 66 feet of this undifferentiated interval consists of massive, coarse-grained sandstone, the top lying approximately 180 feet below the Pittsburgh coal bed (pl. 3*A*, section 2). The massive sandstone apparently fills a channel that has been cut into the underlying shaly siltstone. What seems to be the basal part of the same tongue of sandstone forms massive outcrops to the east along the eastern edge of Piedmont Lake. This sandstone was not identified at any other outcrops, but its stratigraphic position indicates that it is possibly the Saltsburg sandstone member, which Condit says is massive at places in Noble, Harrison, and Jefferson Counties. In these adjacent counties, it is locally a conglomeratic sandstone that fills a channel cut through the underlying Barton coal bed and the Ewing limestone member.

Elsewhere in Ohio, according to Condit (1912, p. 37–39), the Barton coal bed and the Ewing limestone member are about 40 feet below the Ames limestone member. In Belmont County, however, these beds are absent. The relative stratigraphic positions of the strata between the Ames and Portersville limestone members are shown in plate 2.

AMES LIMESTONE MEMBER

The Ames limestone was named by Andrews (1874, p. 235, 271, 296) for exposures in Ames Township, Athens County. This unit, now considered a limestone member, is the most important stratigraphic marker bed in the Conemaugh formation, not only in Ohio but in adjacent States as well. A probable lateral equivalent, the Ames shale, has been recognized as far east as the basin of Georges Creek in Maryland. The approximate line of outcrop of the member is shown on plate 1.

The Ames limestone member, which in Belmont County ranges in thickness from a few inches to 2½ feet, crops out in the northwestern part of the county from sec. 35, Kirkwood Township, to sec. 9, Flushing Township. Because of weathering, exposures of the Ames are generally poor and commonly consist only of boulders of limestone. It is apparently absent in sec. 19 W., Flushing Township (pl. 3*A*, section 2).

An outcrop of typical Ames member is found in the east road bank just north of the stream in south-central sec. 35, Kirkwood Township (pl. 3*A*, section 3). At this locality, several small- to medium-sized, weathered limestone boulders are in a mass of grayish-red mudstone. The limestone is coarsely crystalline, grayish yellow green on a fresh surface, and highly fossiliferous. Beneath the boulders of limestone is a layer of light-gray clay, 1 foot thick, which probably is the lateral equivalent of a coal bed. Elsewhere in Ohio and in adjacent States the Harlem coal bed underlies the Ames, but no coal was seen beneath the limestone in Belmont County.

A fresh exposure of the Ames limestone member is in a road cut along State Highway 311 in the NW¼ sec. 9, Flushing Township, about 400 feet northwest of the highway bridge across Boggs Run (pl. 3*A*, section 7). At this locality it consists of a single bed 1½ feet thick. Along the road cut the limestone grades into calcareous sandstone, but it is easily identified by the abundance of marine fossils. Northwestward into Harrison County along State Highway 311, the Ames is exposed at a few places in weathered outcrops and ranges from 10 inches to 2½ feet in thickness. The Ames is the youngest marine limestone recognized in Belmont County.

In sec. 35, Kirkwood Township, the interval between the Ames limestone member and Pittsburgh coal bed is 178 feet, and in sec. 9, Flushing Township, the interval is 172 feet. The average interval between these two units in the western part of the county is about 175 feet. In a cored well at Glenova, W. Va., just east of Belmont County, the Ames was penetrated at a depth of 93 feet or 198 feet below the Pittsburgh coal bed (Condit, 1912, p. 17–18).

Crinoid stems, *Spirifer* sp. or *Neospirifer* sp.(?), and *Chonetes* sp., are abundant in the Ames member in Belmont County. Condit (1912, p. 29) states that 87 species have been identified from the Ames in Ohio.

UNDIFFERENTIATED STRATA OVERLYING THE AMES LIMESTONE MEMBER AND UNDERLYING THE MORGANTOWN SANDSTONE MEMBER

The strata between the Ames limestone member and the Morgantown sandstone member have a total thickness of approximately 50 to 60 feet and are probably equivalent in part to the Birmingham shale member, Duquesne coal bed, and Skelley limestone members of other areas. The lower 30 to 40 feet consists of interbedded mudstone and sandstone, and the upper 10 to 20 feet consists of interbedded layers of reddish mudstone, thin beds of gray clay from 1 to 2 inches thick, and layers of lenticular shaly siltstone. The upper parts of most of the reddish mudstone layers are calcareous and contain nodules of impure limestone. The beds of clay that overlie the red mudstone sometimes contain carbonaceous material, which is probably the lateral equivalent of coal. Weathering generally obscures this part of the formation, but red soils are common where it is present.

In the SW¼ sec. 17, Kirkwood Township, a conglomeratic limestone overlies the rocks described above (pl. 3*A*, section 4). The stratigraphic position of this limestone suggests that it may be the Skelley limestone of Condit (1912, p. 27) but, as it was not seen elsewhere in western Belmont County, this correlation is conjectural. A thin coal bed containing several partings is exposed at approximately the same stratigraphic position in the NW¼ sec. 3, Londonderry Township, Guernsey County (pl. 3*A*, section 1). This may be the equivalent of the Duquesne coal (Condit, 1912, p. 27). The coal was not seen in other outcrops, and its identity could not be positively determined. Condit (1912, p. 27–29) states that, in addition to the Skelley limestone and the Duquesne coal bed, the Birmingham occurs in the interval between the Ames limestone and Morgantown sandstone members elsewhere in Ohio, at a stratigraphic position that is just above the Skelley limestone. The shale seems to be missing in Belmont County, its position being occupied by the interbedded reddish mudstone, nodular limestone, gray clay, and siltstone. These strata are plotted in section 1, plate 3*A*, and also in the generalized section of the Conemaugh formation in plate 2.

MORGANTOWN SANDSTONE MEMBER

Stevenson (1876, p. 78) named the Morgantown sandstone for exposures at Morgantown, W. Va., where it occurs from 25 to 38 feet above the Ames limestone member and is 30 to 70 feet thick. The Morgantown is now considered a member of the Conemaugh formation.

In western Belmont County the sandstone that lies about 50 feet above the Ames probably is equivalent to the Morgantown member.

This sandstone ranges in thickness from a few inches to approximately 50 feet. It is lenticular and grades laterally into finer grained rocks. (See pl. 3*A*.) In the railroad and highway cuts on the north side of Trail Run, southeast and northwest of Holloway, in secs. 33 E., 3, and 9, Flushing Township (pl. 3*A*, sections 6 and 7), the sandstone is massive, crossbedded, and locally contains thin lenses of conglomerate near the base. Southwestward, however, the sandstone loses its massive character. Mudstone occurs at its stratigraphic position in the SW¼ sec. 17, Kirkwood Township, and shaly siltstone in the south-central part of sec. 35, Kirkwood Township. The member is shaly and about 10 to 15 feet thick just west of the Belmont-Guernsey County boundary (pl. 3*A*, section 1).

UNDIFFERENTIATED STRATA OVERLYING THE MORGANTOWN SANDSTONE MEMBER AND UNDERLYING THE CONNELLSVILLE SANDSTONE MEMBER

The Morgantown and Connellsville sandstone members in western Belmont County are separated by 20 to 35 feet of reddish mudstone, which locally contains impure limestone at the top and base and shaly siltstone and sandstone in the center (pl. 3*A*). This sequence is probably equivalent to the Clarksburg limestone of White (1891) and the Summerfield limestone of Condit (1912). The unit is now considered a member.

The thickness and stratigraphic position of these strata correspond to the Clarksburg limestone member named by I. C. White for outcrops in the vicinity of Clarksburg, W. Va., but because of the difference in lithology, the strata in this interval in Belmont County cannot be called a limestone member. The beds of limestone which occur locally at the base and top, however, are probably tongues of the Clarksburg that are separated in Belmont County by a tongue of mudstone and sandstone.

The outcrops of these strata are so few and so badly weathered in Belmont County that names were not assigned.

The silty conglomeratic limestone that occurs locally at the top of the sequence in Flushing and Kirkwood Townships (pl. 3*A*, sections 3, 5, 6) and also in eastern Belmont County (pl. 3*B* (top), sections 3, 4) corresponds approximately in stratigraphic position to the Summerfield limestone, which Condit (1912, p. 20–23) named for outcrops 50 to 65 feet below the Pittsburgh coal bed at Summerfield, Ohio. Later Condit (1923, p. 17) stated that the position of the Summerfield limestone was 25 feet below the Pittsburgh coal bed, and he discarded the name because he thought it was equivalent to the Lower Pittsburgh limestone, an older name. He says, "This rock has a characteristic roughened, lumpy surface that serves to differentiate it from other beds." In Belmont County, two limestone beds, one 25 to 30 feet and the other 60 to 75 feet below the Pittsburgh coal bed, are conglomeratic so that feature is not restricted to the Lower Pittsburgh limestone. Condit's original definition of the Summerfield limestone was probably correct, but no attempt was made to prove this by lateral tracing of beds.

Fossils found in the two limestone beds in the interval between the Morgantown and Connellsville sandstone members include small ostracodes, *Spirorbis*, and fish remains.

CONNELLSVILLE SANDSTONE MEMBER

Franklin Platt (1876, p. 19) named the Connellsville sandstone for its exposures at Connellsville, Pa.,where it is 65 feet thick. It is now considered a member of the Conemaugh formation.

In western Belmont and in the eastern part of adjacent Guernsey County, the sandstone member that is probably equivalent to the Connellsville ranges in thickness from a few inches to more than 50 feet. The thickest outcrop in the general area is just west of the county boundary along the banks of the road that connects the concession house on Piedmont Lake to State Highway 8. At this locality the sandstone is more than 50 feet thick (pl. 3*A*, section 1). Southward and eastward, in northwestern Belmont County the member is much thinner. To the east in sec. 2, Flushing Township, the position of the sandstone is represented by 6 to 8 feet of siltstone (pl. 3*A*, section 6).

The sandstone is shaly to flaggy and crossbedded. The range in grain size is fine to medium but is predominantly fine, and in most places the basal and upper parts of the member are shaly siltstone. Like most other sandstone beds in the county, the Connellsville is micaceous, mainly along the bedding planes.

LOWER PITTSBURGH LIMESTONE MEMBER

Franklin and W. G. Platt (1877, p. 286) named the Lower Pittsburgh limestone, now considered a member, for its occurrence below the Lower Pittsburgh coal bed in western Pennsylvania.

The Lower Pittsburgh limestone member in western Belmont County ranges in thickness from about 2 feet to 8 feet 3 inches. The maximum thickness was measured in the bank of State Highway 8 at the curve in the road about 500 feet southeast of the Oak Grove Church near the county line in sec. 21 W., Flushing Township.

This nonmarine limestone, which lies approximately 25 feet below the Pittsburgh coal bed, is one of the most persistent members of the Conemaugh formation in western Belmont County. The following stratigraphic section, measured in a road cut on State Highway 8, west of Spencer Creek in the SE¼ sec. 13, Kirkwood Township, shows the lithologic character of the Lower Pittsburgh limestone member and its relation to the associated strata.

	Thickness Ft.	In.
Monongahela formation:		
Pittsburgh coal bed, mostly covered.		
Conemaugh formation:		
Underclay, gray, calcareous; contains many particles of fine white clay that give the bed a speckled appearance		6
Underclay, gray; partly stained bright orange by iron oxides that formed by the weathering of pyrite	2	0
Upper Pittsburgh limestone member:		
Partly covered interval; contains a 1-ft bed of nodular limestone near top; lower 5 ft contains three beds of limestone; rest of unit appears to be clay	8	6
Bellaire sandstone member:		
Siltstone, gray, friable; lower half calcareous with limestone nodules near base; lower 1½ ft greenish gray	16	0
Lower Pittsburgh limestone member:		
Limestone, light-brownish-gray, microgranular to conglomeratic; contains crystals of siderite; weathers yellowish gray; forms angular ledge	5	0
Limestone, light-brownish-gray		6
Limestone, light-gray, siliceous; contains crystals of pyrite	1	0
Connellsville sandstone member:		
Siltstone, gray, calcareous; contains limestone nodules	2	6
Mudstone and interbedded clayey siltstone; lower 4 ft is reddish-gray mudstone	30	6

The limestone is conspicuously conglomeratic or brecciated at many localities. On weathered surfaces, light-gray to almost white limestone pebbles or fragments stand out in contrast to the yellowish-gray to yellowish-orange limestone matrix (fig. 3). The limestone is relatively pure. An analysis taken from Condit (1923, p. 50) is given below. Although the exact location of the sample is not known, it is listed as being near Baileys Mills, which is in the southwestern corner of Warren Township.

	Percent
SiO_2	2.83
Al_2O_3 (includes Fe_2O_3, P_2O_5, and any titanium that may be present)	1.05
$MgCO_3$	.87
$CaCO_3$	94.20

Good exposures of the Lower Pittsburgh occur along State Highway 8 in sec. 36, Kirkwood Township, and sec. 31 W., Flushing Township. The locations of other outcrops are shown on plate 3*A*, sections 4 and 6.

At most places the Lower Pittsburgh member is overlain by gray clay, 1 to 3 feet thick, which contains bands of carbonaceous material. This clay may represent the Lower Pittsburgh coal bed, which is persistent to the east in West Virginia and Pennsylvania.

FIGURE 3.—Outcrop of the Lower Pittsburgh limestone member showing its conglomeratic and brecciated character in western Belmont County. Photographed at top of east road bank near the northwestern corner of sec. 25 W., Flushing Township.

BELLAIRE SANDSTONE MEMBER

The Bellaire sandstone was named by Condit (1912, p. 22) for exposures along McMahon Creek west of Bellaire in eastern Belmont County, where it is a massive unit 10 to 20 feet thick.

In western Belmont County where its thickness ranges from 10 to 15 feet, the Bellaire sandstone member is persistent but consists in most places of shaly siltstone, locally containing some thin lenses of shaly to flaggy sandstone. The base of the Bellaire is separated from the Lower Pittsburgh limestone member by 1 to 3 feet of clay. The top generally lies a few feet below the Pittsburgh coal bed and is separated from it by the Upper Pittsburgh limestone member and the underclay. The siltstone between the Upper and Lower Pittsburgh limestone members in the stratigraphic section on page 12 is typical of the Bellaire member in the western part of the county.

UPPER PITTSBURGH LIMESTONE MEMBER

The Upper Pittsburgh limestone was named by White (1891, p. 87) for its occurrence beneath the Pittsburgh coal bed.

The Upper Pittsburgh, now considered a member of the Conemaugh, is persistent throughout western Belmont County, where it lies a few feet below the Pittsburgh coal bed and ranges from 1 to 8 feet in thickness. This limestone generally occurs in several beds, although at some places it consists of a single bed.

The following section, which shows the typical lithology of the member, was measured along the stream bed in the south-central half of the NE¼ sec. 27, Kirkwood Township.

	Thickness Ft.	In.
Monongahela formation:		
Pittsburgh coal bed: covered; mine entry 1,000 ft east.		
Conemaugh formation:		
Upper Pittsburgh limestone member:		
Limestone; several thin nodular layers partly covered	1	0+
Limestone, light-gray, dense, conglomeratic; has casts of shrinkage cracks and fragments of small pelecypods	1	8
Limestone, light-gray, dense, siliceous; undulatory top and base		6½
Limestone, light-gray, dense, siliceous; conglomeratic at top		9
Clay with limestone nodules		4
Limestone, medium-gray, conglomeratic		7
Limestone, light-gray, dense, slightly siliceous; locally conglomeratic at top		0

Most of this section is shown in figure 4 where the lowest stratum of limestone just above water level shown in the photograph is the lowest unit in the section above.

An analysis of a sample from the Jesse Bethel farm in the east-central part of sec. 8, Flushing Township, where the member occurs as a single bed 3 feet 10 inches thick, is as follows (Lamborn, 1951, p. 57):

Silicates:	Percent
$(NaK)_2O$, Al_2O_3, 6 SiO_2, 2 H_2O	0.75
Al_2O_3, 2 SiO_2, 2 H_2O	1.81
SiO_2	4.56
2 Fe_2O_3, 3 H_2O	.06
FeO, CO_2	5.48
FeS_2	.14
TiO_2	.12
3 CaO, P_2O_5	.30
CaO, SO_3	.82
CaO, CO_2	69.46
MgO, CO_2	15.95
MnO, CO_2	.62

Ostracodes, *Spirorbis*, fish remains, and small pelecypods are found in the Upper Pittsburgh limestone member. The limestone is very fossiliferous in an outcrop on the hillside north of the road in south-central sec. 17, Kirkwood Township. At this locality, coprolites and fragments of either large fish or amphibian bones are abundant. One vertebra, seven-tenths of an inch in diameter, was found. There are also some small pelecypods, so badly crushed that identification is not possible.

CLAY OVERLYING THE UPPER PITTSBURGH LIMESTONE MEMBER AND UNDERLYING THE PITTSBURGH COAL BED

Clay, ranging from several inches to several feet in thickness, overlies the Upper Pittsburgh limestone member and separates it from the overlying Pittsburgh coal bed of the Monongahela formation.

FIGURE 4.—Outcrop of the Upper Pittsburgh limestone member in western Belmont County. Photographed along stream bed in the south-central half of the NE¼ sec. 27, Kirkwood Township.

This clay, which is the uppermost unit in the Conemaugh formation, is variable in character as well as in thickness. Locally it is soft, plastic, and relatively pure, but in much of the area it is an impure shaly claystone. Iron minerals and silt are common impurities. The clay is light gray, but locally many small irregularly shaped particles of lighter gray clay in the upper part of the bed give it a speckled or mottled appearance. In places where this phenonenon occurs, the clay appears coarsely fragmental, but because of plasticity, the "particles" readily adhere and there is no tendency toward friability.

As previously stated, this clay, as well as the clays that underlie most of the other coal beds in Belmont County, are designated, both in the text and illustrations of this report, as underclays without formal names.

EASTERN BELMONT COUNTY

In eastern Belmont County the upper part of the Conemaugh formation is exposed along the Ohio River and its western tributaries from the northeastern corner of the county southward to a point just south of Bellaire in southeastern Pultney Township. The most extensive exposures west of the Ohio River are along Wheeling Creek, where the uppermost part of the formation crops out for a distance of 17 miles. The outcrops along McMahon Creek, the second largest tributary of the Ohio River in Belmont County, extend westward for a distance of only 7½ miles.

The part of the Conemaugh formation exposed in eastern Belmont County is similar in most places to that in western Belmont County. Locally, in southern Pease and northern Pultney Townships, however, most of the upper 100 feet of the formation consists of massive deltaic sandstone that forms a sheer cliff, such as the one extending vertically from the level of Wheeling Creek to the level of the U.S. Highway 40 bridge at Blaine. Parts of this massive sandstone also crop out in places along U.S. Highway 40 east of Blaine.

This sandstone, which is in part crossbedded, is believed to represent continuous sand deposition at or near the mouth of a stream. Laterally, beds of limestone, clay, siltstone, and shale, which elsewhere are assigned to members in the sequence between the Morgantown and Bellaire sandstone members, are intertongued with the massive deltaic sandstone. Plate 3*B* shows the stratigraphic relation of the massive sandstone at Blaine to both the limestone and sandstone members of the upper part of the Conemaugh formation in eastern Belmont County.

UNDIFFERENTIATED STRATA OVERLYING THE MORGANTOWN SANDSTONE MEMBER AND UNDERLYING THE CONNELLSVILLE SANDSTONE MEMBER

The strata between the Morgantown and Connellsville sandstone members in eastern Belmont County were seen at only one locality, in sec. 21, Pease Township. There, only two limestone units, one at the base and another at the top of the interval, are exposed; the remainder is covered (pl. 3*B* (top), section 4). As stated in the section on western Belmont County, these rocks seem to occupy the interval of the Clarksburg limestone member of White (1891), but because of poor outcrops the character of the strata in Belmont County is not sufficiently known to warrant a definite correlation.

The lower limestone unit consists of nodules of limestone embedded in mudstone and a bed of siliceous limestone several feet thick (pl. 3*B* (top), section 4).

The upper limestone, which is separated from the lower by a covered interval 23 feet thick, is made up of three beds of limestone separated by thin layers of clay. The lowest bed is light olive gray, hard, locally conglomeratic, and forms a ledge, whereas the two upper beds are nodular and locally grade into mudstone. This limestone may be equivalent to Condit's original Summerfield limestone. (See p. 11.) The best outcrop is along the base of the highway banks in sec. 19, Pease Township (pl. 3*B*, section 3). To the southwest in sec. 15, Pease Township, the limestone is absent and sandstone occurs in this interval.

The fossils in these limestone beds include ostracodes and fish remains.

CONNELLSVILLE SANDSTONE MEMBER

In eastern Belmont County the Connellsville sandstone member crops out in Pease, Colerain, Richland, and northern Pultney Townships. This sandstone, lenticular and variable in character, ranges in thickness from a few inches to about 50 feet. Its lithologic character and the stratigraphic relation to other members are shown on plate 3*B*.

In general, the basal part of the member contains massive, medium- to coarse-grained sandstone that grades upward to medium- to thin-bedded, fine-grained sandstone and thin-bedded siltstone. In most places at least the upper half of the member is either fine-grained thin-bedded sandstone or siltstone.

Massive outcrops of the Connellsville were studied along the bank of the road to the strip mine in sec. 21, Pease Township (pl. 3*B*, section 4) and to the southwest at the north end of the railroad tunnel in sec. 23 E., Richland Township (pl. 3*B*, section 3). In sec. 21, Pease Township, the member is 36 feet thick and consists of massive medium-grained micaceous sandstone that makes up approximately the lower half of the member, and siltstone, shale, and a thin layer of clay that make up the upper half. The base of the member is undulatory and rests on a thin layer of clay, which contains thin carbonaceous or coaly bands. In sec. 23 E., Richland Township, the base of the sandstone is covered, but the lower 12 feet of the outcrop at the north end of the railroad tunnel is massive, medium to coarse grained, and crossbedded. At this locality the sandstone becomes finer grained upward, and approximately the upper half of the member consists of pale-olive thin-bedded siltstone.

In sec. 19, Pease Township (pl. 3*B* (top), section 3), the Connellsville member has a thickness of only 12 feet and is made up of shaly siltstone, which contains several lenticular layers of fine-grained sandstone in the upper half, each about 1 foot or less thick. To the west of this locality, in the railroad bank at Barton, in sec. 24, Colerain Township (pl. 3*B* (bottom), section 4), the siltstone and sandstone in the upper part of the member are intertongued with variegated olive-gray and reddish-brown mudstone containing small limestone nodules. At the east end of the railroad bank a tongue of sandstone pinches out toward the west. West of Barton along the north railroad bank, sandstone is again abundant in the member and crops out in several places.

In sec. 15, Pease Township (pl. 3*B*, section 2), and for some distance toward the north and east, a part of the massive deltaic sandstone that crops out along Wheeling Creek at Blaine is equivalent in age to the Connellsville sandstone member.

LOWER PITTSBURGH LIMESTONE MEMBER

The Lower Pittsburgh limestone member is generally thinner in the eastern part of Belmont County than it is in the western part, ranging from a few inches to several feet in thickness.

At most places in eastern Belmont County the Lower Pittsburgh consists of nodules of impure limestone embedded in clay. In the quarry of the Standard Brick Co., in sec. 12, Pultney Township, the member consists of a single lenticular nodular bed, averaging 1 foot in thickness. To the north in sec. 21, Pease Township, however, the member consists of about 6 feet of clay and mudstone containing silty limestone nodules (pl. 3*B* (top), section 4). The impure limestone nodules and mudstone near the top of the railroad cut at Barton, sec. 24, Colerain Township (pl. 3*B* (bottom), section 4), also are believed to be equivalent to the Lower Pittsburgh limestone member. The member forms an angular ledge of limestone 2 feet thick above the north end of the Baltimore and Ohio Railroad tunnel in sec. 23 E., Richland Township (pl. 3*B* (bottom), section 3). The following stratigraphic section measured in the road bank near the west end of the bridge across Wheeling Creek in the NW¼ sec. 36, Colerain Township, shows the general character of the Lower Pittsburgh limestone member in eastern Belmont County, but its thickness at this locality is greater than average for the area.

	Thickness Ft.	In.
Monongahela formation:		
Pittsburgh coal bed (small mine nearby).		
Conemaugh formation:		
Covered interval	36	0
Siltstone, olive-gray, shaly; top covered	3	0+
Lower Pittsburgh limestone member:		
Limestone, silty	2	0
Mudstone, shaly		6
Limestone, nodular	1	2
Mudstone, silty; contains large limestone nodules	6	0+
Road level.		

A weathered ledge 1 foot thick, probably equivalent to the Lower Pittsburgh member, occurs in the railroad cut just north of the above section.

At most localities, as in western Belmont County, the Lower Pittsburgh is overlain by a thin carbonaceous clay, which is in the same stratigraphic position as the Lower Pittsburgh coal bed of West Virginia and Pennsylvania.

BELLAIRE SANDSTONE MEMBER

From its type area along McMahon Creek west of Bellaire, Ohio, northward to sec. 19, Pease Township, the Bellaire sandstone member is a massive, coarse-grained unit whose thickness ranges from 10 to 20 feet (pl. 3*B*), but in the northern part of Pease Township and west of Pease Township the member consists of fine-grained thin-bedded sandstone, some interbedded siltstone, and a few lenticular beds of impure limestone (pl. 3*B*). The upper part of the massive deltaic sandstone that crops out along Wheeling Creek at Blaine (sec. 15, Pease Township) is equivalent in age to the Bellaire.

In most places in Pultney and Pease Townships, the basal part of the Bellaire member is made up of fine-grained thin-bedded sandstone and siltstone, which ranges in thickness from a few inches to several feet (pl. 3*B* (top), sections 1 and 3). The fine-grained basal part of the member is overlain by massive coarse grained micaceous sandstone having an undulatory, channellike base. The massive part of the member grades upward into thin-bedded fine-grained sandstone and siltstone, which form the upper part of the member.

The Bellaire sandstone member is typically fine grained throughout most of Belmont County. The massive part, which is confined to the northeastern edge of the county, was apparently deposited near the mouth of a stream as a part of a delta.

UPPER PITTSBURGH LIMESTONE MEMBER

The Upper Pittsburgh limestone member, which lies a few feet below the Pittsburgh coal bed, is persistent over most of eastern Belmont County. It is represented by one or more massive, resistant beds with a total thickness of 1 to 8 feet. The limestone is locally absent in sec. 22 E., Richland Township, sec. 16, Colerain Township, and sec. 15, Pease Township, where the clay beneath the Pittsburgh coal bed lies directly upon the Bellaire sandstone member.

The following section of the Upper Pittsburgh limestone member was measured in the creek bank below a small mine in the NE¼ sec. 26, Pease Township.

	Thickness Ft.	in.
Monongahela formation:		
Pittsburgh coal bed.		
Conemaugh formation:		
Underclay:		
Clay; partially covered	1	0
Upper Pittsburgh limestone member:		
Limestone, dark-olive-gray, silty	1	5
Mudstone, shaly	1	0
Limestone, brownish-gray, silty, laminated		10
Mudstone, shaly		11
Limestone, medium-dark-gray; variable in thickness	2	1
Mudstone, greenish-gray	4	0
Bellaire sandstone member:		
Sandstone, thin-bedded; contains current ripple marks; forms bed of Deep Run.		

To the west, near the center of sec. 26, Colerain Township, the following partial section of the Upper Pittsburgh limestone member was measured along the east fork of Fall Run:

	Thickness Ft.	In.
Monongahela formation:		
Pittsburgh coal bed.		
Conemaugh formation:		
Covered	3	0
Upper Pittsburgh limestone member:		
Limestone, weathered, laminated	1	8
Limestone, light-olive-gray, silty, finely laminated	1	2
Limestone, medium-gray, silty, laminated; contains ostracodes and fish fragments	1	3
Clay, weathered		3
Limestone, brownish-gray, nodular, silty, laminated	1	0
Limestone, brownish- to olive-gray; splits laterally into two or more layers	1	3
Limestone, brownish- to olive-gray, conglomeratic	1	2
Limestone, brownish- to olive-gray, silty		9
Base of section at creek level.		

The following partial section was measured in the east bank of Indian Run near the south edge of the SW¼ sec. 25, Pultney Township:

	Thickness Ft.	In.
Monongahela formation:		
Pittsburgh coal bed.		
Conemaugh formation:		
Underclay:		
Clay and shale	3	6
Upper Pittsburgh limestone member:		
Limestone, thin-bedded, weathered		9
Limestone, olive-gray, dense	1	1
Limestone, thin-bedded, weathered		4
Limestone, olive-gray		7
Shale, calcareous		4
Limestone, olive-gray		10
Creek level.		

In a core hole in the SE¼ sec. 36, Washington Township, the Upper Pittsburgh consists of two beds separated by 8½ inches of claystone. The lower bed is 1 foot 11 inches thick and the upper bed is 1 foot 4 inches thick.

CLAY OVERLYING THE UPPER PITTSBURGH LIMESTONE MEMBER AND UNDERLYING THE PITTSBURGH COAL BED

The clay above the Upper Pittsburgh limestone member is similar in most places to that in western Belmont County, ranging from 1 to 4 feet in thickness and containing calcareous and ferruginous impurities. At one locality, however, on the south side of Indian Run near the western edge of Bellaire, the clay is reported to be 10 to 12 feet thick. Clay was taken from this site by underground mining prior to 1900, indicating that its purity also is probably above average there. The site is now so overgrown with brush that the clay cannot be seen. An exception to the general lithologic similarity of this clay over both the eastern and western parts of Belmont County is the apparent absence of the mottled or "coarsely fragmental" facies in eastern Belmont County.

MONONGAHELA FORMATION

HISTORY OF NAME

The name Monongahela was first used by H. D. Rogers (1840, p. 150) to designate rocks exposed from river level to the ridge summits along the Monongahela River valley at Pittsburgh, Pa. He used the term "Monongahela series" to replace "Pittsburgh series," which he had previously used (1839, p. 88–108) to identify these strata. The "Monongahela series" included the present Conemaugh and Monongahela formations of Pennsylvanian age and the Washington and Greene formations of Permian age.

Rogers (1858, p. 16–20) again revised his classification of the Pennsylvanian coal-bearing strata into the following groups:

V. Upper or Newer Coal-Shale, or Upper Barren Group
IV. Upper or Newer Coal-Measures
III. Older Coal-Shale or Lower Barren Group
II. Lower Coal-Measures
I. Seral Conglomerate

The upper or Newer Coal-Measures of this classification correspond approximately to the present accepted definition of the Monongahela formation.

Stevenson (1873, p. 15–32) gave the name "Monongahela River series" to the strata from the base of the clay below the Pittsburgh coal bed to the top of the Waynesburg sandstone, which overlies the Waynesburg coal bed. White (1891, p. 41) included the strata above the top of the Waynesburg coal bed in his Dunkard Creek series, which he classified as Permian in age, and restricted the name Monongahela River series to the rocks between the base of the Pittsburgh coal bed and the top of the Waynesburg coal bed, which he classified as Pennsylvanian in age. The Monongahela River series as defined by White is equivalent to the present Monongahela formation.

The first studies in Belmont County of rocks now assigned to the Monongahela formation were made by Andrews (1874) and Stevenson (1878) who called these strata the "Upper coal measures" and "Upper coal group," respectively. The "Upper coal measures" of Andrews also included the rocks above the Waynesburg coal bed, which are now called the Dunkard group. Prosser (1901, p. 100) used the formation name "Monongahela" of Stevenson (1873) in referring to the Newer coal measures in Ohio, and since that time the name "Monongahela formation" has been used in Ohio to designate all the strata from the base of the Pittsburgh coal bed to the top of the Waynesburg coal bed. In the present classification, the Monongahela formation includes the youngest strata of Pennsylvanian age in the northern Appalachian basin.

DISTRIBUTION

The Monongahela formation crops out in an arcuate band from the southwestern corner to the northeastern corner of Belmont County and along the Ohio River and its tributaries. (See pl. 1.) It has been removed by erosion in parts of western and northwestern Belmont County, and it is covered by strata of Permian age in much of southeastern and northeastern Belmont County. Rocks of the Monongahela are best exposed along the Ohio River valley and its tributaries; however, because of the southeastward regional dip, the basal strata are below drainage in the southeastern part of the county.

Although the various members of the Monongahela formation are well exposed at many localities in the county, continuous outcrops of the entire formation are rare. The best of such outcrops are in road cuts along U.S. Highway 40 beginning at the bridge at Blaine and continuing westward for more than half a mile. This section is typical of the Monongahela formation in eastern Belmont County. Almost continuous outcrops of the lower part of the formation occur along State Highway 7 south of Shadyside. From the north edge of sec. 31, south to the north edge of sec. 29, Mead Township, strata are well exposed from the top of the Sewickley coal bed up to the shale that represents the McKeefrey siltstone member overlying the Little Captina limestone member. From the mouth of Pipe Creek in sec. 11, Mead Township, south to the south edge of sec. 3, York Township, strata are exposed from the Fishpot limestone up to the Waynesburg limestone member. Along Wegee Creek from sec. 32 to the west-central part of sec. 14, Mead Township, the strata included between the basal part of the Fishpot limestone member and the Waynesburg coal bed are well exposed. Good outcrops of most of the members of the formation occur along Deep Run and the adjacent ravines in secs. 26 and 27, Pease Township, and at many localities along Captina, McMahon, and Wheeling Creeks. Many of the better outcrops are shown in the illustrations accompanying the descriptions of the members.

The Monongahela formation is not so well exposed in western Belmont County because the relief is more subdued than in eastern Belmont County. As a result, the soil accumulation is greater, and the land is more extensively cultivated and grazed, thereby obscuring the outcrops. Although badly weathered in places, most of the formation is exposed along the road in the northwestern part of sec. 36, Somerset Township. The Pittsburgh, Sewickley, Uniontown, and Waynesburg coal beds and some of the strata between them are exposed in the roadcuts for U.S. Highway 40 in east-central part of sec. 2, Kirkwood Township, and in sec. 32, Union Township. The Waynesburg coal bed crops out in a cut in U.S. Highway 40 near the east edge of sec. 32, Union Township. Excellent exposures of the strata above both the Pittsburgh and Sewickley coal beds can be seen in the many strip mines in the county. (See pls. 1 and 10 for locations of strip mines.)

THICKNESS

The thickness of the Monongahela formation ranges from 230 feet in the northwestern part of Belmont County to slightly more than 260 feet in the southern and eastern parts (fig. 5). The total westward and northwestward thinning of the formation across the county is approximately 30 feet.

GENERAL CHARACTER

The Monongahela formation consists of interbedded sandstone, siltstone, limestone, and smaller amounts of shale, mudstone, clay, and coal. Of the seven coal beds, only the Pittsburgh and the Sewickley are mined commercially.

Most of the coal beds are persistent throughout the county, but many of the strata between the coal beds undergo facies changes and, as a result, the ratio of limestone to clastic rocks within the formation is variable. Limestone makes up slightly more than 50 percent of the Monongahela formation in parts of eastern Belmont County, but only about 20 percent in the western part where the formation is composed predominantly of sandstone, siltstone, mudstone, and clay.

The mineralogical composition and physical characteristics of the sandstone and siltstone in the Monongahela formation are similar to those of the underlying Conemaugh formation. The sandstone beds, which range from a few inches to approximately 50 feet in thickness, are lenticular, are commonly crossbedded, and vary from massive to thin bedded.

The bases of the sandstone beds at most points lie from a few inches to several feet above the top of a coal bed and are separated from the coal by finer grained clastic rocks which grade into the overlying sandstone. Locally, however, the sandstone beds have undulatory bases, and at such localities it is obvious that a channel was cut into the underlying strata. At a few places the underlying coal bed has been channeled out completely and the sandstone rests directly on the underlying strata.

The siltstone beds, which are more evenly bedded than the sandstone, are usually thin bedded and commonly are interbedded with thin layers of sandstone.

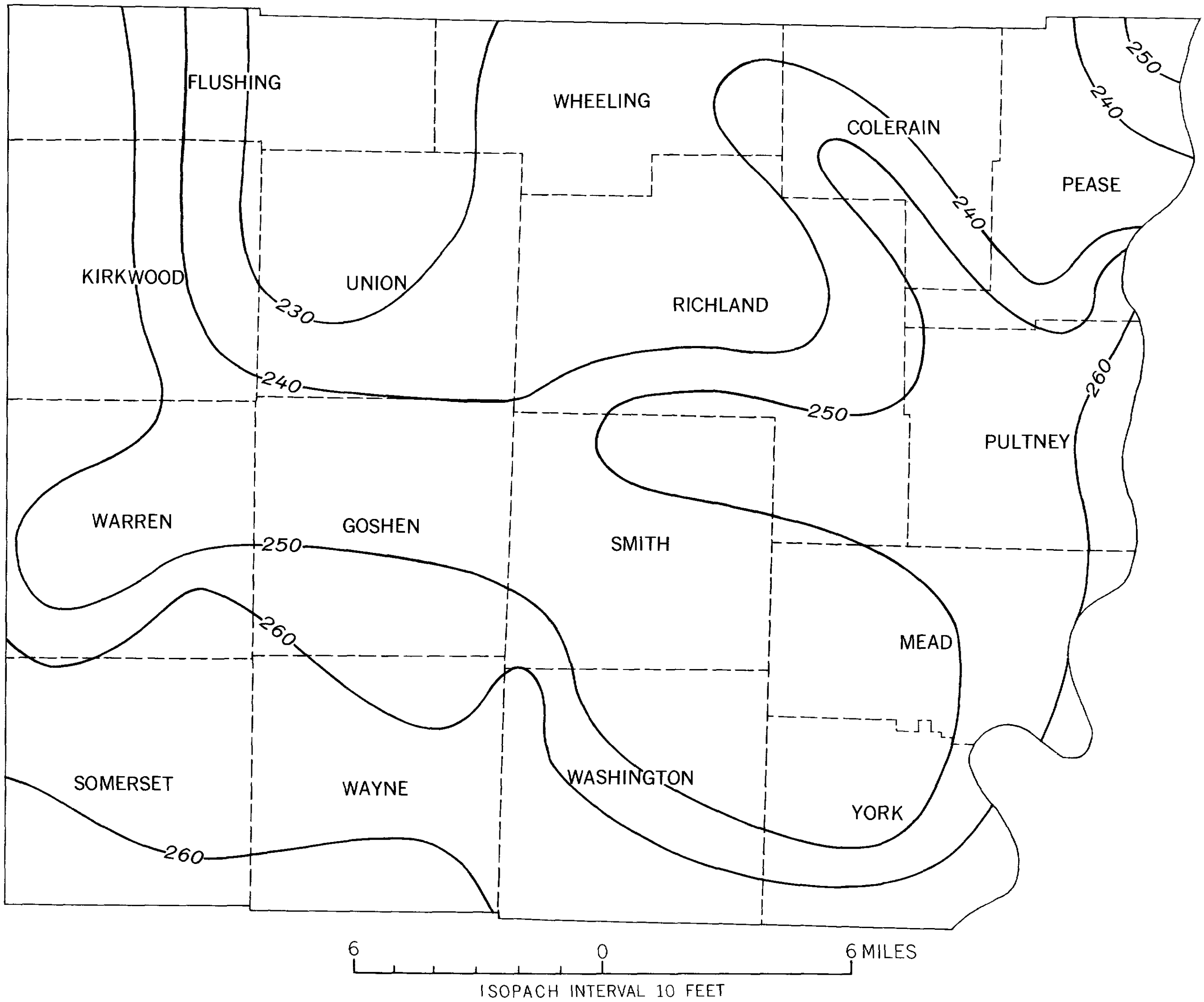

FIGURE 5.—Map showing thickness of the Monongahela formation in Belmont County, Ohio.

The unweathered sandstone and siltstone are gray, but when weathered they are shades of brown or olive gray.

Mica is abundant in both the sandstone and the siltstone, and its presence apparently emphasizes location of the bedding planes. The sandstone beds of the Monongahela formation, similar to the sandstone in the Conemaugh formation, are poorly sorted and appear to have been deposited rapidly with little winnowing. The sand grains are angular to subrounded. The interstices between grains are filled by finely ground mica, feldspar, and clay, which, together with amorphous quartz and iron oxide, form the cement. Many of the sandstone beds, especially the coarser grained ones, become friable after exposure to weathering as the cementing materials are leached away. Grain size of the sandstone varies from fine to coarse, but is aredominantly fine to medium. Conglomerate beds are rare.

Iron occurs in several forms in the Monongahela formation. Concretions containing iron are in the sandstone but are more common in the siltstone. Septarian nodules of calcareous clay-ironstone are present locally in the shale and mudstone just above the coal beds. Siderite nodules occur locally in the siltstone, especially in the very fine grained siltstone. Pyrite and marcasite are common in the shale and in clay partings in the coal beds.

Plant debris, mostly fragments of stems and logs, occurs in the sandstone, particularly in the basal parts. The siltstone and shale that lie just above the coal beds locally contain leaves and other more fragile plant remains.

The limestone occurs in single beds or in sequences of two or more relatively thin beds separated by partings of calcareous mudstone or soft shale. Limestone also occurs as nodular masses in clays and mudstones.

Locally, individual limestone beds within a member coalesce laterally or grade into calcareous clay or mudstone, and some limestone sequences grade laterally through a zone of mudstone into siltstone and sandstone. Some of the beds of limestone are persistent for long distances.

Most of the limestone in the Monongahela formation contains clay and silt, and, depending upon the amount of these materials, the limestone beds vary from hard and resistant to soft and marly. The beds of impure limestone weather relatively rapidly to clay, but the purer beds commonly form angular to rounded ledges. The texture of most of the limestone is very finely crystalline, which gives it a smooth homogeneous appearance. Large crystals of calcite, siderite, and magnesium carbonate are present locally.

The weathered limestone is light to dark gray, but on a fresh fracture the predominant shades are light olive gray and light brownish gray. The purer limestone weathers light gray, whereas the more argillaceous limestone weathers yellowish gray to grayish yellow.

Small gastropods, small pelecypods, ostracodes, *Spirorbis*, some fish remains, and some plant remains are present in the limestone. The presence of a diminutive and nondiveısified fauna implies either a brackish- to fresh-water environment or hypersaline conditions. No saline deposits have been found in the Monongahela formation anywhere in the northern Appalachian basin. To the contrary, the great abundance of coalified plant debris indicates a humid climate during Pennsylvanian time, and a brackish- to fresh-water depositional environment is indicated.

The calcium carbonate content of the limestone ranges from 48 to 80 percent, the magnesium carbonate from 9 to 26 percent, and the combined silica and silicate minerals from 6 to 20 percent. Analyses of the individual limestone beds are included with the descriptions of the members of the formation.

The clay of the Monongahela formation occurs beneath the coal beds. It is usually soft and pliable and commonly contains iron, lime, and silt impurities. The clay ranges in thickness from a few inches to about three feet. In some places the clay is hard enough to be classified as claystone.

The coal beds range in rank from high-volatile bituminous A to high-volatile bituminous B. The lateral persistence of the coal beds and the uniformity of the intervals between them are distinctive features of the Monongahela formation in the county. The coal beds, therefore, are key stratigraphic markers.

DESCRIPTION OF MEMBERS

The Monongahela formation in Belmont County was subdivided by the writer into 16 members, 12 of which were recognized on the basis of correlation with members already named in West Virginia and Pennsylvania. In addition to the 16 members, the Monongahela formation contains 7 coal beds. Following is a list of the members and coal beds of the Monongahela formation in Belmont County. Their stratigraphic relations are shown in the generalized section for the Monongahela formation included on plate 2.

Waynesburg (No. 11) coal bed
Gilboy sandstone member
Little Waynesburg coal bed
Waynesburg limestone member
Uniontown sandstone member
Uniontown (No. 10) coal bed
Uniontown limestone member
McKeefrey siltstone member
Little Captina limestone member
Arnoldsburg sandstone member
Arnoldsburg limestone member
Morningview sandstone member (including lower tongue)
Benwood limestone member
Sewickley sandstone member
Sewickley (No. 9) coal bed
Fishpot sandstone member
Fishpot coal bed
Fishpot limestone member
Redstone sandstone member
Redstone (No. 8A) coal bed
Redstone limestone member
Pittsburgh sandstone member
Pittsburgh (No. 8) coal bed

PITTSBURGH (NO. 8) COAL BED

The Pittsburgh coal bed, the basal unit of the Monongahela formation, was originally named and described by Rogers (1839, p. 96–97) for its exposures at Pittsburgh, Pa. In Belmont County the Pittsburgh coal bed was known as the Bellaire coal bed along the Ohio River and as the Lower Barnesville coal bed in the southwestern part of the county, until Stevenson (1878, p. 267) correctly correlated it with the Pittsburgh coal bed of Pennsylvania.

The Pittsburgh coal bed generally occurs in two benches, separated by a clay parting that ranges from a few inches to as much as 3 feet in thickness. The lower bench forms the main part of the bed and contains all the minable coal. The reserve tonnages and thicknesses in this report are based entirely on the lower bench. The upper bench, which is thin and impure, is absent in the extreme western part of the county, but contorted lenticular masses of coal locally embedded in the base of the overlying sandstone indicate that the upper bench was partly scoured when the sandstone was deposited. Uniformity in thickness and regularity in the occurrence of certain partings characterize the Pittsburgh coal bed over most of Belmont County. Plate 4 is an isopach map which shows the distribution of the bed and the thickness of the coal in the lower bench.

In the eastern three-fourths of Belmont County, the lower bench of the Pittsburgh bed averages 60 to 64 inches in thickness with only a few local variations. It has a thickness of more than 72 inches in northeastern Washington Township, and it is reported by mine operators to be 84 inches thick along the narrow syncline in Pultney and Pease Townships. At the McConnaugh mine in sec. 31, Union Township, the lower bench is 96 inches thick. At a few localities, mainly along Wheeling Creek in Wheeling and Colerain Townships, the lower bench is slightly less than 60 inches thick.

In the extreme western part of Belmont County, only the lower bench of the Pittsburgh coal is present, and it is more variable in thickness, ranging from 8 to 60 inches. The part of the bed shown on plate 2 within the 42- to 60-inch thickness category averages about 50 inches thick, and that part in the 28- to 42-inch thickness category averages 38 inches. Core holes drilled in southwestern Goshen and northwestern Wayne Townships show an area in which the coal is less than 42 inches thick. In the southwestern corner of Belmont County, in Somerset Township, the coal thins abruptly from 42 inches to less than 12 inches. This is the only area in the county where the Pittsburgh coal bed is too thin to be mined.

The upper bench or "roof coal" of the Pittsburgh bed ranges from a few inches to more than 3 feet in thickness, but averages from 14 to 18 inches.

Three to five claystone, bone, or pyrite partings are common in the Pittsburgh coal bed. Locally, however, there are more than five partings. The positions of these partings and the thickness of the coal are shown in plate 5, which contains diagrammatic sections of the Pittsburgh bed.

In the eastern three-fourths of the county the most extensive parting is the claystone, which separates the bed into two benches. It ranges from a few inches to more than 3 feet in thickness and is commonly called "draw slate" by miners. At a few isolated localities this parting is absent and the upper bench of the bed lies directly on the lower bench.

At most places the lower bench of the Pittsburgh coal bed contains two or three thin pyritic claystone and bone partings that are remarkably persistent. (See pl. 5.) Bone is a hard, tough impure coal containing much silty material. Two of these partings, which are 2½ to 6 inches apart, are commonly near the center of the lower bench of the bed. They are ½ to 1¾ inches thick and consist of carbonaceous claystone impregnated with pyrite. Locally, one of these partings may be only a paper-thin layer of either pyrite or bone. The coal between the two partings is called the "bearing-in-coal" by the miners. It commonly contains thin lenticular streaks of fusain or mineral charcoal. A third parting occurs in some places from 12 to 18 inches above the base of the lower bench. This parting generally consists of pyrite-impregnated bone ranging from ⅛ to ¾ inch in thickness. In a few places, pyrite disks as much as 18 inches in diameter and 6 inches thick occur at the position of the lower parting. Several of these disks were found in the strip mine in the SW¼NE¼ sec. 27, Warren Township. Locally, a ¼- to ½-inch layer of bone occurs about 12 inches below the top of the lower bench. In addition to these somewhat persistent partings, thin lenticular layers of fusain, pyrite, or bone are locally present.

"Clay veins" are in the lower bench of the Pittsburgh coal bed where the claystone parting thickens either upward or downward at the expense of the coal. At some places the entire lower bench is of carbonaceous claystone. The "clay veins" range from a few feet to a few tens of feet in width. These "veins" probably resulted from lateral variation in the amount of sediment deposited within the coal basin, and they may indicate the position of stream channels. Thinner "clay veins" that have a definite crosscutting relation to the coal are probably fillings of fissures formed in the coal bed by minor crustal disturbances. The lower bench of the Pittsburgh coal bed is underlain by impure claystone of irregular thickness that grades to a plastic clay at some places.

The upper bench of the Pittsburgh coal bed generally contains several irregular clay partings ranging from a fraction of an inch to several inches in thickness. Several thin bands of carbonaceous and coaly clay and thin lenticular stringers of coal are usually interbedded with the claystone above the main layer of the upper bench. The stringers of coal are erratic in their occurrence and are generally deformed. As previously mentioned, the deformed lenses of coal above the lower bench in the western part of the county may represent the upper bench.

In the past, when hand-cutting tools were used to mine the coal, the following terminology, based primarily on the position of the partings just described, was applied to the Pittsburgh coal bed:

Roof coal	Upper bench
Draw slate	
Breast coal	Lower bench
Parting	
Bearing-in-coal	
Parting	
Brick coal	
Parting	
Bottom coal	

The Pittsburgh coal bed has a prominent vertical cleavage or joint pattern which consists of two sets of joints or "cleats." The joints represent lines of weakness that probably developed during the solidification of the coal and during regional structural stresses. Because of these joints the coal breaks into cubes when it is mined or exposed to the weather. The most conspicuous of these joints is called the "face" by the miners. It is the direction in which the bed breaks most readily. The average strike of the "face" is N. 75° W. The second direction of fracture is at right angles to the main direction of fracture and is called the "butt" by miners. In general, the part of the bed below the two closely spaced partings in the lower bench tends to break into large-sized cubes or blocks and the upper part of the lower bench tends to break into smaller sized blocks.

Macrostructure

The Pittsburgh is a banded coal. The banding is caused by alternate layers of anthraxylon, fusain, and attritus. Anthraxylon is the ingredient forming the shiny black bands that have a vitreous appearance and conchoidal fracture. According to Thiessen (1931, p. 118) it comprises the constituents in coal that are derived from the woody tissues of plants—such as stems, limbs, and branches, including both wood and cortex—which are changed and broken up into fragments of a wide variety of sizes through biological decomposition and weathering during the peat stage and which are later flattened and transformed into coal through the coalification process but are still definite unit constituents. In thin section these bands invariably reveal some of the original plant structure. Thiessen states further that it is mainly the anthraxylon that possesses the coking properties and it chiefly lends these properties to the coal as a whole.

Fusain is the material forming the dull black bands resembling charcoal, and in older reports is often referred to as "mineral charcoal." It is soft and typically has a fibrous and porous structure. Because it is not cleated and is not cohesive, fusain commonly forms planes of weakness parallel to the bedding of the coal. Fusain is the "dirty" constituent of coal; during mining it generally disintegrates into very fine coal dust.

Attritus consists of the very fine vegetal particles within the coal including spore-exines, resinous matter, cuticular matter, and other woody degradation products. Thiessen and Francis (1929, p. 11) considered attritus a general coal matrix that appears uniformly granular and amorphous except at high magnification. Parks and O'Donnell (1956, p. 6) say that attritus is derived from the same class of plant remains as anthraxylon, but it has been subjected to intensive and relatively rapid biochemical alteration, which has resulted in a variable but comparatively high degree of carbonization.

Although no detailed petrographic study was made of the various coal constituents of the Pittsburgh coal bed in Belmont County, a number of megascopic observations were made. Anthraxylon in the Pittsburgh coal bed occurs generally in thin (1/60 to 1/12 inch) laminae with some thicker layers ranging from 1/12 to 1/5 inch. It is estimated that the anthraxylon content averages about 50 percent. The concentration of anthraxylon bands varies from one part of the bed to another and also from one locality to another. In general, anthraxylon is more abundant in the lower part of the bed.

In the Pittsburgh coal, fusain forms thin lenticular layers distributed throughout the bed. The fusain content of the Pittsburgh coal bed in Belmont County is generally low.

Other megascopic minerals in the Pittsburgh coal bed are pyrite and sulfate. The occurrence of pyrite in the regular partings in the coal bed has already been described. Pyrite is also present as very thin lenticular sheets and as large discoid nodules within the coal. Sulfate occurs as white vitreous encrustations on the "cleat" or joint surfaces of the coal.

Quality

Coal from the Pittsburgh bed is of high-volatile A bituminous rank throughout most of Belmont County. There is some variation in rank from east to west across the county. The coal from the east is slightly higher in Btu or heating value and slightly lower in ash content. Some of the coal in western Belmont County is of high-volatile B bituminous rank. As shown by 17 analyses on the "as-received" basis, the coal in eastern Belmont County has a heat value of 13,081 Btu, and the coal in western Belmont County as shown by 12 analyses (as received) has a heat value of 12,659 Btu.

The available analyses of the Pittsburgh coal bed are given in table 11.

At the south end of the ridge near the center of sec. 17, Kirkwood Township, for a distance of 75 feet or more laterally, the entire thickness of the Pittsburgh coal bed is composed of a reddish material described by Charles Milton as "burnt earth." The material is earthy and is composed of clay-sized particles. It has a low specific gravity, is vesicular, and ranges from pale red to moderate reddish orange. Some of the material is dark gray and because it is more resistant to weathering forms rubble of fist-sized chunks. Few, if any, quartz grains are in the material, but fragments of kaolinized feldspar occur in small quantities. The appearance of the material suggests that it is "burnt earth"; however, the contact between this material and the adjoining coal bed is very sharp and even. No deformation or evidence of burning was seen. The bedding of the strata both above and below the red material seems to be normal. The Upper Pittsburgh limestone member, which is present a few feet below the "burnt earth," is also red.

REDSTONE LIMESTONE MEMBER

In the eastern three-fourths of Belmont County, the Redstone limestone member overlies the Pittsburgh coal bed (pl. 6). In the extreme western part of the county, the interval of the limestone is occupied by the Pittsburgh sandstone member (pl. 4).

The name "Redstone" was originally given by Franklin and W. G. Platt (1877, p. 55–104, 286) to an 8- to 10-foot limestone which they designated as the basal member of the Pittsburgh limestone group in southwestern Pennsylvania. They gave its position as 30 feet above the Pittsburgh coal and directly below the Redstone coal.

White (1891, p. 62–63) used the name "Redstone" for the limestone beneath the Redstone coal bed on Redstone Creek, Fayette County, Pa. He correlated the Redstone limestone of Pennsylvania with the limestone between the Pittsburgh and Redstone coal beds in eastern Belmont County, Ohio.

The Redstone limestone member is persistent over the eastern three-fourths of Belmont County and ranges in thickness from 18 feet in sec. 23 E., Richland Township, to as much as 30 feet in the northwestern part of sec. 31, Union Township. Its average thickness is slightly more than 20 feet. Plate 6 contains diagrammatic sections that show the stratigraphic position of the limestone, its thickness, character, and relation to the Pittsburgh sandstone member.

The Redstone in most places consists of four or more massive beds of limestone, which vary from hard and resistant to soft and crumbly. At most places thin layers of claystone or soft shale lie between the beds of limestone. At the base of the member is a unit of calcareous claystone that ranges from about 4½ to 11 feet in thickness. In sec. 31, Union Township, and sec. 31, Somerset Township, the claystone is locally absent.

The claystone at the base of the member is shaly and contains in its upper part limestone nodules at most places. At some places thin carbonaceous clay bands and thin lenses of coal are interbedded with the basal part of the claystone. The claystone weathers to shaly clay, which is commonly light olive to light greenish gray. But along the tributary to Rock Creek in secs. 31 and 32, Somerset Township, at the southwestern corner of the county, this clay is variegated gray and grayish red.

An outcrop showing the typical character of the member in the eastern part of the county is in the NW¼SW¼ sec. 36, Pultney Township, along the bank of State Highway 147, where 7 feet of claystone is overlain by four closely spaced, massive beds of limestone, each 3½ to 4 feet thick (pl. 6, section 22). A detailed description of that section follows:

	Thickness Ft.	In.
Monongahela formation:		
Redstone coal bed and associated clay:		
Mudstone, light-gray, hard; crumbles after desiccation; contains 6-in. hard calcareous layer in center and 1-in. carbonaceous band thick at base	1	8
Redstone limestone member:		
Limestone, medium-gray, argillaceous; has faint brownish hue	1	5
Limestone, medium-gray, massive, hard; has a light-olive hue; contains 1- to 2-in. shaly band near center; conchoidal fracture	3	5
Limestone, medium-gray, massive, hard; has light-olive hue; contains a 1- to 1½-in. shaly band 1 ft 5 in. above base	4	0
Shale, light-olive-gray, soft, calcareous		1
Limestone, medium-gray, massive, argillaceous; has light-olive hue and subconchoidal fracture; undulatory base; contains highly fragmented fossil remains	2	9
Claystone; contains light-olive-gray limestone nodules in upper half	7	0
Pittsburgh coal bed.		

Thin calcareous shaly soft clay partings locally separate the limestone beds, which are dense and relatively resistant to weathering. Individual beds of limestone generally protrude as rounded ledges. In eastern Belmont County the undulatory tops and bottoms of the limestone beds in the Redstone member distinguish it from the more even bedded Fishpot limestone member that lies just above.

In west-central Belmont County, where the Redstone member locally grades into the deltaic Pittsburgh sandstone member, the beds of limestone are more variable in number, more argillaceous, and less resistant to weathering. They are separated by a greater amount of interbedded clay and soft shale and are locally conglomeratic. (See pl. 6.) Three of the limestone beds, however, are fairly widespread. The most extensive is a 2- to 3½-foot bed that is light brownish gray and, at many places, forms a prominent angular ledge from 5 to 7 feet above the Pittsburgh coal bed. This bed contains clayey laminae and the upper part is locally conglomeratic. Several feet above this bed is very argillaceous limestone, which commonly ranges from 4 to 7 feet in thickness and is distinctive because of its conspicuous yellowish color and its tendency upon weathering to break into large irregular slabs that spall off normal to the bedding. Because of the large amount of contained clay, the limestone weathers rapidly and is seen only in the strip mines. The third bed, which ranges from 1 to 3½ feet in thickness, commonly forms a ledge several feet below the clay that is associated with the Redstone coal. This bed, which is similar to the one just above the Pittsburgh coal bed, also contains clayey laminae and is locally conglomeratic. The detailed section below, measured in the high wall of a strip mine in the north-central part of sec. 24 E., Flushing Township, is typical of the member in the western part of Belmont County.

	Thickness *Ft.*	*In.*
Monongahela formation:		
Redstone coal bed and associated clay.		
Redstone limestone member:		
Limestone, yellowish-gray to dusky-yellow, very argillaceous; breaks into jagged, irregularly shaped fragments upon weathering; variable in thickness	6	0
Limestone, yellowish-gray; forms persistent protruding ledge; contains clayey laminae; upper part conglomeratic laterally, and the pebbles seem to be penecontemporaneously disturbed desiccation fragments; variable in thickness	3	0
Limestone, yellowish-gray to dusky-yellow, very argillaceous, persistent; weathers rapidly into jagged, irregularly shaped fragments in the same manner as uppermost unit	4	6
Siltstone, light-olive-gray, very fine grained, shaly, highly calcareous	2	0
Limestone, light-gray, massive; has slight brownish hue; forms persistent angular protruding ledge; contains clayey laminae and is conglomeratic laterally; weathers almost white at some places; variable in thickness	3	7
Mudstone, olive to greenish-gray; contains silty limestone nodules near the top	5	0
Pittsburgh coal bed.		

Locally, the entire lower half of the member is argillaceous yellowish limestone. (See pl. 6, section 5, which was measured in a strip mine in sec. 31, Union Township.) Figure 6 shows the general character of the Redstone limestone member in west-central Belmont County. The thick stratum just above the center of the picture is the persistent middle bed of argillaceous yellowish limestone. In sec. 31, Somerset Township, the Redstone limestone member is split into two parts by a siltstone tongue of the Pittsburgh sandstone member (pl. 6, section 13). The uppermost bed of the Redstone limestone member in secs. 31 and 32, Somerset Township, is distinctive and forms an angular ledge about 2 feet thick. It is brownish gray, contains many siliceous laminae and a carbonaceous band near the center, and tends to weather into slabs and plates. The bed also contains a profusion of small pelecypods. The best outcrop of this limestone bed is in the east bank of the tributary to Leatherwood Creek near the southwestern corner of sec. 32, Somerset Township. In sec. 33, Warren Township, the Redstone member consists of 10 feet of clay and a thin nodular bed of limestone that overlie the Pittsburgh sandstone member (pl. 6, section 15).

FIGURE 6.—Exposure of the Redstone limestone member (*a*) showing the argillaceous character of the member in west-central Belmont County. Carbonaceous clay (*b*) at the top of the cut lies at the position of the Redstone coal bed. The Pittsburgh coal bed (*c*) at the base of the cut is obscured by talus. Photographed in strip mine in sec. 2, Kirkwood Township.

In several places in the northwestern part of the county, the Redstone has been channelled out by the massive upper part of the Pittsburgh member (pl. 6, section 4).

The color of the limestone in the Redstone member ranges from medium gray to light olive and light brownish gray. Because of clay and silt impurities, much of the limestone in the western part of the county is yellowish gray to dusky yellow, especially that in the central part of the member.

Locally, throughout the county, the tops of some of the beds of limestone are sedimentary breccias. Shrinkage cracks occur in the Redstone in sec. 22 E., Richland Township, and the casts of these cracks are in the base of the overlying bed (fig. 7).

In addition to clay and silt impurities, small amounts of siderite are present in the Redstone limestone member.

The fossils are diminutive forms of gastropods, pelecypods, ostracodes, *Spirorbis*, and highly fragmented fish remains. The pelecypods seem to be mainly in the uppermost bed of the member.

PITTSBURGH SANDSTONE MEMBER

The Pittsburgh sandstone member occurs in the western fourth of Belmont County and is in part a stratigraphic equivalent of the Redstone limestone member. (See pl. 4 for the areal distribution of the sandstone and pl. 6 for the stratigraphic relation of the sandstone and limestone.)

Rogers (1858, p. 505) originally used the name Pittsburgh sandstone to designate a sandstone overlying the Pittsburgh coal bed in Greene County, Pa. White (1891, p. 63), in his report on the bituminous coal field of Pennsylvania, Ohio, and West Virginia, also used the name "Pittsburgh" to designate the sandstone that occupies the interval between the Pittsburgh and Redstone coal beds in some parts of the northern Appalachian coal basin.

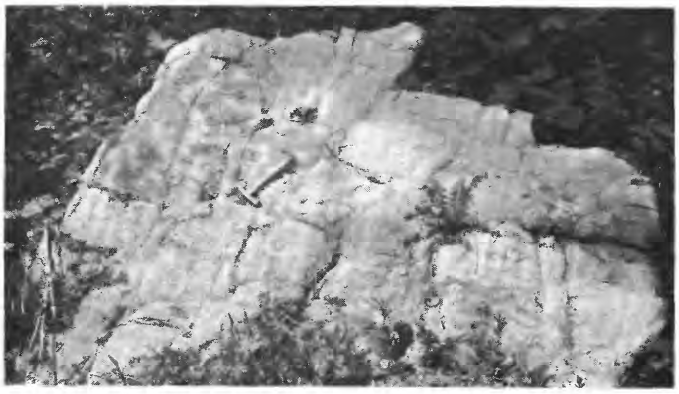

FIGURE 7.—Casts of shrinkage cracks on the bottom of a bed in the Redstone limestone member. Photographed in the east-central part of sec. 22 E., Richland Township.

The Pittsburgh sandstone member underlies parts of Flushing, Kirkwood, Warren, Goshen, Somerset, and Wayne Townships, and its thickness ranges from a few inches to 50 feet.

The Pittsburgh sandstone member is part of a deltaic deposit that covers, in addition to western Belmont County, parts of Harrison County to the north, Guernsey County to the west, and Monroe County to the south. This deposit seems to represent two stages of clastic deposition. The lower part of the member consists mostly of fine-grained sandstone, siltstone, and mudstone, which laterally intertongues with the Redstone limestone member and represents contemporaneous deposition with the limestone. The upper part, which makes up most of the member, is massive channel-type sandstone of variable thickness that unconformably overlies the finer grained part of the member. In places all the strata down to the underclay beneath the Pittsburgh coal bed have been removed and their stratigraphic position filled by coarse-grained sandstone. In parts of northwestern Union, northeastern Kirkwood, and central Flushing Townships, the coarse-grained sandstone extends eastward beyond the underlying fine-grained sandstone and siltstone and unconformably overlies the Redstone limestone member. Excellent outcrops show the channel relation of the sandstone to the limestone in the high wall of the strip mine in the NE¼ sec. 7, Flushing Township (pl. 6, section 4). Section 4 in plate 6 also shows the stratigraphic position of a lens of allochthonous (transported) coal that lies within the Pittsburgh sandstone member.

The fine-grained sandstone and siltstone beds in the lower part of the member are generally only a few feet thick; however, they are believed to have been thicker, but were partly scoured away prior to deposition of the overlying massive sandstone. Sections 1, 2, 14, 15 and 16 of plate 6 show the relation of the fine-grained rocks to the overlying massive sandstone. Thin-bedded siltstone comprises the lower part of the Pittsburgh sandstone member in most places, and locally the siltstone grades downward into soft clayey shale or shaly mudstone that rests on the top of the Pittsburgh coal bed. The siltstone contains plant remains and in places a thin coal band which apparently is equivalent to the upper bench of the Pittsburgh coal bed of eastern Belmont County.

In the northwestern part of sec. 36, Union Township, the lower part of the Pittsburgh sandstone member grades laterally into the Redstone limestone member through a zone of shale containing many carbonaceous plant remains. This gradation was observed in the wall of a strip mine. Near the southwestern corner of the county, the siltstone phase intertongues with the Redstone (pl. 6, section 13). The unconformity between the siltstone and the overlying massive sandstone is well exposed in the strip mine on the south side of the stream in the northeastern part of sec. 33, Warren Township (pl. 6, section 15). At this locality the sandstone is overlain by clay and limestone. A detailed description of this outcrop follows:

	Thickness Ft.	In.
Monongahela formation:		
Redstone coal bed?:		
Clay, weathered; position of Redstone coal?	5	0
Redstone limestone member?:		
Limestone, nodular		6
Clay, brownish; weathered	5	0
Pittsburg sandstone member:		
Sandstone, light-gray, fine- to coarse-grained, crossbedded, micaceous, poorly sorted; has undulatory, channel-type base; variable in thickness	13	0
Siltstone, medium-gray, thin-bedded, micaceous; variable in thickness	3	0
Pittsburgh coal bed:		
Coal, lenticular; upper bench		1½
Mudstone, olive-gray, shaly; contains carbonaceous bands	2	0
Lower bench covered by talus at base of high wall.		

The massive upper part of the Pittsburgh sandstone member is a sheetlike body that underlies western Flushing and western Kirkwood Townships, and most of Warren and Somerset Townships. Data from drill holes indicate that it extends into southwestern Goshen and western Wayne Townships. The massive coarse-grained sandstone first filled channels that had been cut into the lower siltstone and locally into the Redstone limestone member. After filling these channels, the coarse-grained sandstone was spread laterally to form a sheet deposit that approximates the width of the older siltstone deposit. The upper sandstone is irregularly bedded and crossbedded, medium to coarse grained, micaceous, poorly sorted, and has an undulatory base. Some lenses of conglomerate consisting of well-rounded limestone pebbles in a sandstone matrix lie near the base. Such a conglomerate is exposed in the strip mine in the northeastern part of sec. 7, Flushing Township. Coalified and pyritized log fragments and thin distorted stringers of coal also occur locally near the base. Excellent outcrops of the massive upper sandstone that contains fossilized logs occur in the small strip mine north of Barnesville in the southwestern part of sec. 17, Warren Township, and in the small strip mine north of U.S. Highway 40 in the northwestern part of sec. 20, Kirkwood Township. Fresh exposures of the sandstone are medium to light gray, but weathered exposures are rusty brown. Locally, pyrite is abundant and its breakdown upon weathering forms yellow blotches of sulfur. Encrustations of white powdery organic sulfate form in places after the sandstone is exposed to moisture and air.

The fine-grained sandstone and siltstone of the Pittsburgh sandstone member was deposited near the terminus of a deltaic lobe and is equivalent to at least the lower part of the Redstone limestone member. The massive sandstone, which unconformably overlies the fine-grained rock and locally the Redstone limestone member, represents a change in the pattern of deposition, which brought coarse-grained sand into this part of the basin, probably as a result of a lowering of base level.

At some places, thin limestone layers overlie the massive sandstone phase of the member (pl. 6, section 15). Presumably these are localized deposits within the delta, but they may be equivalent to the uppermost part of the Redstone limestone member.

REDSTONE (NO. 8A) COAL BED

White (1891, p. 62) used the name "Redstone" to designate a thin coal bed that crops out along Redstone Creek in Fayette County, Pa., 40 to 45 feet above the Pittsburgh coal bed. He correlated the thin coal and associated clay 20 feet above the Pittsburgh coal bed in eastern Belmont County with the Redstone coal bed of Pennsylvania. White states that the name "Redstone" was originally used by the geologists of the First Pennsylvania Geological Survey. The Redstone coal bed is probably equivalent to the Pomeroy coal of southeastern Ohio.

The Redstone coal bed is 18 to 50 feet above the Pittsburgh coal bed. The average interval between the two coals is about 20 to 25 feet in eastern Belmont County but increases westward to as much as 50 feet in the western parts of Flushing, Kirkwood, and Somerset Townships. Plate 6 shows the intervals between the two coals across the county.

The Redstone coal overlies the Redstone limestone member in the eastern three-fourths of the county and overlies the Pittsburgh sandstone member in the western fourth. It is represented in most places either by an impure shaly coal, generally less than 2 inches thick, or by several thin bands of carbonaceous clay. Along Cat Run in sec. 20, York Township, however, the coal thickens in places to slightly more than 2 feet but is impure (pl. 6, section 21). In the eastern three-fourths of Belmont County, the thin coal and carbonaceous bands always occur in a bed of greenish-gray clay that ranges from 3 to 5 feet in thickness, but in the western fourth of the county, the clay is more variable in thickness and is commonly gray with a grayish-red layer in the upper part. The lower part of the clay contains discontinuous beds of nodular limestone.

Figure 8 shows the character of the coal bed and its stratigraphic relation to the underlying Redstone limestone and overlying Fishpot limestone members.

FIGURE 8.—Exposure of the upper part of the Redstone limestone member (*a*), the Redstone coal (*b*), and the lower part of the Fishpot limestone member (*c*). The Redstone coal is 2 inches thick in a bed of clay separating the limestone members. Photographed in a strip mine in the northwestern part of sec. 30, Colerain Township.

REDSTONE SANDSTONE MEMBER

The Redstone sandstone member, which is a stratigraphic equivalent of the lower part of the Fishpot limestone member, was seen only in the southwestern corner of Somerset Township, in the western part of Flushing Township, and along Cat Run in sec. 20, York Township, in eastern Belmont County. (See pl. 7, sections 2, 10, and 15 for its general distribution and stratigraphic position.) The thin layer of shaly sandstone that is interbedded in the upper part of the Fishpot limestone member in sec. 27, Pease Township, may be a tongue of the Redstone sandstone member (pl. 7, section 9).

Swartz, Price, and Bassler (1919, p. 567–596) and Swartz (1922, p. 74) used the name "Redstone" to designate the sandstone that lies between the upper and lower benches of the Redstone coal bed in the Georges Creek basin of western Maryland. The sandstone present above the Redstone coal bed in parts of Belmont County is named the Redstone sandstone member of the Monongahela formation in this report.

The Redstone sandstone member is lenticular and variable in grain size. In the southeastern part of Belmont County, in sec. 20, York Township, the member consists of siltstone and silty shale having a combined thickness of approximately 9 feet. In sec. 32, Somerset Township, it is made up of 9 feet of siltstone and 2 feet of sandstone.

FISHPOT LIMESTONE MEMBER

Stevenson (1876, p. 67) used the name "Fishpot" to designate a limestone unit in the strata between the Redstone and Sewickley coal beds along Fishpot Run in Washington County, Pa. Condit (1923, p. 51) used the name "Fishpot" for the limestone below the coal, which he named the Lower Meigs Creek bed (Fishpot coal bed of this report), and this usage has been retained.

The Fishpot limestone member is uniform and persistent (pl. 7). It ranges from 23 to 31 feet in thickness in all parts of Belmont County, except near the southeastern and southwestern corners where the stratigraphic position of the lower part of the member is occupied by the sandstone, siltstone, and shale of the Redstone sandstone member.

The member consists of several beds of limestone, which individually range in thickness from about 9 inches to as much as 4 feet. The Fishpot limestone member is more evenly bedded than the older Redstone limestone member. Slight differences in lithology distinguish the lower part of the member from the upper part. The beds of limestone in the lower part are somewhat more argillaceous than those in the upper part and are generally interbedded with several layers of calcareous shaly clay or calcareous shale as much as 3 feet in thickness (pl. 7, section 13). A remarkably persistent bed of limestone, 1½ feet thick, lies from 8 to 9 feet above the base of the member. It is traceable across northern Belmont County from southwestern Union Township to the eastern outcrop limit of the Fishpot limestone member in eastern Pease Township—a distance of 20 miles. This bed, which weathers to a very light gray to white angular ledge, contains several distinctive argillaceous laminae that weather light yellowish brown and are offset by small normal faults within the bed. Figure 9 shows the faulted laminae.

FIGURE 9.—Boulder from a persistent bed of laminated limestone in the lower part of the Fishpot limestone member showing faulted laminae. Photographed in a strip mine in sec. 21, Pease Township.

The upper limestone beds of the Fishpot are purer than those in the lower part. The pure beds are separated by beds of shaly, argillaceous limestone or calcareous shale that are nowhere more than an inch or two thick. In the eastern two-thirds of Belmont County the 3 to 5 resistant beds at the top of the member characteristically form protruding ledges. Underlying these beds is a persistent argillaceous limestone which forms a reentrant and which has a conspicuous conchoidal fracture. This bed and the overlying ledge-forming beds are shown in the sections in plate 7 and also in figure 10.

The Fishpot limestone member is described in detail in the following section, which was measured in a strip mine in the southeastern part of sec. 3 W., Wheeling Township:

	Thickness Ft.	In.
Monongahela formation:		
Fishpot coal bed (lenticular ½-in. carbonaceous band lying on top of limestone below).		
Fishpot limestone member:		
Limestone, light-olive-gray, silty		11
Shale, olive-gray, soft, calcareous		3
Limestone, light-olive-gray, massive, siliceous, laminated; contains angular limestone fragments	2	0
Shale, olive-gray, soft, very calcareous		4
Limestone, light-olive-gray to yellowish-gray, laminated; contains two thin shaly partings that cause it to weather into three beds, the uppermost of which is highly argillaceous	3	4
Limestone, light-olive-gray, massive, argillaceous; contains many angular limestone fragments and is a limestone breccia rather than a conglomerate	3	4
Mudstone, light-olive-gray, calcareous		9
Limestone, light-olive to yellowish-gray, massive, slightly argillaceous, conchoidal fracture	2	3
Mudstone, greenish-gray, calcareous	1	0
Limestone, light-olive-gray, massive, siliceous; conchoidal fracture	2	3
Shale, greenish-gray to dusky-yellow-gray, soft		10
Limestone; distinctive laminated bed having thin silty laminae offset by small-scale faults; laminae weather dusky yellow gray and the main part of the bed very light yellowish gray; persistent across the northern half of the county	1	7
Limestone, light-olive-gray, silty; contains lenses of small-pebble limestone conglomerate; weathers olive to brownish gray	1	0
Shale, light-olive-gray, soft, highly calcareous		2
Limestone, yellowish-gray, massive, argillaceous; limestone breccia in part	1	4
Shale, greenish-gray, soft, calcareous		3
Limestone, brownish-gray, laminated, silty; contains two thin shale partings	1	3
Shale, dark-gray, soft, calcareous; contains limestone nodules		3
Limestone, light-olive-gray, massive, siliceous; conchoidal fracture	1	2
Limestone, highly argillaceous; nodular	1	0
Mudstone, pale dusky yellow to greenish-gray. Overlies carbonaceous clay which takes the place of Redstone coal bed.		

Some of the limestone beds are locally fragmental and form limestone breccias. This suggests a shallow-water environment of deposition interrupted by short periods of subaerial erosion during which the surface

FIGURE 10.—Outcrop of the upper part of the Fishpot limestone member in the SE¼NE¼ sec. 9, Colerain Township, showing typical weathering characteristics. The overlying Fishpot coal bed is concealed in the brush in the upper part of the photograph.

was desiccated and cracked. Later currents reworked the fragments and redeposited them as breccias.

The fresh surfaces of most of the limestone beds of the Fishpot member are light brownish gray to light olive gray. After weathering they are light gray and yellowish gray.

Diminutive forms of gastropods, ostracodes, and *Spirorbis* occur in the Fishpot limestone member.

The upper part of the Fishpot has been quarried at several places, mainly in the western part of the county, for road metal, agricultural lime, and cement. Limestone of the Fishpot from a quarry just southwest of Barnesville was used in making the cement for the Baltimore and Ohio Railroad bridge at Bellaire. Only two quarries are now active in the county. One is in the northeastern part of sec. 31, Somerset Township, and the other just north of the southeastern corner of sec. 30, Wayne Township.

The sample for the following analysis of the Fishpot limestone member was collected by Lamborn (1951) from a quarry just north of Barnesville.

Silicates	8. 47
Silica	9. 09
Ferric oxide	. 04
Ferrous carbonate	3. 06
Iron disulphide	. 20
Titanium dioxide	. 20
Calcium phosphate	. 26
Calcium sulphate	. 10
Calcium carbonate	55. 02
Magnesium carbonate	22. 26
Manganese carbonate	. 19

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In sec. 23, Wayne Township, the percentages of calcium carbonate and magnesium carbonate in the Fishpot limestone member are 71.62 and 15.49, respectively, and in sec. 4, Washington Township, they are 69.22 and 14.34.

FISHPOT COAL BED

Condit (1916, p. 237) noted and described the coal bed directly above the Fishpot limestone member. He named this bed the Lower Meigs Creek because of its proximity to the Meigs Creek (Sewickley) coal bed, 20 feet or more above.

Stout (1953, p. 31) proposed that the name "Lower Meigs Creek" be replaced by the name "Fishpot" because the coal bed is more closely associated with the underlying Fishpot limestone member than with the Meigs Creek coal bed.

Because the Fishpot limestone member and the overlying thin coal bed are persistent over wide areas in Ohio, West Virginia, and Pennsylvania, the name "Fishpot coal bed," as suggested by Stout, is used in this report. It is equivalent to the Lower Sewickley coal bed of West Virginia.

The Fishpot coal bed is continuous throughout the county from 52 to 64 feet above the Pittsburgh coal bed, and from 18 to 52 feet below the Sewickley coal bed. Plate 8 shows the stratigraphic relation of the Fishpot and Sewickley coal beds.

The thickness of the Fishpot coal bed ranges from a few inches to slightly more than 3½ feet, but only in the southern third of the county does its thickness average more than 14 inches. The average thickness exceeds 28 inches in parts of Warren, Somerset, Wayne, Washington, York, and Mead Townships. The bed thins northward and is less than a foot thick over the northern two-thirds of the county. Plate 9 is an areal map showing the thickness of the bed and the line of outcrop in and near the area where the thickness is more than 14 inches. The bed contains several partings, is impure, and is not of commercial value at present. In the northern two-thirds of Belmont County, the coal bed consists of thin layers of shaly

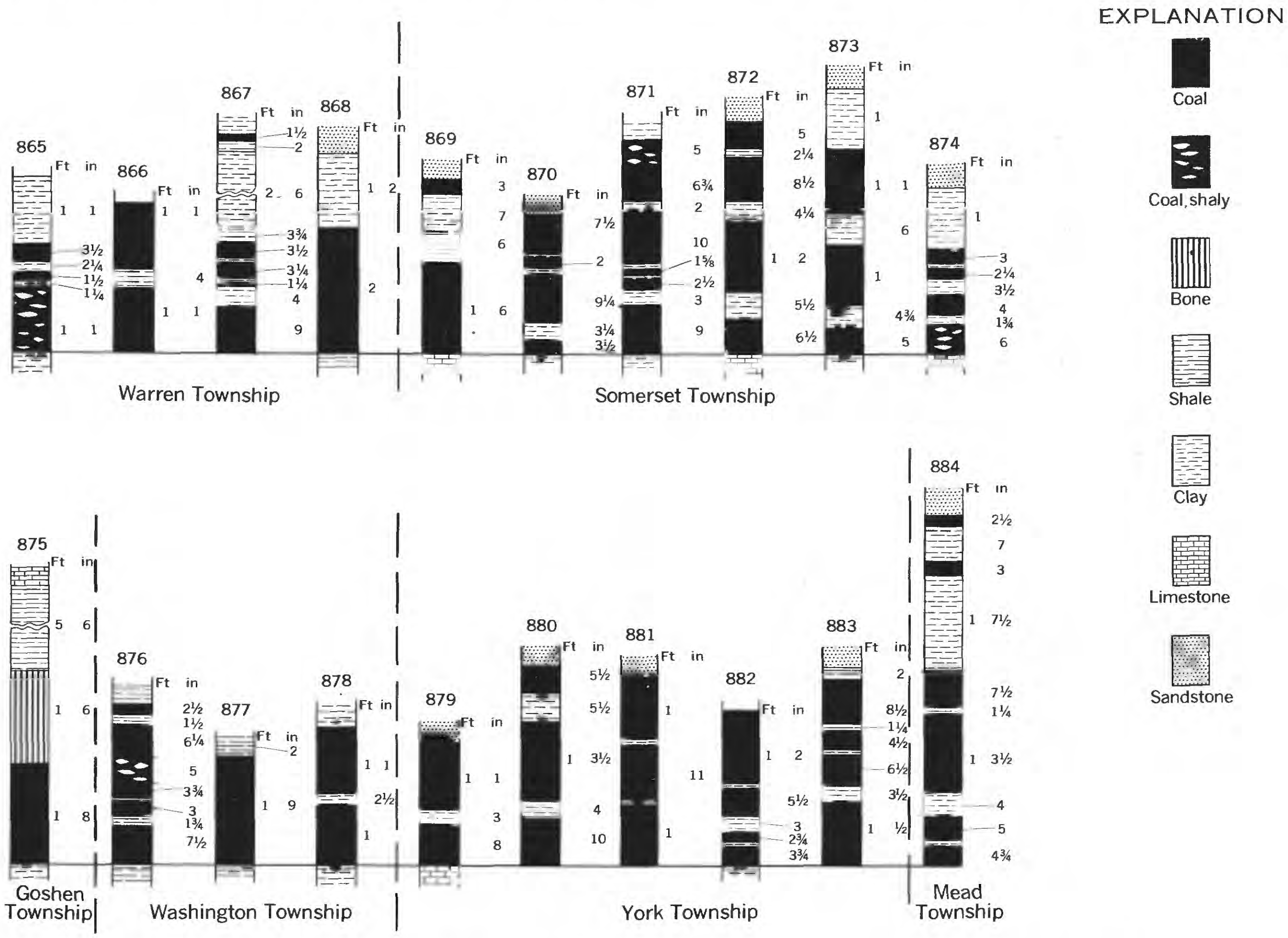

FIGURE 11. Sections of the Fishpot coal bed in Belmont County, Ohio. For geographic location of individual sections see plate 15.

coal, bone, carbonaceous shale, and clay. In the northeastern fourth of the county, it consists primarily of bone, which at some places is massive and weathers out as slabs.

In the southern fourth of the county, where the average thickness of the bed is more than 14 inches, the Fishpot coal bed consists of coal interbedded with clay and shale partings which are as much as 5½ inches thick. Figure 11 shows diagrammatic sections showing both the thickness and the lithologic character of the bed. In the vicinity of Barnesville and along the western part of Somerset Township the Fishpot coal bed has been mined in the past for home use. In the southwestern corner of Warren Township and in Somerset Township, where the Sewickley (No. 9) coal bed is thin and impure, the thicker Fishpot coal bed has been erroneously identified as the Sewickley by the local people. The Fishpot coal bed is also thicker than the overlying Sewickley in many parts of York Township, but it contains several thick clay and shale partings and consequently has not been prospected extensively. The associated underclay is variable in thickness but is generally thin. In places the underclay is absent, and the coal bed lies directly on the Fishpot limestone member. Both the Fishpot and the Sewickley coal beds are well exposed in several of the cuts and banks along the spur line of the Pennsylvania Railroad that is parallel to Captina Creek westward across York Township from the Ohio River to sec. 4, Washington Township.

The only analysis made of the Fishpot coal bed (table 11) indicates an ash content of 16 percent and a heat value of 11,739 Btu on the as-received basis.

FISHPOT SANDSTONE MEMBER

In a report on Jefferson County, Lamborn (1930, p. 235) designated the sandstone overlying the Fishpot coal bed and underlying the Sewickley (Meigs Creek) coal bed as the Fishpot sandstone member.

The member is persistent throughout Belmont County, but it grades laterally from massive crossbedded coarse-grained sandstone to an interbedded sequence of calcareous shale, mudstone, and impure limestone.

The massive sandstone, which seems to be the filling of a broad channel, lies mainly in the southwestern and southern parts of the county, and the calcareous shale and limestone is mainly in the central part. In most other parts of the county the Fishpot sandstone member is composed of fine-grained laminated sandstone and shaly siltstone. The laminations are caused by abundant mica lying along bedding planes and by very thin layers of macerated carbonized plant remains. Locally the laminated sandstone is ferruginous. Plate 8 contains diagrammatic sections showing the stratigraphic position of the member and its lithologic character.

The thickness of the Fishpot sandstone member ranges from 18 to 26 feet over most of the county, but the massive sandstone in the southwestern part is locally as much as 50 feet thick.

Good outcrops of the massive sandstone are along Leatherwood Creek and its tributaries in Dog Hollow and Cat Hollow and around the head of Beaver Creek just southeast of Temperanceville. The western limit of the massive sandstone is exposed on the east side of the valley opposite the quarry in the northeastern part of sec. 31, Somerset Township, and on the hillside east of the house at the west-central edge of sec. 25, Somerset Township. To the west in most of adjacent secs. 31 and 32, the Fishpot sandstone member consists of shaly siltstone and mudstone (pl. 8, section 15). The massive part of the Fishpot sandstone member is present eastward from Somerset Township across the southern part of the county, but it thins from 50 to about 25 feet, and locally it grades into siltstone. Approximately the upper half of the massive sandstone is exposed along the South Fork of Captina Creek in sec. 21, Wayne Township, and the upper 2 to 3 feet crops out along Captina Creek in sec. 17, Wayne Township. Farther east the massive sandstone crops out in the railroad cut in the northeastern part of sec. 27, York Township, along Pipe Creek westward from its mouth for a distance of half a mile, and near the northeastern corner of Colerain Township (pl. 8, section 8).

The massive sandstone is irregularly bedded and crossbedded, and locally in the northeastern part of sec. 33, Somerset Township, contains conglomerate in the basal part. The sandstone is poorly sorted, micaceous, and the grain size ranges from fine to coarse.

The calcareous shale and impure limestone, which grade laterally into the laminated sandstone and siltstone, crop out in several places in central Belmont County, mainly in northern Smith, Richland, southwestern Pease, and southern Colerain Townships; locally in northeastern Belmont County in northeastern Pease Township; in southeastern Belmont County in southern Mead and southern York Townships; and in northwestern Belmont County in northwestern Kirkwood Township (pl. 8). An exposure showing the typical character of the calcareous shale and limestone is in the railroad cut at Glencoe where 21 feet of soft olive-gray shale containing several lenticular beds of impure limestone crops out (pl. 8, section 12). The following section was measured in the Glencoe railroad cut:

	Thickness Ft.	In.
Monongahela formation:		
Sewickley coal bed	4	4½
Underclay:		
Clay, shaly; contains silt and iron impurities	1	4
Fishpot sandstone member:		
Limestone, lenticular, argillaceous		5
Clay, shaly; stained by iron oxide	1	3
Limestone, olive-gray, silty, laminated; splits into two or three thin beds laterally	1	0
Shale, olive-black, soft, clayey, calcareous; weathers olive gray	7	5
Limestone, yellowish-gray, silty		4
Shale, similar to shale unit above	2	4
Limestone; three thin silty beds separated by two layers of olive-black clayey shale	1	3
Shale, brownish-black, soft, clayey, calcareous; 3-in. carbonaceous layer near base	2	6
Mudstone, olive-gray, shaly, soft		8
Limestone, light-olive-gray, argillaceous, irregularly bedded; contains lenticular band of claystone; weathers yellowish gray	1	8
Mudstone, olive-gray, very silty, shaly; contains silty limestone nodules in upper part	2	6
Fishpot coal bed (lies 4 ft 3 in. above railroad track)		7

This excellent outcrop also includes the upper part of the Fishpot limestone member, the Fishpot and Sewickley coal beds, and the lower part of the Benwood limestone member.

SEWICKLEY (NO. 9) COAL BED

Rogers (1858, p. 505) used the name "Sewickley" to designate the coal bed 4 to 5 feet thick that lies 100 feet above the Pittsburgh coal bed along Sewickley Creek in Westmoreland County, Pa.

In Belmont County the coal 75 to 120 feet above the Pittsburgh coal bed was originally called the "Upper Bellaire" in the eastern part of Belmont County and the "Upper Barnesville" in the western part. Andrews (1874, p. 462) named this coal bed the "Cumberland seam" for its exposures at Cumberland in Guernsey County, Ohio, and traced it across Noble, Washington, Monroe, Guernsey, and Belmont Counties. Brown (1884, p. 1059) correlated the "Cumberland seam" with the Sewickley coal bed of Pennsylvania. He dropped the name "Cumberland seam," but instead of substituting the older name "Sewickley," he used "Meigs Creek" for exposures of this coal bed along Meigs Creek in Morgan County, Ohio. The name "Sewickley" is used in this report because it has prior usage and also because the bed is much more widely known in the northern Appalachian basin as Sewickley.

The Sewickley coal bed is called the "Mapletown coal" by oil drillers, and it is still erroneously called the 8A coal bed by some mine operators in Belmont County.

The Sewickley coal bed lies about 75 to 85 feet above the Pittsburgh coal bed in the northeastern and central parts of the county, but the interval increases to the south and west (fig. 12).

The thickness of the bed is variable and ranges from a few inches in the southwestern corner of the county to slightly more than 15 feet in Kirkwood Township.

The bed is multiple benched and consists of one persistent thick middle bench, which contains all the coal of commercial quality, and upper and lower benches that are impure and lenticular. Plate 10 shows the areal distribution of the bed and the thickness of its middle bench, and plate 11 contains diagrammatic sections showing the thickness, lithologic character of the bed, and stratigraphic relations and distribution of its three benches.

The upper bench, which ranges from a few inches to almost 3 feet in thickness, is present only in the western part of the county. Its distribution is virtually identical to that of the overlying Sewickley sandstone member (pl. 10). The upper bench is impure, containing almost everywhere lenticular clay, shale, and bone partings commonly an inch or more thick. Locally, massive bone makes up the bench. A shaly clay parting, 1 to 2 feet thick, separates the upper from the middle bench.

The middle bench is persistent over all the county except central Pease Township. The thickness of the middle bench ranges from 68 inches in southwestern Union Township (pl. 11, section 289) to about 1 inch in southwestern Somerset Township. The area of thickest coal lies in southern Union and northern Goshen Townships, where the average thickness is more than 54 inches. Two smaller areas in which the thickness of the coal averages more than 54 inches are to the east in northeastern Richland Township and in northeastern Smith Township (pl. 10). The average thickness is more than 42 inches over most of northern Belmont County, but the bench thins toward the northeast and also toward the south and southwest to less than 14 inches.

Several partings of shale, clay, or bone, ranging from a fraction of an inch to about 2½ inches thick, are in the middle bench at most places but not in a consistent pattern like those of the lower bench of the Pittsburgh bed. In parts of eastern Belmont County, however, one and in many places two partings lie near the center of the bench. In general the partings are more prevalent in the eastern part of the county (pl. 11). In addition to the main partings, thin lenses of carbonaceous shale occur throughout the middle bench. On

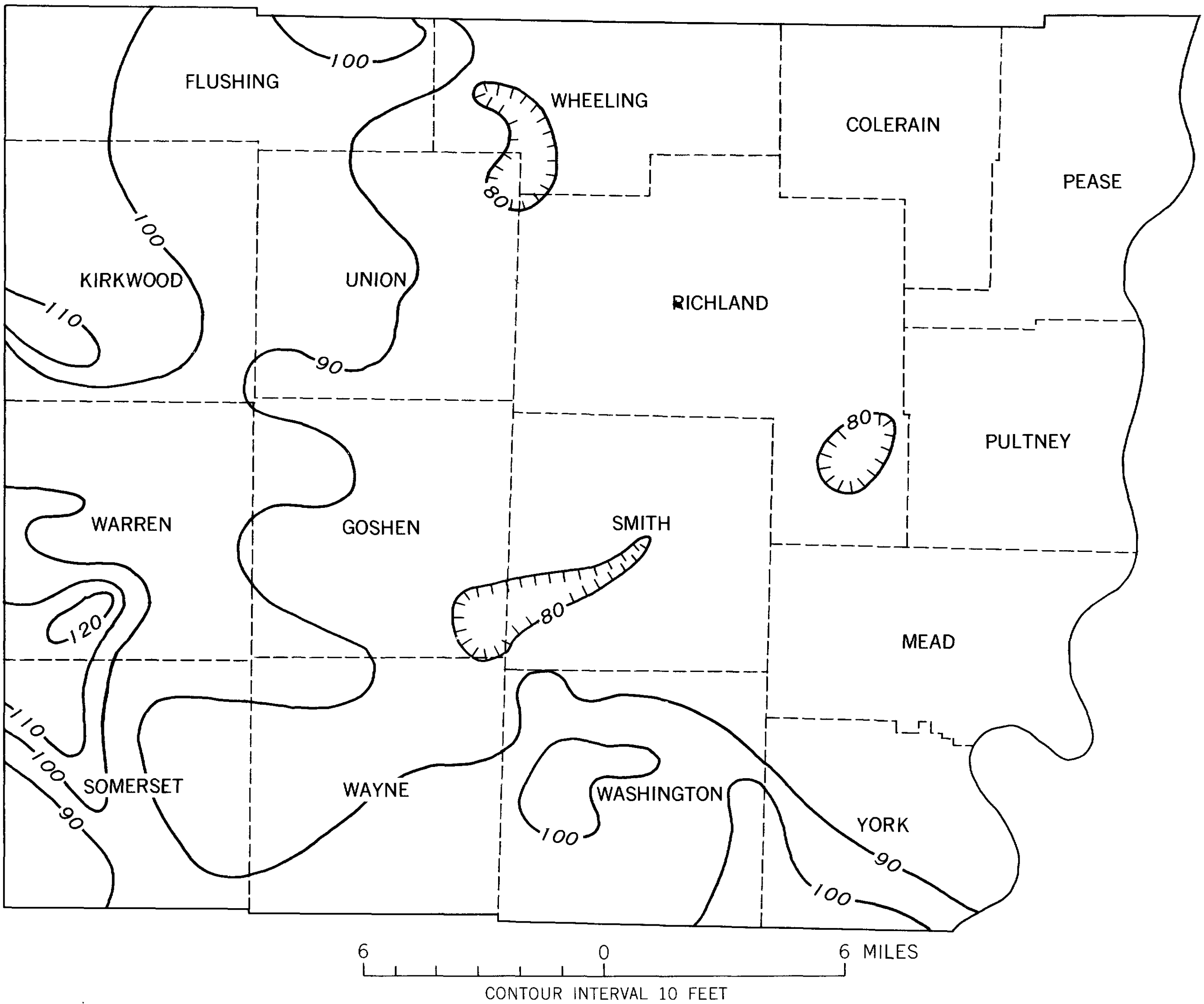

FIGURE 12.—Map of Belmont County showing the interval from the base of the Pittsburgh coal bed to the base of the Sewickley coal bed.

a fresh outcrop, the shale is difficult to detect, but it stands out on a weathered surface because of its greater resistance. This shale adds to the cost of cleaning the coal and also increases the ash content.

The lower bench, which is thin and impure, is persistent in the northeastern part of the county in southeastern Wheeling, southern Colerain, and central Pease Townships and is present in places in the western part of the county in southwestern Union, southwestern Warren, and northwestern Kirkwood Townships (pls. 10 and 11). The layer of impure coal and bone that is separated from the middle bench by a parting of micaceous shaly clay in parts of Kirkwood, Flushing, Union, and Wheeling Townships may be equivalent to the lower bench (pl. 11, sections 205, 219 and 268). In western Belmont County the lower bench lies from a few inches to as much as 9 feet below the middle bench and is separated from it by either soft shale or shaly clay. In eastern Belmont County the lower bench lies from a few inches to about 12 feet below the middle bench and is separated from it by micaceous silty shale, laminated shaly siltstone, and thin-bedded sandstone. In central Pease Township, where both the middle and the upper benches are absent, the shale, siltstone, and sandstone lie between the lower bench and the Benwood limestone member.

The Sewickley coal bed has a prominent cleavage consisting of two sets of perpendicular joints or "cleats." Like the Pittsburgh coal bed, the "face" or main joint has an average strike of about N. 75° W.

The Sewickley is a banded coal, and the banding results from alternation of laminae of anthraxylon or bright coal and duller components. Anthraxylon constitutes about 50 percent or less of the coal. The distribution of anthraxylon varies both vertically and horizontally but the concentration is greatest in the basal third of the bed. Bands of anthraxylon vary from very fine (less than one-fiftieth of an inch) to thick (greater than one-fifth of an inch), but are predominantly thin (1/50 to 1/12 inch) to medium (1/12 to 1/5 inch). The thickest bands are in the upper bench and in the upper part of the middle bench. Fusain occurs as thin irregular lenses throughout the bed. Pyrite occurs locally as an impregnation in the clay, shale, and bone partings and also as fine globules or crystals disseminated throughout the coal. Encrustations of white vitreous sulfate cover some joint faces.

Coal from the Sewickley bed in Belmont County is of high-volatile A and high-volatile B bituminous rank. Coal of high-volatile B bituminous rank occurs in Flushing, Wheeling, Pease, and the northern half of Richland Townships.

Twenty-two analyses of Sewickley coal have an average ash content of 12.68 percent and heating value of 12,124 Btu on an as-received basis. The analyses of coal from the western half of the county average 11.54 percent ash and 2.88 percent sulfur and have a heating value of 12,284 Btu, as compared to 13.83 percent ash, 3.54 percent sulfur, and 11,957 Btu for the coal from the eastern area. These averages compare on a countywide basis with 9.0 percent ash, 4.1 percent sulfur, and 12,870 Btu for the Pittsburgh coal bed. In contrast with the Sewickley coal the Pittsburgh coal increases in heating value eastward and decreases in ash and sulfur.

SEWICKLEY SANDSTONE MEMBER

White (1891, p. 60) used the name "Sewickley" to designate the sandstone that overlies the Sewickley coal bed and underlies the Benwood limestone member along the Monongahela River between Morgantown and Fairmont, W. Va.

In Belmont County the Sewickley sandstone member extends from the northwest into the western part of the county as a tongue between the Sewickley coal bed and the Benwood limestone member. The sandstone is more than 30 feet thick in the northwestern part of Belmont County in Flushing and Kirkwood Townships, but the member pinches out entirely in the eastern part where the Benwood limestone member overlies the Sewickley coal. Plate 10 shows the areal distribution of the sandstone, and plate 12 shows the stratigraphic relation of the Sewickley sandstone and Benwood limestone members. Although the Benwood contains more clay and silt in the western part of the county, there is no evidence that the limestone and the Sewickley member are intricately interfingered (pl. 12).

Shale, siltstone, sandstone, and some clay and mudstone make up the Sewickley sandstone member. Even-bedded laminated siltstone and laminated sandstone are most abundant, but lenses of medium- to coarse-grained sandstone are present at most outcrops. Generally the base of the member contains a thin layer of shaly clay or mudstone that rests on the upper bench of the Sewickley coal bed. This clay grades upward into soft shale which in turn grades into even-bedded laminated siltstone and fine-grained sandstone. Laminae in these rocks are mica and macerated carbonized plant remains. In many places these laminae are so closely spaced that the rock forms thin plates upon weathering. The following detailed stratigraphic section, measured in a strip mine in the south-central part of sec. 11, Warren Township, shows the typical lithologic character of the member.

	Thickness Ft.	In.
Monongahela formation:		
Sewickley sandstone member:		
Siltstone, medium-gray to olive-gray, very fine grained, or poorly bedded mudstone; weathers into large irregularly shaped lumps that slack and crumble to small fragments; contains lenses of fine-grained sandstone and siltstone laterally	15	0+
Sandstone, light-gray, fine- to medium-grained, highly micaceous, thin-bedded to massive, crossbedded; variable in thickness	6	0+
Siltstone, finely laminated; laminae are mica and highly macerated, carbonaceous plant remains cut by large vertical joints resembling large shrinkage cracks; weathers to large subangular masses which slack and break up into splinter-shaped fragments	5	0+
Sewickley coal bed—upper bench.		

Lenses of medium- to coarse-grained crossbedded micaceous sandstone similar to the sandstone in the above section, and ranging in thickness from a few inches to several feet, are mainly in the lower half of the member. In a few places these sandstone lenses thicken and become channel sandstones whose bases lie a foot or less above the Sewickley coal bed. Figure 13 shows a channel of the Sewickley sandstone member exposed in a strip mine in the northwestern part of sec. 35, Goshen Township. A similar sandstone crops out in a strip mine north of the highway in the southeastern part of sec. 18, Union Township. Other outcrops of the channel sandstone are in the east road bank in the northeastern part of sec. 31, Goshen Township; in the east bank of Captina Creek in the southwestern part of sec. 36, Wayne Township; on both sides of Captina Creek in the north-central part of sec. 35, Wayne Town ship; in the western part of section 21, Wayne Township; in the northeastern part of sec. 33, Warren Township; and in the bank of State Highway 8 at Sewellsville in sec. 29, Kirkwood Township.

FIGURE 13.—Exposure of the middle (*a*) and upper (*b*) benches of the Sewickley coal bed and lower part of the Sewickley sandstone member in a strip mine in the NW¼ sec. 35, Goshen Township. The Sewickley member is a massive channel sandstone at this locality.

In places the entire member consists of laminated siltstone, which locally contains a thin light-gray clay band about 10 feet above the base. Figure 14 shows

FIGURE 14.—Exposure of the middle and upper benches of the Sewickley coal bed and the overlying laminated siltstone of the Sewickley sandstone member in a strip mine in the SW¼SW¼ sec. 33, Union Township.

the laminated siltstone of the Sewickley sandstone member. Spheroidal fracturing that is commonly developed in the siltstone is shown in the center of the photograph.

Along its eastern edge in Wheeling and Richland Townships and in part of Goshen Township, the Sewickley member consists of about 2 to 3 feet of soft, clayey shale or mudstone containing septaria nodules, and an overlying layer of conspicuous grayish-green friable conglomeratic siltstone whose thickness ranges from a few inches to about 2½ feet. Plate 12, section 5, shows the stratigraphic position of the green siltstone. The following is a detailed description of this section:

	Thickness Ft.	In.
Monongahela formation:		
Benwood limestone member:		
Limestone, massive, argillaceous; conspicuous conchoidal fracture; measured to top of high wall in strip mine	4	9
Sewickley sandstone member:		
Siltstone, dusky-green; conglomeratic; pebbles are limestone; contains desiccation cracks; base undulatory; thickness variable	2±	0
Siltstone, dusky-green to medium-gray, soft, shaly; contains limestone nodules	3±	0
Sewickley coal bed, upper bench.		

As the member thickens westward in Wheeling and Richland Townships, the green siltstone grades into a layer of green highly micaceous, fine-grained sandstone about 5 to 7 feet thick that lies at the top of the member for a distance of several miles west of its eastern edge. This green sandstone crops out in many of the strip mines in central Wheeling Township. Plate 12, section 4, shows the stratigraphic position of the green sandstone.

A sample of the green sandstone was studied with X-rays by F. A. Hildebrand and optically by both Hildebrand and R. L. Smith. They found that it contained quartz, mica, and feldspar (microcline and plagioclase)—minerals that are common in all of the sandstone beds in the county—and, in addition, glauconite, which gives the rock its green color. They also identified a chlorite-type mineral that is intimately associated with the glauconite. Hildebrand and Smith believe that the glauconite has formed from the alteration of biotite. Furthermore, they describe it as having better crystallinity than most glauconite found in marine sediments.

Many excellent outcrops of the Sewickley sandstone member occur in the high walls of the strip mines that are shown on plate 10.

BENWOOD LIMESTONE MEMBER

The Benwood limestone member overlies the Sewickley coal bed in the eastern two-thirds of Belmont County and in the extreme southwestern corner, and overlies the Sewickley sandstone member in the western part. (See pl. 12 for its stratigraphic position and relation to associated strata.) The best outcrops are in the eastern part of the county, mainly along the Ohio River and its tributaries. The member crops out continuously along the west side of the Ohio River in the cuts of State Highway 7 from east-central Mead Township southward almost to Powhatan Point. Other good outcrops of parts of the member lie along Captina Creek and in the cuts of the highway that follows the creek.

Campbell (1903, p. 10), following the suggestion of White, used "Benwood limestone" to replace the name "Great limestone," which formerly had been used to designate the thick sequence of limestone beds that lies between the Sewickley and Uniontown coal beds. The type locality of the Benwood limestone member is in the Ohio River bluffs near Benwood, W. Va. Grimsley (1907, p. 92–94) and Hennen (1909, p. 297–301) restricted the name "Benwood" to the lower part of the "Great limestone" and used "Fulton green shale" for a thin shale which, according to them, locally separated the Benwood limestone from the Uniontown limestone, the upper part of the "Great limestone."

The discovery by the author of several "green shales" instead of one and contradictory statements by Grimsley regarding the thickness of the Benwood limestone member necessitate a redefinition of the units in this part of the stratigraphic sequence. Grimsley (1907, p. 92) states that the "Fulton green shale" lies 80 to 90 feet above the Sewickley coal bed, but he places it 72 feet above the Sewickley coal bed in what is presumably the type section of the shale, measured at Fulton, near Wheeling, W. Va., (Grimsley, 1907, p. 82). On the next page, however, Grimsley states that the Benwood limestone is only 30 to 60 feet thick. Remeasurement of the type section revealed that the coal which Grimsley apparently called the Sewickley is actually a thin lower bench that lies 12 feet below the main coal and is separated from it by shaly sandstone and siltstone. The "Fulton green shale," therefore, is 60 feet above the Sewickley coal bed at the type section. During remeasurement of the type section at Fulton, the writer noted a pale-olive mudstone, 3 feet thick, 67 feet above the Sewickley coal bed. This unit is not listed in Grimsley's type section. Confusion exists as to which bench of the Sewickley coal bed Grimsley used to determine the interval to the base of the Benwood limestone and which "green" layer he used for the "Fulton green shale." In the southern part of Belmont County where the Benwood limestone member contains layers of green shale down to within 10 feet of the Sewickley coal bed, its top cannot be placed with logic at the base of a "green shale." Furthermore, the "Fulton green shale" appears to be absent in the extreme western part of the county.

In order to define the top of the Benwood limestone member more accurately, the writer proposes: (1) that the name "Fulton green shale" be dropped, because the shale is actually a lower tongue of the Morningview sandstone member interbedded with the upper part of the Benwood limestone member and, therefore, is not a good stratigraphic marker bed, and (2) that the top of the Benwood limestone member be raised to the base of the main body of the Morningview sandstone member, heretofore unnamed. The lower tongue of green shale and the main body of the Morningview member do not join in Belmont County, but they do merge to the east in West Virginia and Pennsylvania. Figure 15 is a schematic diagram showing the relation of the Morningview sandstone member to the Benwood limestone member, and plate 13 is a group of stratigraphic sections showing probable correlations of strata between the Sewickley and Uniontown coal beds in Belmont County, Ohio, western Pennsylvania, and northern West Virginia.

The maximum thickness of the Benwood limestone member is 74 feet in sec. 27, Pease Township, near the northeastern corner of Belmont County (pl. 12, section 7). Its average thickness in the eastern half of the county is about 60 to 65 feet, but the member thins toward the west and is 15 to 20 feet thick over most of the western part of the county. The thickness of the Benwood could not be accurately determined in

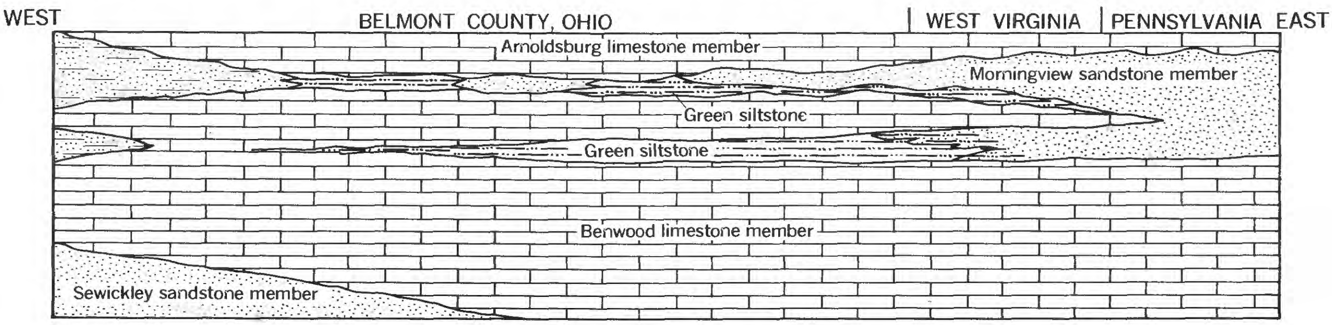

FIGURE 15.—Schematic diagram showing the relation of the Morningview sandstone member to the upper part of the Benwood limestone member.

the southwestern part of the county nor in the northwestern part in northern Warren, Kirkwood, and western Flushing Townships. In northwestern Union, northeastern Warren, and Kirkwood Townships, the Benwood limestone member seems to be replaced by sandstone and siltstone (pl. 14*B*, sections 1–5).

The Benwood limestone member is a sequence of argillaceous limestone beds which individually range in thickness from a few inches to more than 10 feet. The number and thickness of the limestone beds, the number of shale and clay interbeds, and the clay and silt content of the limestone, are variable from one part of the county to another, but in general the lithologic character of the member is more uniform over the eastern part of the county. The description of a section typical of Benwood limestone member in northeastern Belmont County measured eastward along the ravine that lies just north of the secondary road in the southeastern part of sec. 27, Pease Township (pl. 12, section 7) follows.

	Thickness Ft.	In.
Monongahela formation:		
Morningview sandstone member (forms ledge)	5	7
Benwood limestone member:		
Limestone, silty, shaly; weathers to three beds	2	2
Mudstone, grayish-olive, silty; contains impure limestone nodules	4	0
Tongue of Morningview sandstone member:		
Siltstone, grayish-olive, shaly; upper part a massive, sandy ledge 2½ ft thick	6	7
Benwood limestone member:		
Limestone, yellowish-gray to dusky-yellow, argillaceous; weathers to semiflaggy fragments	1	1
Siltstone and mudstone, grayish-olive	1	6
Limestone, yellowish-gray, argillaceous; weathers to large jagged, semiflaggy fragments	3	8
Limestone, argillaceous, weathers to semiflaggy fragments	1	4
Mudstone, greenish-gray, silty, shaly	2	0
Limestone, silty	2	6
Covered interval	5	7
Limestone, grayish-olive, argillaceous; three closely spaced beds	4	0
Limestone, argillaceous; upper half weathers to semiflaggy fragments; lower half has fracture pattern similar to that characteristic of flint clay	5	5
Limestone, light-olive-gray, massive; distinctive bed has "flint clay" type fracture	3	4
Limestone, silty, lenticular		4
Limestone, silty		3
Limestone, light-olive-gray, argillaceous	1	7
Limestone, argillaceous; weathers semishaly	1	0
Limestone, argillaceous; has "flint clay" type fracture	2	0
Monongahela formation—Continued		
Benwood limestone member—Continued		
Limestone, argillaceous; weathers semiflaggy	3	9
Limestone, light-olive-gray, argillaceous; has "flint clay" type fracture	4	3
Limestone; similar to overlying unit	5	7
Limestone, light-olive-gray, argillaceous; has very pronounced "flint clay" type fracture; weathers to small block fragments	3	3
Limestone, argillaceous		6
Limestone, silty; forms ledge; weathers to semiflaggy fragments	2	10
Limestone; several thin lenticular beds interbedded with soft calcareous shale	1	9
Limestone, light-olive-gray, argillaceous	1	0
Claystone in lower 2 ft; upper part of interval covered	4	6

Sewickley coal bed lies 76 feet above base of Pittsburgh coal bed which was seen in a small mine on the west side of the ravine below this section.

In the northeastern part of the county, in Colerain, eastern Richland, Pease, and Pultney Townships, the Benwood limestone member contains few shale and clay beds more than a few inches thick, the limestone beds being closely spaced, but to the south and southwest in Mead, York, Washington, and Wayne Townships, the member contains a number of shale and clay beds, most greenish gray (pl. 12). Individual limestone beds are lenticular, but certain groups of beds are persistent over most of the eastern part of the county.

The basal unit of the member is a claystone and clay layer 1 to 5 or more feet thick that, in places, contains limestone nodules and thin limestone beds in its upper part. The claystone unit is overlain by a group of 4 to 6 slightly silty limestone beds that, because of their greater resistance, protrude in most places beyond the beds above and below. Overlying the resistant beds is a zone of marly limestone 10 to 15 feet thick consisting of from 1 to 3 compact beds, which are distinctive because they have a fracture pattern similar to that of flint clay. This zone commonly weathers rapidly to soft clay. Above the marly limestone are 3 to 4 massive silty limestone beds which tend to form ledges. These beds are overlain by a group of marly limestone beds that, in the northeastern part of the county, have a fracture pattern like flint clay and are similar to the marly beds lower in the member.

The upper marly limestone beds are overlain by the grayish-green silty mudstone or siltstone tongue of the Morningview sandstone member. This siltstone tongue is persistent in the northeastern part of the county where its thickness ranges from 3 to 6½ feet. It generally lies from 5 to 11 feet below the main body of the Morningview sandstone member and is separated from it by the upper part of the Benwood limestone member. (See pl. 12 for the stratigraphic position of the unit and geographic locations of some of its outcrops.) In the southern part of the county the green mudstone-siltstone tongue is less distinctive because other greenish-colored clay and shale units are in the Benwood member (pl. 12, sections 11–13). Locally, there is nodular limestone in the unit. Toward the west the tongue thins, and in Somerset, Warren, Kirkwood, and western Flushing Townships it was not recognized, apparently because it pinches out.

The limestone that overlies the siltstone tongue of the Morningview sandstone member consists of 2 to 4 beds of massive, slightly silty limestone. Along Deep Run in Pease Township (pl. 14A, section 6) and in parts of Wayne and Washington Townships (pl. 14D, sections 3 and 4), the uppermost bed of the Benwood limestone member is conspicuous because it is very light yellowish gray and also because it weathers to large slablike masses that spall perpendicular to the bedding. This bed, which in some places is 4 feet or more thick, is best exposed along the bank of Deep Run in sec. 32, Pease Township (pl. 14A, section 6). This outcrop shows both the lithologic character of the uppermost beds of the Benwood limestone member and the contact between the limestone and the overlying Morningview sandstone member. The greenish shaly siltstone tongue of the Morningview member is also well exposed at this locality.

In western Belmont County the claystone and clay layer at the base of the member is generally overlain

FIGURE 16.—Exposure of the Sewickley coal bed (*a*) and the Sewickley sandstone (*b*) and basal part of the Benwood limestone (*c*) members of the Monongahela formation. The base of the Benwood limestone member is about 15 feet above the Sewickley coal. Photographed in a strip mine in the NW¼ sec. 6, Union Township.

by a bed of impure, silty to argillaceous limestone whose thickness ranges from 5 to 15 feet. Figure 16 shows this limestone and its stratigraphic position above the Sewickley sandstone member. This impure limestone, which is conglomeratic in places, has silt laminae that cause it to split into several beds upon weathering. Locally these beds contain a profusion of ostracode remains which form coquinalike lenses. The upper part of the member, which is also shown in part in figure 27, consists of relatively thin argillaceous limestone beds interbedded with clay and shale. The lithology of the Benwood limestone member is described in detail in the following section, measured in a strip mine near the center of sec. 27, Wheeling Township. This section is typical of the member in western Belmont County.

	Thickness *Ft.*	Thickness *In.*
Monongahela formation:		
Benwood limestone member:		
Weathered interval containing limestone boulders (measured to top of high wall)	1	0
Mudstone, greenish-gray, soft	1+	0
Weathered interval; lower half highly argillaceous, weathered limestone; upper half mostly weathered to shaly clay	4	6
Limestone; two argillaceous beds of variable thickness separated by shaly mudstone	1	4
Limestone, weathered, highly argillaceous, shaly	2	0
Limestone, light-gray, massive, highly argillaceous, persistent; cut by vertical joints resembling large desiccation cracks; weathers rapidly; weathered surfaces are yellowish gray to dusky yellow	8	0
Limestone, silty, laminated; contains ostracodes; forms ledge		10
Limestone, shaly, very argillaceous; weathers rapidly	1	6
Limestone, light-brownish-gray, silty; forms ledge; basal contact with Sewickley sandstone member disconformable	1	0
Sewickley sandstone member: Sandstone, dusky-green; upper unit of member		9

The base of the "green" sandstone at the base of the above section lies 8 feet above the upper bench of the Sewickley coal bed and is separated from it by laminated, thin-bedded siltstone containing discoid ironstone nodules, some having septarian structure.

The Benwood limestone member in sec. 34, Warren Township (pl. 12, section 9), consists of reddish mudstone containing three thin limestone beds at its base. In parts of Kirkwood, northeastern Warren, and southwestern Union Townships, the entire Benwood limestone member appears to be absent and its place occupied by sandstone and siltstone (pl. 12, section 2; and pl. 14*B*, sections 3–5).

The upper parts of some of the beds in the Benwood limestone member are sedimentary breccias, indicating deposition in shallow water with periodic exposure to subaerial desiccation. An erosional unconformity occurs in the lower part of the member about 10 feet above the Sewickley coal bed in southwestern Goshen and north-central Wayne Townships. This local unconformity was studied in three places: in a strip mine west of Long Run in the southwestern part of sec. 32, Goshen Township; in the bank of State Highway 148 near the center of the southeastern part of sec. 23, Wayne Township; and in the bank of State Highway 148 a few feet east of the road intersection near the center of sec. 10, Wayne Township. In sec. 32, Goshen Township, the beds beneath the unconformity are folded. To the southeast in sec. 23, Wayne Township, the beds beneath the unconformity have also been flexed but less than those to the northwest. In sec. 23, Wayne Township, gently folded beds and a dark-gray channel shale which cuts the folded limestone beds in one place are truncated by a flat-lying bed of conglomeratic limestone containing fragments of the underlying shale and limestone. About 2 miles farther to the southeast in sec. 10, Wayne Township, a thin bed of conspicuous iron-stained limestone conglomerate composed of subrounded to rounded limestone pebbles lies 10 feet above the Sewickley coal bed. The beds beneath the conglomerate do not appear to be folded but the base of the conglomerate is undulating, indicating probably deposition on an erosional surface.

Unweathered surfaces of limestone in the Benwood member are generally light gray to olive gray, but weathered surfaces are generally yellowish gray to grayish yellow.

The fauna of the Benwood limestone member consists of small gastropods, ostracodes, and *Spirorbis*.

An analysis of the Benwood limestone member from the center of sec. 36, Pease Township (Lamborn, 1951, p. 67–68), is as follows:

	Percent
Silica and silicates	29. 20
Hydrated ferric oxide	. 71
Ferrous carbonate	1. 85
Iron disulphide	. 32
Titanium dioxide	3. 20
Calcium phosphate	2. 17
Calcium sulphate	. 02
Calcium carbonate	49. 35
Magnesium carbonate	19. 44
Manganese carbonate	. 10

Limestone from the Benwood member was also sampled by Condit (1923, p. 53) at Armstrongs Mills in Washington Township, and the chemical composition of that sample is similar to the one above.

MORNINGVIEW SANDSTONE MEMBER

Overlying the Benwood limestone member in Belmont County is a clastic unit whose stratigraphic position ranges from 43 to 74 feet above the Sewickley coal bed (pl. 12) and from 36 to 52 feet below the Uniontown coal bed (pl. 14). This unit is, in many places, greenish-gray siltstone, but locally in parts of Pease, Pultney, Wayne, and Washington Townships, it is mainly massive crossbedded sandstone. Sandstone is more prevalent in the unit to the east in West Virginia and Pennsylvania, but it has not been previously named. In the past it was included first in the "Uniontown limestone," which included all strata, sandstone and limestone alike, between the "Fulton green shale" and the Uniontown coal bed, and later, when the "Uniontown limestone" was subdivided, it was included in the "Arnoldsburg limestone" which included all strata between the "Fulton green shale" and the "Arnoldsburg sandstone."

The unit is hereby designated the Morningview sandstone member for excellent outcrops along the south bank of Deep Run near the east edge of sec. 32, Pease Township, at a point 2½ miles east of Morningview. The layer of greenish-gray siltstone in the upper part of the Benwood limestone member is a lower tongue of the Morningview sandstone member. This tongue joins with the main body of the member eastward in West Virginia and Pennsylvania. Figure 15 and plate 13 show the regional relation of the Morningview and its lower tongue, and plates 12 and 14 show the stratigraphic relation of the Morningview sandstone and Benwood limestone members in Belmont County. The lower greenish siltstone tongue ("Fulton green shale" of older reports) has been included in the description of the Benwood limestone member. All descriptions of the Morningview member in this section, therefore, refer to the main body of the member.

The Morningview sandstone member ranges from 3 to 12 feet in thickness (pl. 14). Over most of the county it is grayish-green shale or clayey, greenish-gray siltstone, ranging from 2½ to 5 feet in thickness. The member is thickest in secs. 3 and 32, Pease Township; sec. 28, Pultney Township; sec. 28, Washington Township; and secs. 4 and 10, Wayne Township, where it is massive, locally crossbedded sandstone. In secs. 3 and 32, Pease Township, and sec. 10, Wayne Township, the lower part of the member is conspicuous grayish-green shale that is overlain by massive greenish-gray sandstone with an undulatory base. The best outcrop of massive Morningview sandstone member in Belmont County is at the type section in the south bank of

Deep Run south of the paved road in the eastern part of sec. 32, Pease Township (pl. 14*A*, section 6), where the stratigraphic relation to associated strata can be seen. There the member includes at the base grayish-green shale a few inches to about 1½ feet thick and massive crossbedded grayish-green micaceous sandstone 10 to 12 feet thick. The basal part of the massive sandstone contains very small fragments of the underlying green shale that were torn loose by scouring. At this locality and also in sec. 3, Pease Township (pl. 14*A*, section 5), the greenish-gray shale in the main body of the Morningview member is indistinguishable from the greenish shale of the lower tongue that lies a few feet below. Massive sandstone also crops out in southern Belmont County in road cuts in secs. 4 and 10, Wayne Township, in the east banks of Captina Creek in the northwestern part of sec. 28, Washington Township (pl. 14*D*, sections 3–5), and in east-central Belmont County in the southeastern part of sec. 28, Pultney Township (pl. 14*C*, section 5).

In northwestern Belmont County in southwestern Union, northwestern Warren, and Kirkwood Townships, the Morningview sandstone member appears to coalesce with other sandstone beds that may be equivalent in age to limestone beds of eastern Belmont County (pl. 14*B*, sections 1–5). The exact thickness of the Morningview cannot be determined in that area.

An isolated outcrop of a massive crossbedded channel-type coarse-grained friable sandstone is in the road cut at the curve of State Highway 8 southwest of Sewellsville in the northeast part of sec. 34, Kirkwood Township (pl. 14*B*, section 1). This sandstone, which is 23 feet thick, has limestone conglomerate 3 feet thick at the base and apparently fills a channel cut into the Benwood limestone member. The lateral extent of the channel sandstone could not be determined. It appears to have been formed by the coalescence of the Morningview and overlying sandstones, but it may be a channel of the Uniontown sandstone member.

The Morningview sandstone member ranges in grain size from fine to medium. It is poorly sorted and micaceous.

The shale and siltstone of the member vary from grayish olive to grayish green. Where associated with greenish shale, the sandstone is light greenish gray because of included fine particles of green clay and shale.

ARNOLDSBURG LIMESTONE MEMBER

Reger (1929, p. 140, 143) used the name "Arnoldsburg" to designate the limestone and shale beds between the "Fulton green shale" and the Arnoldsburg sandstone member in northern West Virginia. By introducing the name "Arnoldsburg limestone," Reger restricted the Uniontown limestone member to the strata between the Arnoldsburg sandstone member and the Uniontown coal bed. Originally the Uniontown limestone member included all strata—limestone, shale and sandstone—between the "Fulton green shale" and the Uniontown coal bed.

Stout (1931, p. 212), in a generalized section of the Monongahela formation for Ohio, used the name "Arnoldsburg" for the sandstone, limestone, and calcareous shale beds between the "Fulton green shale" and the Uniontown limestone member. In this report the Arnoldsburg limestone member includes only the limestone and interbedded thin mudstone beds between the Morningview sandstone and Arnoldsburg sandstone members (pl. 14).

The Arnoldsburg limestone member ranges in thickness from 5 to 22 feet. It is thickest in the southern part of the county in Mead and York Townships and thins to the north. In western Belmont County in parts of Kirkwood Township, the limestone is absent and its place is occupied by sandstone (pl. 14*B*, sections 1 and 4). The member consists of 3 to 12 beds of limestone separated by clay and calcareous shale. Individual beds of limestone range in thickness from a few inches to as much as 4½ feet.

The beds of limestone contain silt and impurities and in most places form slightly protruding ledges. In eastern Belmont County the member contains from 5 to 8 feet above its base a massive bed about 2 feet thick that weathers in conspicuous grayish-yellow "pillow-shaped" boulders. In parts of Pease and Colerain Townships, this bed is conglomeratic but has the characteristic yellowish color. Other beds of the Arnoldsburg limestone member are also conglomeratic and in that respect resemble other limestones of the Monongahela formation.

On fresh surfaces the Arnoldsburg member ranges from medium to light brownish gray and light olive gray, but after weathering it is yellowish gray.

The fauna of the Arnoldsburg limestone member consists of diminutive high-spired gastropods, ostracodes, and *Spirorbis*.

ARNOLDSBURG SANDSTONE MEMBER

Hennen (1911, p. 57, 202–204) used the name Arnoldsburg to designate a sandstone 25 to 45 feet thick that lies 40 to 50 feet below the Uniontown sandstone member at Arnoldsburg, Calhoun County, W. Va. In Belmont County, Ohio, the top of the Arnoldsburg sandstone member lies from 19 to 31 feet below the Uniontown coal bed and from about 22 to 33 feet below the Uniontown sandstone member. The stratigraphic position of the member in various parts of Belmont County is shown on plate 14, and its position in Belmont County relative to the position of the Arnoldsburg sandstone of Hennen in the type area is shown on plate 13.

The thickness of the Arnoldsburg sandstone member in Belmont County ranges from 6 inches to 7½ feet, averaging about 3 to 4 feet (pl. 14). The average thickness is greatest in northern Pease, northern Colerain, and northern Wheeling Townships, but the maximum thickness of 7½ feet is in sec. 8, Goshen Township (pl. 14*C*, section 3). Farther west in Goshen Township (pl. 14*C*, section 2) and also in southeastern Kirkwood Township (pl. 14*B*, section 4) several sandstone members have coalesced, and the part equivalent to the Arnoldsburg may be thicker.

Characteristically in Belmont County the Arnoldsburg sandstone member is greenish-gray micaceous friable poorly bedded siltstone. However, in sec. 8, Goshen Township, it is crossbedded sandstone (pl. 14*C*, section 3), and farther west in western Goshen (pl. 19*C*, section 2) and Kirkwood Townships (pl. 14*B*, sections 1, 2, and 4) it is part of several sandstone members that have coalesced. In the northwestern part of sec. 33, Richland Township, a nodular bed of limestone lies near the middle of the member (pl. 14*B*, section 6). Two thin lenticular layers of gray clay that contain carbonaceous bands are locally associated with the member. One layer occurs locally at the top of the member and the other at the base. In parts of eastern Belmont County, a reddish-brown band of shale, one-fourth of an inch or less thick, lies near the middle of the member.

LITTLE CAPTINA LIMESTONE MEMBER

The Little Captina limestone member is a part of the Uniontown limestone member of Stout (1929, p. 121) and is the upper part of the unit which he later called the Arnoldsburg limestone member (1931, p. 212). Stout's Uniontown limestone member included, in addition to limestone, a very persistent sandstone, siltstone, and shale unit that he later named the "Arnoldsburg sandstone member" (1953, p. 325–347). In his 1953 report, Stout restricted the Uniontown limestone member to the interval between the "Arnoldsburg sandstone member" and the Uniontown coal bed and included all the limestone beds between this sandstone and the "Fulton green shale" in the Arnoldsburg limestone member. The "Arnoldsburg sandstone member" of Stout, which lies a few feet below the Uniontown coal, does not appear to be equivalent to the Arnoldsburg sandstone member of Hennen (1911) in Calhoun County, W. Va., which lies 40 to 50 feet below the Uniontown coal bed (pl. 13). The sandstone and siltstone unit 19 to 31 feet below the Uniontown coal bed in Belmont County, which was named the Arnoldsburg sandstone member on page 38 of this report, more nearly corresponds in stratigraphic position to the Arnoldsburg sandstone of West Virginia. The "Arnoldsburg sandstone" of Stout is renamed the McKeefrey siltstone member. The limestone beds that lie between the McKeefrey siltstone member and the Arnoldsburg sandstone member are here named the Little Captina limestone member for excellent outcrops north of the mouth of Little Captina Creek in eastern York Township along State Highway 7 west of the Ohio River. In the type area the Little Captina limestone member lies 17 feet below the Uniontown coal bed and is 10 feet thick. Plate 14*D*, section 9, shows the lithologic character of the member, its thickness, and its stratigraphic relation to associated strata. With the exception of the lower siltstone tongue of the Morningview sandstone member, which crops out a short distance to the north, all the strata shown in plate 14*D*, section 9, crop out in the high cut of State Highway 7 at a point about half a mile north of the mouth of Little Captina Creek.

The thickness of the Little Captina limestone member ranges from 6 to 14 feet (pl. 14). In general it is thickest in northeastern Belmont County and thinnest in the central part of the county.

The member consists of 3 to 6 beds of limestone that generally are separated by shaly clay partings, but in places shaly clay and mudstone make up more than half of the unit. In western Belmont County in southwestern Union, southeastern Kirkwood, and western Goshen Townships, the place of the limestone is occupied by sandstone (pl. 14 *B* and *C*).

The limestone is commonly impure and locally conglomeratic. In places it is dense, hard, and resistant, but in other places it weathers readily to clay. Over most of southeastern Belmont County the member has at the top a distinctive thin, jointed bed that weathers to conspicuous "brick-sized" blocks.

The color of the limestone on fresh surfaces ranges from medium gray to brownish gray and light olive gray, but brownish- and olive-gray shades are predominant. In southern Belmont County the basal bed is light brownish gray. In northeastern Belmont County a bed in the upper part of the member weathers conspicuous grayish yellow, but elsewhere the limestone beds weather light olive to yellowish gray.

The fauna of the Little Captina limestone member consists of diminutive forms of gastropods, ostracodes, and *Spirorbis*.

MC KEEFREY SILTSTONE MEMBER

In the past the entire sequence between the Arnoldsburg sandstone member and the Uniontown coal bed has been designated as the "Uniontown limestone." In the discussion of the Little Captina limestone member, it was pointed out that the "Uniontown limestone" of earlier workers included a sandstone-siltstone-shale unit. This unit is 5 to 30 feet thick. Field studies and a review of the literature show that this sandstone-siltstone-shale unit is persistent over wide areas in Ohio, West Virginia, and Pennsylvania. Because of its regional persistence, this unit is here named the McKeefrey siltstone member for the excellent outcrop on the west side of the Ohio River in the high west bank of State Highway 7 in east-central sec. 3, York Township, at a point half a mile S. 30° W. of McKeefrey, W. Va. There the member is thin-bedded siltstone about 17 feet thick, but about three-eighths of a mile to the south for a distance of several hundred feet along the highway, the member is a massive channel sandstone about 30 feet thick. The sandstone-filled channel cuts out all underlying strata to the top of the Arnoldsburg limestone member. Plate 14*D*, section 9, measured at the type locality, shows the thickness of the member, its stratigraphic position relative to other members, and the vertical extent of the locally developed channel.

In Belmont County the top of the McKeefrey siltstone member lies from 6 inches to as much as 15 feet below the Uniontown coal bed and is separated from it in most places by the Uniontown limestone member and by the underclay of the coal bed (pl. 14). Where the limestone is absent, the sandstone member commonly is separated from the coal by a thin underclay, but locally this clay is absent and the sandstone member is overlain by the coal.

The McKeefrey siltstone member ranges from 5 to 30 feet in thickness, but averages about 10 feet. It is thickest in the southern part of the county and thins northward. Near the northern boundary of the county, it is generally less than 10 feet thick (pl. 14*A*).

Over most of the county the member is made up of shaly siltstone containing lenses of massive siltstone or fine sandstone (pl. 14). The typical lithologic character is shown by the outcrop in the railroad cut in sec. 19, Richland Township, where the member consists of 6 feet of shale overlain by 12 feet of shaly siltstone, the top of which directly underlies the Uniontown coal bed. Thin bands of coal are interbedded with the basal 6 feet of shale (pl. 14*C*, section 4). This is the only place where coal was observed in the McKeefrey siltstone member, but clay with carbonaceous bands is common at the base and separates the member from the underlying Little Captina limestone member. Along Jug Run north of St. Clairsville in sec. 11, Richland Township (pl. 14*B*, section 7), the member consists of massive crossbedded sandstone, 15 feet or more thick, but because of cover, it was impossible to determine whether this sandstone, like the one in York Township, filled a channel. Along Cat Run in York Township, the entire unit is made up of compact shale. In parts of western Belmont County, the McKeefrey siltstone member apparently is a part of several coalesced sandstone members (pl. 14*B*, sections 2 and 4).

The sandstone is olive gray to pale olive; the siltstone ranges from dusky yellow to pale olive and grayish olive. The shale in the lower part is commonly greenish gray and over most of eastern Belmont County contains a 4- to 6-inch reddish-brown streak near its base. Along Cat Run in York Township, the shale that makes up the member is a conspicuous grayish green. The following is a detailed section of the McKeefrey siltstone member measured in the railroad cut south of State Highway 147 in sec. 19, Richland Township (pl. 14*C*, section 4). This section also shows the lithologic character of other members that crop out in this cut.

	Thickness Ft.	In.
Monongahela formation:		
Uniontown sandstone member:		
Sandstone, massive, medium- to coarse-grained, highly micaceous, friable	12+	
Uniontown coal bed:		
Coal, shaly, weathered		8
McKeefrey siltstone member:		
Siltstone, shaly; upper few feet silty mudstone	12	0
Mudstone, greenish-gray, shaly	2	1
Siltstone, finely laminated; laminae are coal and seem to be vitrain bands; contains thin lenses of fine-grained sandstone	4	0
Little Captina limestone member:		
Limestone, olive-gray, massive, argillaceous; splits to two beds because of shaly parting; weathers to large rounded boulders; weathers yellowish gray to grayish yellow	8	10
Limestone, olive-gray, siliceous, has iron-oxide stains	1	9
Mudstone, shaly, calcareous		1
Limestone, olive-gray, argillaceous; concontains abundance of ostracodes; weathers to large rounded boulders	1	2
Arnoldsburg sandstone member:		
Mudstone, silty; upper half greenish gray; lower half dark gray and may be carbonaceous		6
Arnoldsburg limestone member:		
Limestone, highly argillaceous; weathers to shaly fragments	1	3
Limestone, argillaceous; thickness variable		8
Mudstone, olive-gray to dark-green, shaly		11
Limestone, argillaceous; thickness variable; weathers to rounded boulders	1	2
Mudstone, olive-gray, shaly, calcareous		6
Mudstone, silty, clayey; contains nodular, silty limestone bed in upper half	1	8
Morningview sandstone member:[1]		
Siltstone, shaly; upper 1½ ft contains calcareous nodules	6	9

[1] Base of Morningview sandstone member lies 12 ft above the railroad tracks.

UNIONTOWN LIMESTONE MEMBER

Franklin and W. G. Platt (1877, p. 55–104, 286, 292) gave the name "Uniontown limestone" to the upper part of the "Great limestone," which previously had included all the limestone between the Sewickley and Uniontown coal beds. Subsequently "Uniontown limestone" included all strata between the Benwood limestone member (lower part of the "Great limestone") and the Uniontown coal bed. Reger (1929, p. 140; 143–144) and Stout (1953, p. 325–347) divided the "Union limestone" into two members. They gave the name "Arnoldsburg limestone" to the lower member and restricted the name "Uniontown limestone" to the upper member. In this report the Uniontown limestone is further restricted to the interval between the top of the McKeefrey siltstone member and the base of the underclay beneath the Uniontown coal bed.

The Uniontown limestone member ranges from a few inches to 15 feet in thickness. It is thickest in Wheeling, northern Richland, Colerain, and Pease Townships in the northern and northeastern parts of the county but thins to the south and southwest. The member is absent over most of west-central, south-central, and southeastern Belmont County. Plate 14 shows the stratigraphic position of the member and its thickness in various parts of the county.

The member includes from 1 to 7 beds of lenticular, silty limestone interbedded with shaly clay, which, locally, exceeds the combined thickness of the limestone. The member is multiple bedded in the northern part of the county but generally consists of a single bed in the southern part. In places the limestone beds are resistant and protrude as ledges, but at other localities the limestone has weathered to clay. One or more beds at most outcrops are either wholly or in part conglomeratic, but in places the fragments of limestone are angular and the limestone beds are sedimentary breccia rather than conglomerate.

The following section, measured in the east bank of the highway near the southeast corner of sec. 6, Smith Township, shows the lithologic character of the Uniontown limestone member and its relation to associated strata:

	Thickness Ft.	In.
Monongahela formation:		
Waynesburg coal bed; seen in small abandoned mine above the highway cut.		
Uniontown sandstone member:		
Covered interval	19	0
Sandstone, thin-bedded, fine-grained	20	0+
Uniontown coal bed:		
Coal; variable in thickness; contains clay band 2½-in. thick	1	9
Underclay:		
Clay, calcareous; contains small limestone pellets	1	7
Uniontown limestone member:		
Limestone, olive-gray, argillaceous; upper part conglomeratic	1	9
Mudstone, olive-gray, shaly, soft	1	0
Limestone, argillaceous, nodular		11
Mudstone, shaly, soft	1	6
McKeefrey siltstone member:		
Siltstone, shaly, sandy; massive, cross-bedded, channel sandstone west along road cut	9	6
Mudstone, olive-gray, hard		10
Little Captina limestone member:		
Limestone, massive, argillaceous; contains lenticular shaly zones; splits to several beds laterally	6	0
Limestone, yellowish-gray, argillaceous	2	0
Covered interval	4	1
Level of highway.		

Fresh surfaces of Uniontown are medium gray or greenish gray, but weathered surfaces are light gray, light olive gray, and yellowish gray.

The fauna consists of diminutive gastropods, ostracodes, and *Spirorbis*.

UNIONTOWN (NO. 10) COAL BED

Rogers (1858, p. 506) named the fourth well-defined coal bed above the base of the Monongahela formation the "Uniontown" for its exposures at Uniontown, Fayette County, Pa. He described it as a benched coal bed 200 feet above the Pittsburgh coal bed. Stevenson (1878, p. 261–287) traced the bed in Belmont County but incorrectly correlated it with the Waynesburg (No. 11) coal bed of Pennsylvania. Condit (1916, p. 237) correctly identified this bed as the Uniontown. Locally it is erroneously called the No. 9 coal bed.

The Uniontown coal bed, including local thick clay and shale partings, ranges from a few inches to about 6 feet in thickness in Belmont County and is separated from the underlying Uniontown limestone member by impure underclay that ranges from a few inches to 5 feet in thickness. The thickness averages about 2 feet in an elongate area that extends northeast from Wayne Township to Pease Township (pl. 15). Elsewhere, with the exception of a small area in southern Pultney Township, the Uniontown coal bed averages less than 14 inches in thickness.

In Belmont County the Uniontown coal bed is 90 to 110 feet above the base of the Sewickley coal bed and 34 to 63 feet below the base of the Waynesburg coal bed.

The coal is variable in thickness and contains several clay, shale, or bone partings, which in many places are thick enough to divide the bed into two or more benches.

In sec. 15, Pease Township, at an outcrop in a cut along U.S. Highway 40, a thin limestone parting is in the central part of the bed. Plate 15 shows the thickness and distribution of the bed and plate 16 contains diagrammatic sections showing its lithology. Outside of the 14-inch isopach line shown on plate 15, the coal is not only thin but contains a greater number of partings.

The quality of the coal is best along Bend Fork and Jakes Run in Goshen, Wayne, and northwestern Washington Townships, where it is more than 3 feet thick in a few places. Locally within this area the bed contains no partings and has been mined by farmers for home use. Over most of this same area the Uniontown coal can easily be mistaken for the overlying Waynesburg coal, which is thin and locally absent. The Uniontown coal bed is also slightly thicker than average in northern Smith, southwestern Richland, and Pease Townships, where it has also been mined in a few places for local use (pl. 16). The place of the coal is occupied by clay containing carbonaceous bands in York Township, southern Mead Township, southeastern Smith Township, and in most of Washington Township. The underclay beneath the coal is light gray in most places, but in the southwestern corner of Belmont County, the underclay is grayish red.

Based on two analyses on the as-received basis of samples that were taken along Bend Fork in the area of thickest coal, the Uniontown coal is of high-volatile A bituminous rank, but the ash content of the coal is relatively high. A detailed analysis for each of the two samples is given in table 11.

UNIONTOWN SANDSTONE MEMBER

White (1891, p. 58–59) named the Uniontown sandstone member for exposures at Uniontown, Fayette County, Pa., where this sandstone lies between the Uniontown coal bed and the Waynesburg limestone member. In the south-central and east-central parts of Belmont County the Uniontown sandstone member occupies the interval between the Uniontown coal bed and the Waynesburg limestone member, but over most of the central, north-central, and northeastern parts of the county, where both the Waynesburg limestone member and the Little Waynesburg coal bed are absent, the Uniontown sandstone member lies between the Uniontown coal bed and the mudstone facies of the Gilboy sandstone member. In the extreme western part of the county where the mudstone facies of the Gilboy sandstone member pinches out, the Uniontown sandstone member occupies the interval between the Uniontown and Waynesburg coal beds except for the space occupied by the underclay beneath the Waynesburg coal. In southeastern Belmont County, where the Waynesburg limestone member occupies the entire interval between the Uniontown and Little Waynesburg coal beds, the

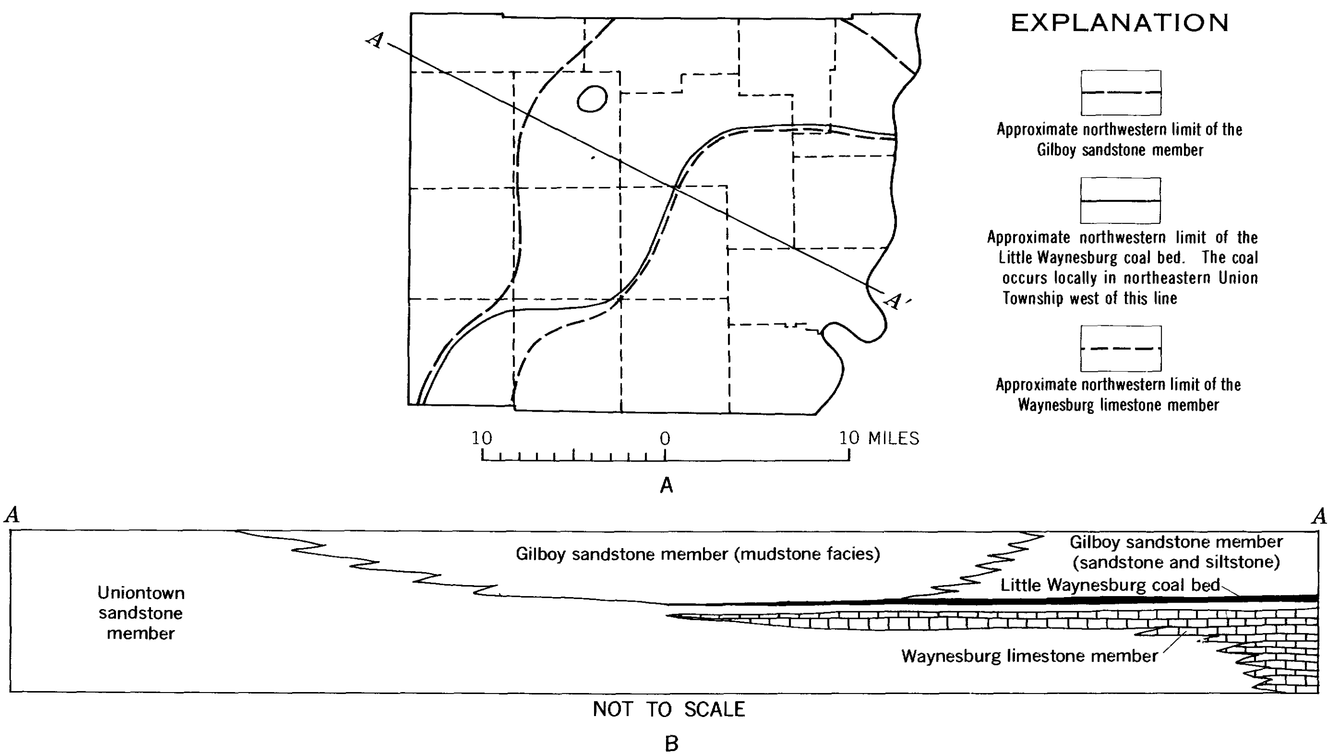

FIGURE 17.—Map of Belmont County and diagrammatic section showing the areal distribution and stratigraphic relation of the Gilboy sandstone member, Little Waynesburg coal bed, and Waynesburg limestone member of the Monongahela formation to the Uniontown sandstone member.

Uniontown sandstone member is absent. In Belmont County, therefore, the lower part of the Uniontown sandstone member is equivalent in age to the Waynesburg limestone member and the Little Waynesburg coal bed and the upper part is equivalent in age to the Gilboy sandstone member. The cross section in figure 17 shows the stratigraphic relation of the Uniontown sandstone member to the Gilboy sandstone and Waynesburg limestone members and to the Little Waynesburg coal bed.

The Uniontown sandstone member ranges in thickness from a few inches in southeastern Belmont County to 50 feet or more locally in the northeastern and western parts, but it is generally 20 to 30 feet thick. The range of thickness is shown in plate 17, which also shows the stratigraphic position of the member and its relation to the Waynesburg limestone member.

The Uniontown sandstone member in Belmont County is made up of sandstone, shaly siltstone, and shale and has no unique feature that distinguishes it from other Pennsylvanian sandstones. It is irregularly bedded and crossbedded and ranges from thin bedded to massive. Generally the basal part of the member is shale that grades upward to siltstone and sandstone. In many places the shale was either partly or totally removed by channeling and by scouring action when the overlying massive sandstone was deposited. The distribution of the sandstone, siltstone, and shale is somewhat irregular, but in general, the most massive and coarsest grained sandstone lies in the western half of the county.

The most massive part of the member occurs in south-central Belmont County, where thick crossbedded sandstone crops out along Bend Fork in sec. 1, Goshen Township; sec. 6, Wayne Township, and sec. 36, Washington Township; and along Jakes Run in secs. 18 and 24, Wayne Township. Farther southwest, prominent lenses crop out in the northeastern part of sec. 26 and in the western part of sec. 21, Somerset Township, and in sec. 30, Warren Township. North of these outcrops much of the Uniontown sandstone member has been removed by erosion, but in southwestern Kirkwood Township massive Uniontown caps an isolated hilltop in sec. 26 above the roadside park and forms a pinnacle at the end of a long ridge in the center of sec. 27. The massive sandstone in sec. 34, Kirkwood Township, that is discussed on page 38 might be a channel remnant of the Uniontown sandstone member (pl. 14*B*, section 1). In eastern Belmont County massive Uniontown is restricted to the southeastern part of sec. 27, Pease Township, the northeastern part of sec. 5, Pultney Township, and the south-central part of sec. 9, Richland Township, where excellent outcrops occur along the railroad cut at the Saginaw mine. At this locality the irregularity of the sandstone is easily seen. About half a mile east of the Saginaw mine, the massive sandstone pinches out in the railroad cut near the southwestern corner of sec. 3, Richland Township. The massive Uniontown sandstone member commonly has an undulatory base that lies from a few inches to several feet above the Uniontown coal bed.

Elsewhere the Uniontown sandstone member consists of interbedded shaly or flaggy fine-grained sandstone and shaly siltstone locally containing lenticular massive layers which protrude as ledges. The upper part of the member generally consists of shaly siltstone that grades into the underlying, coarser grained part of the member. In places the sandstone is even bedded, as in the bank of U.S. Highway 250 just south of the two hairpin curves near the northwestern corner of sec. 28, Pease Township.

The sandstone is micaceous and poorly sorted; its grain size ranges from fine to coarse, but is generally fine to medium. It is gray on fresh exposures and tan on weathered outcrops. The siltstone and shale ranges from light olive gray to dusky yellow.

Locally casts and molds of *Cordaites* and *Calamites* are in the Uniontown sandstone member. The shale, generally at the base of the member, contains a profusion of *Neuropteris* remains in places. The two best plant fossil localities are the road cut that runs north from Martins Ferry to the City Memorial Park in southeastern sec. 24, Pease Township, and the bank of a small draw in the NW¼SW¼ sec. 3, Pease Township. Noteworthy is the lack of plant forms other than *Neuropteris*.

WAYNESBURG LIMESTONE MEMBER

Stevenson (1877, p. 35) named the limestone between the Uniontown sandstone and the Little Waynesburg coal bed the "Waynesburg" for its exposures at Waynesburg, Greene County, Pa. In southeastern Belmont County it extends downward to the top of the Uniontown coal bed.

The thickness of this limestone member in Belmont County ranges from a few inches to 31 feet (pl. 17). It is thickest in the southeastern part of the county in York and Washington Townships, but it thins toward the north and west and is absent in Somerset, Warren, Kirkwood, Flushing, Union, Goshen, Wheeling, and Colerain Townships.

In the southeastern part of the county, where the Waynesburg limestone member is thickest, the member consists of several limestone beds, 6 inches to 2½ feet thick, interbedded with shaly clay and soft shale, which commonly make up about half the total thickness. To the west and north, a tongue of the Uniontown sandstone member splits the limestone into two parts. The lower part, which is rarely more than 3 feet thick, overlies the Uniontown coal bed and consists of 2 or more nodular beds. These lower beds thin westward and northward and are not present north of central Mead Township or west and north of Washington Township. The upper part of the member, which also thins to the west and north, generally consists of several massive beds and interbedded clay, but in the central part of sec. 9, Smith Township, it is limestone conglomerate that ranges from 1 to 4 feet in thickness. The conglomerate and the overlying Little Waynesburg coal bed are well exposed in the bank of Williams Creek north of the road intersection. Where the Waynesburg limestone member occupies the entire interval between the Uniontown and Little Waynesburg coal beds or where the lower part of the Waynesburg member is present, the place of the Uniontown coal bed is occupied by clay containing carbonaceous bands indicating a basin depth too great for swamp development. The best outcrops of the Waynesburg limestone member are along the road cuts adjacent to Wegee Creek in Mead Township and along Peavine and Crabapple Creeks in Washington Township. The stratigraphic position of the member is shown in plate 17, and its areal distribution is shown in figure 17. Following is a detailed section measured in the south bank of Wegee Creek in the southeastern part of sec. 14, Mead Township:

	Thickness Ft.	In.
Monongahela formation:		
Little Waynesburg coal bed - covered.		
Waynesburg limestone member (upper tongue):		
Limestone, light-olive-gray, massive, argillaceous; contains undulating shale parting; conglomeratic laterally	3	6
Mudstone, olive-gray; weathers semishaly	3	5
Limestone, nodular, silty		11
Limestone, light-olive-gray, silty, hard; weathers light brown	1	2
Mudstone, semishaly; contains thin nodular limestone bed at base	1	0
Limestone, massive, silty; has thin shaly parting 8 in. above base	2	4
Mudstone, dusky-green		4
Limestone, argillaceous		8
Uniontown sandstone member:		
Siltstone, dark-greenish-gray, semishaly to shaly; contains limestone nodules in upper part	4	5
Siltstone, shaly, blocky; upper part more sandy and massive; grades laterally to sandstone	9	0
Shale, greenish-gray	1	0
Waynesburg limestone member (lower tongue):		
Limestone, two thin beds, nodular, argillaceous		9
Uniontown coal bed:		
Claystone, containing carbonaceous bands	1	6

The limestone beds contain clay and silt impurities and are locally conglomeratic. The more massive beds, which underlie the Little Waynesburg coal bed, are relatively resistant and commonly form ledges. The Waynesburg limestone member is separated from the Little Waynesburg coal in most places by 1 to 3 feet of impure underclay.

The color of the limestone beds ranges from medium gray to shades of olive and greenish gray on fresh exposures and from light olive to yellowish gray on weathered surfaces.

The fauna consists of diminutive forms of gastropods and *Spirorbis*.

LITTLE WAYNESBURG COAL BED

White (1891, p. 58) used the name "Little Waynesburg" for a thin coal bed that lies below the Waynesburg coal bed in southwestern Pennsylvania. He states that the coal bed was named by J. J. Stevenson but gives no reference to the publication. In Belmont County the Little Waynesburg coal bed overlies the Waynesburg limestone member or the Uniontown sandstone member where the limestone is absent and lies from 12 to 27 feet below the Waynesburg coal bed. The average interval between the two coal beds is about 15 feet.

The thickness of the Little Waynesburg coal bed ranges from a fraction of an inch to about 6 inches. It is absent in most of northern and western Belmont County. The Little Waynesburg coal bed consists of clay with carbonaceous streaks or a few inches of banded coal. It is thickest in York, Mead, Washington, and Wayne Townships. Plate 17 shows its stratigraphic position, and figure 17 shows its areal distribution.

GILBOY SANDSTONE MEMBER

White (1891, p. 58) gave the name "Browntown" to the sandstone that occupies the interval between the Waynesburg and Little Waynesburg coal beds at Browntown, Harrison County, W. Va. He stated that it was sometimes called the "Gilboy" sandstone from a rocky cut of that name near Mannington, Marion County, W. Va. White subsequently (1903, p. 150) changed the name to Gilboy sandstone because a sandstone unit of Early Pennsylvanian age in Kanawha County, W. Va., had already been named Browntown sandstone.

In the southern and east-central parts of Belmont County, the Gilboy sandstone member occupies the interval between the Little Waynesburg and Waynesburg coal beds. In the west-central and northern parts of the county, where the Little Waynesburg coal bed is missing, a mudstone facies of the member lies between the Uniontown sandstone member and the Waynesburg coal bed. In the western part of the county, the Gilboy sandstone cannot be recognized because it forms a continuous sequence with the Uniontown sandstone member. The areal distribution and facies of the member are shown in figure 17, and its stratigraphic position is shown in plate 18.

The average thickness of the Gilboy sandstone member is about 15 feet, but the member has a maximum thickness of 29 feet near the southeastern part of Belmont County (pl. 18).

The lithologic character of the member varies from southeast to northwest across the county. Sandstone and siltstone are the predominant components in the southern and east-central parts of the county and mudstone in the central and northern parts (fig. 17). The sandstone in the southern and eastern parts of the county is irregularly bedded, shaly to flaggy, fine grained, and micaceous and is generally interbedded with shaly siltstone. Locally, lenses of massive medium- to coarse-grained crossbedded sandstone are interbedded with the finer grained sandstone and siltstone. In some places the entire member is siltstone, and in southwestern Pultney and southern Richland Townships (pl. 18, sections 8 and 9), several limestone beds interbedded with clay are in the upper part of the member. Limestone also occurs in the upper part of the member in the creek bank near the southeastern corner of sec. 4, Richland Township.

The mudstone facies, which is best developed in Smith, southern Richland, Union, and Goshen Townships, is silty and friable and contains impure nodules and stringers of limestone. This mudstone, which is characteristically olive gray to yellowish gray, grades upward into the impure underclay beneath the Waynesburg coal bed. The following section, measured in the north bank of U.S. Highway 40 near the center of the northeastern part of sec. 32, Union Township, shows both the lithologic character of the mudstone facies of the member and the relation of it to the overlying Waynesburg coal bed.

	Thickness Ft.	In.
Monongahela formation:		
Waynesburg sandstone member:		
Sandstone, shaly, fine-grained; stained by iron oxide, contains thin massive ledge; contains carbonized plant remains	12	0+
Clay, gray, shaly, silty		3
Waynesburg coal bed:		
Coal, shaly, bony		9
Coal, banded, cleated	2	0
Underclay:		
Clay, gray, silty; contains carbonaceous bands in top	2	0
Gilboy sandstone member (mudstone facies):		
Mudstone, olive-gray; heavily stained by iron oxide; contains limestone nodules; base concealed; measured to road level	12	0+

About half a mile west the lower part of the uppermost sandstone in the above section and also the upper part of the underlying Uniontown sandstone member crop out in the south bank of U.S. Highway 40.

The mudstone facies is thin and is poorly exposed in most places in Pease, Colerain, Wheeling, and northern Richland Townships.

WAYNESBURG (NO. 11) COAL BED

Rogers (1858, p. 506–507) named the Waynesburg coal bed for exposures around Waynesburg, Greene County, Pa. White (1891, p. 20–40; 57) lowered the Pennsylvanian-Permian boundary from the top of the Waynesburg sandstone to the top of the Waynesburg coal bed and thereby made this coal bed the uppermost unit in the Monongahela formation. Stevenson (1878, p. 261–287) used numbers to designate the various coal beds in Belmont County and assigned No. 11 to the coal that he thought was the Waynesburg of Pennsylvania. The No. 11 coal of Stevenson, however, is now known to be the Uniontown bed and his No. 12 coal is the Waynesburg. The coal beds in Ohio were renumbered and Stevenson's No. 12 bed was changed to No. 11, the present number of the Waynesburg coal bed. Condit (1916, p. 237) correctly correlated this bed with the Waynesburg coal bed of Pennsylvania. Locally the Waynesburg coal is erroneously called the No. 10 coal bed.

In Belmont County, the top of the Waynesburg coal lies from 230 to slightly more than 260 feet above the base of the Pittsburgh coal. It is separated from underlying sandstone members by an impure grayish underclay, which ranges from a few inches to about 4 feet in thickness. In southwestern Somerset Township this clay contains a reddish-brown layer.

The thickness of the Waynesburg coal bed is variable and ranges from a few inches to as much as 60 inches in Belmont County. Its average thickness is more than 42 inches in central and southern Richland, east-central Smith, western Wheeling, and western Colerain Townships, but it thins to the east, south, and west except for small isolated areas in western Mead and eastern Pultney Townships, where its average thickness also exceeds 42 inches. The bed is less than 14 inches thick in parts of Mead, York, and Washington Townships in southeastern Belmont County, and in parts of Wayne, Goshen, Somerset, and Warren Townships in the southwestern part of the county. Its thickness is also less than 14 inches in most of Kirkwood and Flushing Townships in northwestern Belmont County. Plate 19 contains diagrammatic sections showing its thickness and lithologic character, and plate 20 shows its areal distribution and thickness.

The Waynesburg coal generally contains several thin clay partings, principally in the lower half of the bed (pl. 19). In the eastern half of the county a band of shaly impure coal makes up the top 1 to 6 inches of the bed. This persistent band of impure coal grades westward into coaly shale, bone, and carbonaceous shale, and in Warren, Kirkwood, and Flushing Townships, the shale and bone make up more than half of the total thickness of the bed.

In southeastern Goshen Township at location 524, plate 19, the coal bed is absent, and in its place is a yellow and reddish-brown material that resembles flint clay. The bed is also absent locally in northwestern Washington, northern Wayne, and southern Goshen Townships, where it was either eroded in channels prior to the deposition of the overlying Waynesburg sandstone or was never deposited.

The Waynesburg coal bed in Belmont County is of high-volatile A and B bituminous rank and is relatively high in ash content. Detailed analyses of the coal are given in table 11. On the as-received basis, analyses of 11 samples indicate an average heating value of 11,628 Btu, ash content of 15.0 percent, and sulfur content of 3.0 percent.

PENNSYLVANIAN AND PERMIAN ROCKS

DUNKARD GROUP, WASHINGTON AND GREENE FORMATIONS UNDIFFERENTIATED

HISTORY OF NAMES

In the Appalachian coal field, strata now classified as Permian in age were originally included in the "Pittsburgh series" by Rogers (1839, p. 88–108). In 1840 Rogers (p. 150) changed the name to "Monongahela series" but did not subdivide the strata. Later he (1858, p. 14–20) revised the series and named the 900–1,000 feet of strata above the Waynesburg sandstone in Greene County, Pa., the "Upper Barren group."

Stevenson (1876, p. 35–56) named these rocks the "Upper Barren series" and subdivided them into two groups. He used the name "Washington County group" for the beds between the top of the Waynesburg sandstone and the top of the "Upper Washington limestone" in Washington County, Pa., and used the name "Greene County group" for all the beds above the "Upper Washington limestone" in Greene County, Pa. Fontaine and White (1880, p. 29–32) redefined the lower boundary of the "Upper Barren" of Rogers and Stevenson by lowering it from the top of the Waynesburg sandstone to the top of the Waynesburg coal bed. They stated (p. 119–120) that, on the basis of fossil plants, the "Upper Barrens" of the Appalachian coal field were Permian in age. White (1891, p. 20) revised the nomenclature of the "Upper Barrens" by renaming these strata the "Dunkard Creek series" for exposures along Dunkard Creek in Greene County, Pa. He described the series as follows:

> The rocks of these series (Upper Barren measures, No. XVI) begin with the roof shales of the Waynesburg coal and extend upward to the topmost beds of the Appalachian region.
> * * * Several independent measurements from the highest accessible summits foot up a little more than 1,150 feet for the thickness of the series and it is certain that no other localities could exceed this by more than 100 feet.

Subsequently, "Dunkard Creek series" was shortened to Dunkard group. This group includes the Washington and Greene formations, which are the "Washington County" and "Greene County" groups of Stevenson.

White (1891, p. 28–29) correctly identified the Waynesburg coal bed in describing sections in Monroe and Washington Counties, Ohio. He also stated that the strata above the Waynesburg coal bed in Ohio were equivalent to the "Dunkard Creek series" of Pennsylvania.

Prosser (1905, p. 2, 5, 6, 7) accepted White's correlation of the rocks above the Waynesburg coal bed in Ohio with the "Dunkard Creek series" of Pennsylvania but called the Permian rocks of Ohio the "Dunkard formation."

Stauffer and Schroyer (1920, p. 15–16) subdivided the Permian strata of Ohio into the Washington and Greene formations which they placed in the "Dunkard series." Their statement concerning this subdivision is as follows:

> In this State, as in Pennsylvania, the Dunkard series may be separated into two distinct formations. Following the usage of the United States Geological Survey, these may be called the Washington and the Greene formations. The former begins with the shales above the Waynesburg coal bed and ends with the Upper Washington limestone. The latter includes the remainder of the series. In Belmont and adjacent counties, the line of separation between these two formations is fairly well marked because of the presence of the limestone, but southward from Washington County, where this fails, it is rather hard to trace. However, it may still be continued southward by the use of the Jollytown "A" coal horizon or base of the Jollytown sandstone.

In a footnote below the above statement, they describe the Jollytown "A" coal bed as follows:

> This is the coal which I. C. White called the Jollytown coal, * * * but it does not agree in position with the one to which that name was originally applied by J. J. Stevenson, * * * the latter lying 60 to 70 feet lower in the Pennsylvania sections. The coal here indicated, however, appears to be much more persistent than Stevenson's Jollytown, but to avoid confusion it will be designated the Jollytown "A" coal in this report.

Plate 21, sections 9 and 10, shows the difference between the Greene County sections of Stevenson and White.

Unfortunately, the Jollytown "A" coal bed in Belmont County lacks the persistence and definitive character attributed to it by Stauffer and Schroyer. The coal occurs sporadically, is nowhere more than a few inches thick, and is readily obscured by weathering. Locating the Jollytown "A" coal bed, therefore, is difficult and must be done at most places by considerable searching and digging at a stratigraphic interval of about 100 to 120 feet above the Washington coal bed. Where the place of the coal is taken by clay a few inches thick, the problem of correlation is even more difficult.

The criteria used by previous workers in correlating the strata above the Washington coal bed in Belmont County with the type Dunkard section in Pennsylvania are not known; however, diagnostic fossils and distinctive marker beds are lacking. Previous workers apparently assumed that the coal overlying the third limestone above the Washington coal bed in Belmont County was equivalent to White's Jollytown coal, which overlies the third limestone above the Washington coal bed on Dunkard Creek in Pennsylvania. The interval between the Washington coal and White's Jollytown coal on Dunkard Creek is 267 feet (pl. 21, section 9). In Belmont County the interval between the Washington and the Jollytown "A" coals averages only 110 feet. (See pl. 21, which shows, in addition to White and Stevenson's sections of the Permian strata above the Washington coal bed in southwestern Pennsylvania, sections above the Washington coal bed in Belmont County, and tentative correlations of these strata with the "Permian" of Pennsylvania.) In correlating the coal bed, therefore, previous workers must have assumed that the strata thinned westward.

Past correlations of the Permian strata of Belmont County, Ohio, with the formations and members of the Dunkard group of Pennsylvania do not seem satisfactory on the basis of present data. Stevenson and White did not agree on the stratigraphic position of the Jollytown coal, and later workers in adjoining areas have not been consistent in their correlations even within relatively small areas. The Jollytown "A" coal bed of Ohio may be the equivalent of the Washington "A" coal bed of Pennsylvania, or it may be absent in Pennsylvania. One of the uppermost coals in Belmont County may be equivalent to White's Jollytown coal of Pennsylvania, but probably the Jollytown equivalent has been removed by erosion from Belmont County, if it was ever deposited. If correlations suggested in this report are correct, very little if any of the Greene formation is present in Belmont County. However, more data are needed to substantiate this.

If one assumes that the problem of the relations of the Ohio Jollytown "A" coal bed to White's Jollytown coal bed did not exist, the Permian strata in Belmont County do not possess lithologic differences that warrant subdivision into two formations. In this report, therefore, strata above the Waynesburg coal bed in Belmont County are called the Dunkard group, Washington and Greene formations undifferentiated.

Plant remains are scarce in the Dunkard strata of Belmont County, and no faunal remains that clearly indicate Permian age have been found. Though Fontaine and White were satisfied that all strata above the Waynesburg coal throughout the northern Appalachian basin were of Permian age, not all geologists have agreed fully with their conclusion. Essentially the controversy has arisen because of different interpretations of the floral data in a conformable sequence whose age relations are clearly transitional. Fontaine and White felt that plants with Permian affinities appeared as low as the Conemaugh formation and that these types became predominant above the Waynesburg coal. Others have contended that, inasmuch as *Callipteris conferta*, a diagnostic Permian plant throughout the world, has never been found in the northern Appalachian basin below the Washington coal bed of the Washington formation, rocks below that horizon should be designated as Pennsylvanian rather than Permian. Recently Cross (1958) concluded from an extensive study of Dunkard group flora, including spores, that plant species from the Allegheny formation of Pennsylvanian age, upward through the Dunkard group, indicate a gradual dying out of Pennsylvanian forms with the addition of only a few new forms that might be considered Permian. His report stresses the weathered and fragmentary condition of many of the collections from the Dunkard, but he summarizes his findings with the statement, "We do have a stable basis for some revision of the existing record." Based on Cross' study of the flora, the Pennsylvania Geological Survey had planned to redesignate the Washington formation as Pennsylvanian in age and to reclassify the Greene formation as Pennsylvanian and Permian on the forthcoming new geologic map of Pennsylvania. On November 1, 1959, representatives of the U.S. Geological Survey and representatives of the Pennsylvania, Ohio, and West Virginia Geological Surveys met in conference and formally revised the age of the Dunkard group. Henceforth, the Washington formation (lower part of Dunkard group) will be designated as Pennsylvanian and Permian in age and the Greene formation as Permian. In this report strata above the Waynesburg coal bed are classified as Washington and Greene formations undifferentiated of Pennsylvanian and Permian age.

DISTRIBUTION

Rocks of the Dunkard group crop out in every township in Belmont County, but the most extensive deposits are in the southeastern part. The base of the group lies well down on the ridge slopes in York, Mead, and Washington Townships, but because of the dip, the elevation of the base increases gradually toward the northwest; therefore, more of the Dunkard group has been removed by erosion toward the west. In the extreme western part of Belmont County in northern Warren, southeastern Kirkwood, and western Flushing Townships, the lower few feet of the Dunkard group form small isolated cappings on the tops of the highest ridges.

THICKNESS

Only the lower 475± feet of Dunkard strata remain in Belmont County, as the upper part of the group has been removed by erosion. The Pennsylvanian and Permian rocks are thickest in York Township and thin progressively by erosion to the northwestern corner of the county where the Pennsylvanian and Permian strata are missing altogether.

GENERAL CHARACTER

The Dunkard group in Belmont County consists of interbedded sandstone, siltstone, shale, mudstone, clay, limestone, and coal. These strata were deposited in a cyclic pattern as were the rocks of Pennsylvanian age, so that each lithologic type is repeated vertically. The lithologic components also intergrade laterally as do those of Pennsylvanian age.

The sandstone ranges from massive to shaly and is commonly interbedded with siltstone. The thickest and most massive sandstone beds are in the lower half of the group in the southern part of the county. Above the Jollytown "A" coal bed, the sandstone is shaly to flaggy bedded and grades laterally into siltstone at many places. The sandstone beds of the Dunkard are micaceous, poorly sorted, and generally fine to medium grained, and in most places they overlie the coal beds or the carbonaceous clays that, in places, occupy the horizon of the coal beds.

The limestone beds are commonly thin and make up about 13 percent of the total thickness. In northeastern Belmont County, however, the interval between the Washington and Jollytown "A" coal beds contains 4 limestone members that constitute as much as 40 percent of the strata in this interval (pl. 22). The sequences of limestone generally underlie the coal beds, but limestone beds are interbedded with the sandstone and siltstone above the Waynesburg, Waynesburg "A," and Washington coal beds in eastern Belmont County.

The mudstone beds are associated with sequences of limestone, and they seem to be a transition between the shale at the top of the sandstone beds and the overlying limestone. Locally mudstone takes the place of an entire sequence of limestone.

The limestone is lenticular, and beds may be either massive or nodular. Where several beds occur together, they are separated by partings of clays, shale, or mudstone. Most of the limestone beds contain some clay and silt as impurities.

Underclays generally lie directly beneath the coal beds and are soft and plastic. These underclays are thin and impure and unsuitable for commercial use.

The coal beds are thin, impure, and discontinuous. An exception is the Washington coal bed, which is persistent throughout the county, and locally is more than 4 feet thick. The thin coal beds are represented at many places by coaly to carbonaceous shale or by carbonaceous clay. The intervals between the coal beds are uniform in the Dunkard group, as in the Monongahela, and rarely vary more than 1 to 2 feet per mile.

The Pennsylvanian and Permian strata resemble the Conemaugh formation in the occurrence of red beds and in the thinness of coal beds. All the red beds are above the Washington coal bed, with the exception of a few reddish blotches in the clay associated with the Waynesburg "A" coal bed. The most prominent zone of red rock is the mudstone which takes the place of the upper tongue of the Middle Washington limestone member in southern Belmont County. Beds of red mudstone or red shale overlie the thin coals above the Washington coal bed.

DESCRIPTION OF MEMBERS

Previous workers have divided the Dunkard group into a number of members on the basis of lithologic differences. A total of 16 members and 7 coal beds are recognized in Belmont County. They are listed below in descending order:

Hendershot coal
Powhatan Point limestone
Big Run coal bed
Dilles Bottom limestone
Aults Run sandstone
Jollytown "A" coal bed
Upper Washington limestone
Upper Marietta sandstone
Washington "A" coal bed(?)
(Upper tongue) Middle Washington limestone
Middle Marietta sandstone
(Lower tongue) Middle Washington limestone
Lower Marietta sandstone
Lower Washington limestone

Washington coal bed
Bristol limestone of Hennen (1912)
Washington sandstone
Little Washington coal bed
Mannington sandstone of Grimesley (1909)
Waynesburg "A" coal bed
Mount Morris limestone
Wegee limestone
Elm Grove limestone
Waynesburg sandstone

The stratigraphic relation of these units is shown in plate 2.

Few changes were made in the nomenclature of the strata between the Waynesburg sandstone and the Jollytown "A" sandstone, except for recognizing that the Middle Washington limestone splits into lower and upper tongues in Belmont County and except for naming a new member, the Wegee limestone, which is in the lower part of the Dunkard group just above the Elm Grove limestone member. The correlation of the members between the Lower Washington limestone and the Jollytown "A" coal bed in Belmont County with members of the same name in the Dunkard Creek section in Pennsylvania is doubtful, but until a detailed regional study of these strata is made, the substitution of new names for the entire Ohio section would do no more than add to the existing confused state of the nomenclature of the Pennsylvanian and Permian strata of the Eastern United States. New local names are introduced above the Jollytown "A" sandstone because with present data it is impossible to attempt a correlation of the relatively thin beds in Ohio with named strata in West Virginia and Pennsylvania.

WAYNESBURG SANDSTONE MEMBER

The Waynesburg sandstone was named by Stevenson (1873, p. 16) for its exposures near Waynesburg, Pa. He designated it as the uppermost unit in the "Upper Productive Coal Measures" or Monongahela formation. Fontaine and White (1880, p. 29–32) reassigned the Waynesburg sandstone member to the Washington formation of the Dunkard group, which they designated as Permian in age on the basis of plant fossils found in the shale beds that separate the Waynesburg sandstone member from the underlying Waynesburg coal bed at Cassville, W. Va. Plant-bearing shale beds were not seen above the Waynesburg coal bed in Belmont County.

The Waynesburg sandstone member occupies the interval between the Waynesburg coal bed and the Mount Morris limestone member in western Belmont County. In the eastern part of the county, the lower part of the member, which in places consists of shale, clayey shale, and clay, is interbedded with the Elm Grove and Wegee limestone members. Plate 23 shows the character and the stratigraphic relation of the sandstone to the two limestone beds which are, in part, stratigraphic equivalents. Locally in northwestern Wayne, southwestern Goshen, northwestern Washington, and southeastern Warren Townships, the overlying Mount Morris limestone and Waynesburg "A" coal bed are absent, and the Waynesburg and Mannington sandstone members merge.

The member ranges in thickness from 16 feet in western Somerset Township (pl. 23, section 9) to more than 40 feet in parts of Wayne and Smith Townships (pl. 23, sections 11–14).

The Waynesburg sandstone member consists mostly of sandstone and siltstone but in places contains shale and mudstone. The sandstone is lenticular, thin to thick bedded, irregularly bedded, and commonly crossbedded.

The typical irregularly bedded character of the Waynesburg sandstone member is obvious at the outcrop in the railroad cut at Belmont. The sandstone at that outcrop apparently was deposited as part of a delta that was transgressing eastward. Massive lenses of channel sandstone, 5 to 10 feet thick, occur locally in secs. 19 to 25, Goshen Township, and sec. 5, Pultney Township.

The siltstone is platy and generally interbedded with sandstone. Siltstone and some shale make up a large percentage of the lower part of the Waynesburg sandstone member in eastern Belmont County.

The sandstone and siltstone are separated from the underlying Waynesburg coal bed in most places by shale or shaly clay from a few inches to several feet thick. Along Welsh Run in sec. 36, Richland Township, platy silty shale, as much as 6 to 7 feet thick, forms the basal part of the member, and because of its incompetence makes underground mining of the underlying Waynesburg coal bed difficult. The shale and clay above the coal bed grade upward to siltstone and sandstone, but locally the shale and clay have been channeled and scoured away and massive sandstone lies directly on the Waynesburg coal bed. The upper part of the Waynesburg sandstone member grades upward into the shale and mudstone associated with the overlying Mount Morris limestone member. In western Richland, northern Goshen, and Union Townships in central Belmont County, approximately the upper third of the member is gray to greenish-gray impure clay or mudstone that locally contains reddish blotches and calcareous nodules (pl. 23, section 1).

The sandstone and siltstone beds are gray, but weather brown to olive gray. The grain size ranges from fine to coarse, but is predominantly fine.

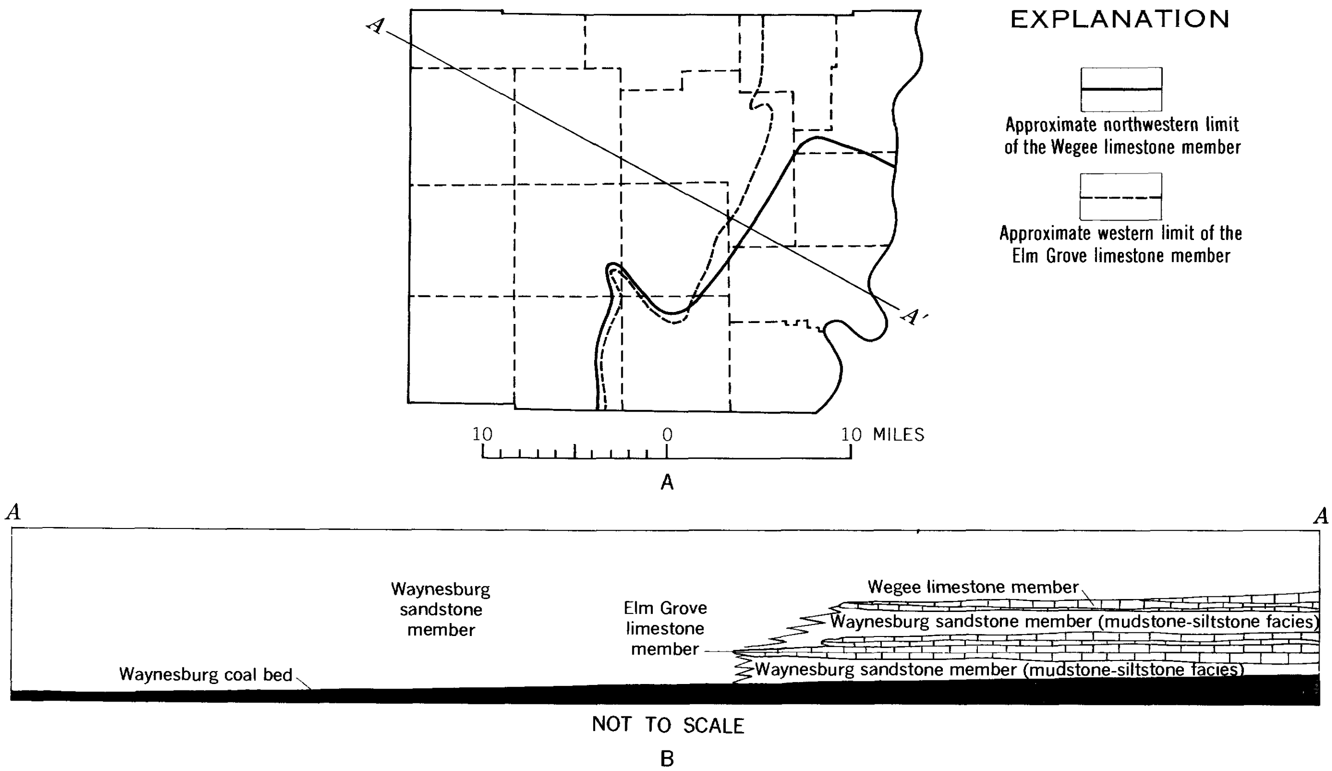

FIGURE 18.—Map of Belmont County and diagrammatic section showing the areal distribution and stratigraphic relation of the Wegee and Elm Grove limestone members of the Dunkard group to the Waynesburg sandstone member and to the Waynesburg coal bed.

Both the sandstone and the siltstone contain abundant mica and, like the underlying sandstone beds of the Conemaugh and Monongahela formations, are poorly sorted.

ELM GROVE LIMESTONE MEMBER

The lower of the two limestone members interbedded with the lower part of the Waynesburg sandstone member in the eastern third of Belmont County (pl. 23) is a correlative of the Elm Grove limestone, which was named by Grimsley (1907, p. 68–69) for its outcrops at Elm Grove, W. Va.

The Elm Grove limestone member in Belmont County consists of one to three or more closely spaced beds having a combined thickness ranging from 1 to 7 feet. Its areal distribution is shown in figure 18. The limestone lies from 1 to 8 feet above the Waynesburg coal bed and is generally separated from the coal by clayey shale, which is locally replaced by silty shale, siltstone, or fine-grained sandstone. The clay, shale, siltstone, and sandstone are a tongue of the Waynesburg sandstone member.

Most of the beds in the Elm Grove limestone member are argillaceous and disintegrate rapidly upon weathering. The uppermost bed, however, is resistant and forms a distinctive angular ledge. This limestone bed contains silty laminae that are resistant to erosion and stand out as ridges on weathered surfaces. Locally this bed contains shaly carbonaceous partings an inch or so thick. After prolonged weathering the bed breaks into large slabs resembling "flagstone." The upper bed is 3½ feet thick along the east branch of Moore Run in sec. 35, York Township. The following section measured at an abandoned mine just east of the road in the SW¼ NW¼ sec. 14, Mead Township, shows the lithologic character of the member and its relation to associated strata:

	Thickness Ft.	In.
Dunkard group, Washington and Greene formations undifferentiated:		
Wegee limestone member:		
Limestone, silty, conglomeratic	1	0
Waynesburg sandstone member:		
Siltstone, shaly, even-bedded; consists of interbedded shaly layers and sandy layers 1 to 2 in. thick; contains at top shaly fine-grained sandstone	11	0
Shale; contains carbonaceous band in base; grades into unit above	3	0
Elm Grove limestone member:		
Limestone, silty, laminated; has ridged outer edge; forms ledge; weathers into slabs and plates	2	4
Mudstone, silty, calcareous; contains limestone nodules	1	0
Limestone, silty; weathers to two beds	1	2
Clay, shaly, partially covered	5	6
Monongahela formation: Waynesburg coal bed crops out in bank at small abandoned mine.		

The argillaceous beds of Elm Grove limestone member weather olive to yellowish gray. The upper resistant bed, however, weathers bluish gray, and its color, together with its lithologic characteristics and position above the Waynesburg coal bed, makes it a valuable stratigraphic marker.

Overlying the uppermost bed of the Elm Grove in most places is a thin carbonaceous to coaly shale and clay band that ranges from a few inches to 1½ feet in thickness. In the southwestern part of section 9, Smith Township (pl. 23, section 14), an unnamed coal bed 2 feet thick lies 12 feet above the Waynesburg coal bed and at the approximate position of the carbonaceous shale. There shaly siltstone takes the place of the Elm Grove limestone member.

The Elm Grove member contains ostracodes, fish remains, and other unidentifiable broken fossil remains.

WEGEE LIMESTONE MEMBER

Along the valleys of Wegee and Pipe Creeks in Mead Township and locally in Pease, Pultney, York, Washington, Wayne, and Goshen Townships, a thin limestone unit that in places consists of two beds of limestone separated by shale or shaly siltstone lies from 6 to 18 feet above the Elm Grove limestone member and is separated from it by a siltstone tongue of the Waynesburg sandstone member. This limestone is thickest in eastern Mead Township, along the valley of Wegee Creek, but it occurs as far north as sec. 15, Pease Township (pl. 23, section 6), and as far west as sec. 2, Goshen Township (pl. 23, section 13), and sec. 9, Wayne Township (pl. 23, section 12).

Because this limestone is a distinct unit and not a part of the Elm Grove limestone member, it warrants member status and is named the Wegee limestone member for its outcrop in the cut of the ridge road in the SE¼SW¼ sec. 32 E., Mead Township, where it lies 12 feet above the Elm Grove limestone at a point about half a mile due west of Wegee. Figure 18 shows the areal distribution of the Wegee limestone member, and figure 19 is a photograph of the lower bed of the member taken at the type locality. Following is a detailed description of the type section:

	Thickness Ft.	In.
Dunkard group, Washington and Greene formations undifferentiated:		
Waynesburg sandstone member:		
Sandstone, massive; forms ledge	2	6+
Shale, silty, blocky; contains reddish-brown band near base	3	0
Wegee limestone member:		
Limestone, olive-gray, very silty, laminated; forms angular ledge; weathers to blocks		6
Siltstone; lower two-thirds compact, blocky, with thin layer of carbonaceous clay at base; upper third shaly	7	10

	Thickness Ft.	In.
Dunkard group, Washington and Greene formations undifferentiated—Continued		
Wegee limestone member—Continued		
Limestone, olive-gray, silty, laminated, conglomeratic; contains lenticular, shaly partings; forms ledge	3	0
Tongue of Waynesburg sandstone member:		
Siltstone, shaly, blocky	12	2
Elm Grove limestone member:		
Limestone, laminated; weathers to slabs	2	3
Shale		8
Limestone, silty		8
Covered interval; appears to be soft mudstone	5	7
Monongahela formation:		
Waynesburg coal bed:		
Coal; too highly weathered for measurement.		

The Wegee limestone member is lenticular and occurs either as a single massive bed ranging from 1½ to 3 feet in thickness or as two beds separated by a few feet of shale or shaly siltstone. The upper bed, which is more lenticular than the lower main bed, ranges from a few inches to about 2 feet in thickness.

FIGURE 19.—Outcrop of the lower bed (*a*) of the Wegee limestone member at the type locality in a road cut in the SW¼ sec. 32 E., Mead Township. The upper bed (*b*) is in the upper shaded part of the photograph.

The general character of the Wegee limestone member is argillaceous and conglomeratic, which distinguishes it from the underlying Elm Grove limestone. Fresh surfaces are olive gray, but weathered surfaces are a characteristic yellowish gray. No fossils were found in the Wegee limestone member.

MOUNT MORRIS LIMESTONE MEMBER

The Mount Morris limestone member was named by White (1891, p. 39, 40) for its exposures along Dunkard Creek at Mount Morris, Greene County, Pa., where it is 2 to 5 feet below the Waynesburg "A" coal bed.

In Belmont County the Mount Morris limestone member lies from a few inches to 10 feet below the Waynesburg "A" coal bed and is separated from the coal by impure underclay or mudstone. The limestone over most of the eastern half of the county consists of one or more lenticular beds, but in most of the central and southwestern parts of the county the member is represented by mudstone or clay containing nodules of limestone. The limestone and associated clay range from a few inches to as much as 9 feet in thickness. Because of its position near the hilltops in the northwestern part of the county, the few outcrops of this limestone are so highly weathered that the lithology and thickness are largely unknown in that area. The member is absent in western Wayne, southern Goshen, east-central Warren, and southeastern Richland Townships.

Where the member is a single layer, it forms a massive ledge. Where it is multibedded, the individual layers are thin, lenticular, and intercalated in clay or mudstone. Locally the overlying Waynesburg "A" coal bed is interbedded with the Mount Morris limestone member, as shown in the following section measured in the bank of U.S. Highway 40 in the NE¼NE¼ sec. 20, Union Township:

	Thickness Ft.	In.
Dunkard group, Washington and Greene formations undifferentiated:		
Mannington sandstone member:		
Sandstone, shaly	5	0+
Waynesburg "A" coal bed and Mount Morris limestone member:		
Limestone, conglomeratic, weathered		9
Shale, iron-encrusted	3	0
Clay, carbonaceous		8½
Shale, arenaceous	11	3
Coal		3¼
Clay, gray, iron-stained	2	2
Clay, carbonaceous		3
Clay, light-gray, iron-stained		2
Clay, carbonaceous		5
Siltstone, shaly, iron-stained	3	6
Clay, carbonaceous, shaly		1¾
Limestone, silty; forms ledge	1	2
Clay, carbonaceous		8
Limestone, silty, nodular		7
Level of U.S. Highway 40.		

The Mount Morris limestone contains clay and silt impurities, and at some places it is conglomeratic.

Fossils in the member include ostracodes and *Spirorbis*.

WAYNESBURG "A" COAL BED

The Waynesburg "A" coal bed was named by Stevenson (1876, p. 56) for exposures in Washington and Greene Counties, Pa., where the coal is 1 to 3 feet thick.

In Belmont County the thickness of the Waynesburg "A" coal bed ranges from a few inches to 4 feet 10 inches. Figure 20 contains diagrammatic sections of the coal, and plate 15 is an isopach map of the bed. The coal is thin or represented by clay in most of the county, and only in the southeastern part in Washington and York Townships is the Waynesburg "A" coal more than 14 inches thick. In the southern and southeastern parts of Washington Township and in the southwestern and southeastern corners of York Township, the average thickness is more than 28 inches. The thickness is variable in both townships except along Peavine Creek in secs. 8, 13, and 14, Washington Township, where the coal is uniformly about 40 inches thick. The maximum observed thickness of the bed is 58 inches in sec. 13, Washington Township (pl. 15 and fig. 20, section 858), although the lower 17½ inches is impure. It is 55½ inches thick but impure in the southwestern part of sec. 26, Washington Township (pl. 15 and fig. 20, section 851). Because the Waynesburg "A" coal bed is well above average thickness in Washington and York Townships and because the Waynesburg coal is very thin there, the Waynesburg "A" coal can easily be mistaken for the Waynesburg. In secs. 4, 10, 19, 20, and 25, Warren Township, the bed consists of a single layer of coal, from 4½ to 15 inches thick, that is commonly overlain by a thin band of coaly shale.

Although it is carbonaceous clay or impure coal at many places, the Waynesburg "A" coal bed is persistent throughout most of Belmont County. Its stratigraphic position lies near the tops of the hills in the western and northwestern parts of the county, and the thin coal is obscured in most places by weathering. The interval between the Waynesburg "A" coal and the underlying Waynesburg coal ranges from 17 feet in sec. 33, Somerset Township (pl. 23, section 9) to 50 feet in sec. 9, Smith Township (pl. 23, section 14). The average interval between the two coals is 45 feet.

In Washington and York Townships the Waynesburg "A" coal bed generally contains from 1 to 6 lenticular partings of clay, shale, or bone individually from 1 to 10 inches thick (fig. 20). Along Crabapple Creek in Washington Township, a limestone parting, locally 10 inches thick, occurs in the coal (fig. 20, sections 852 and 857) and in places bone or carbonaceous shale replaces a part of the bed. Elsewhere in

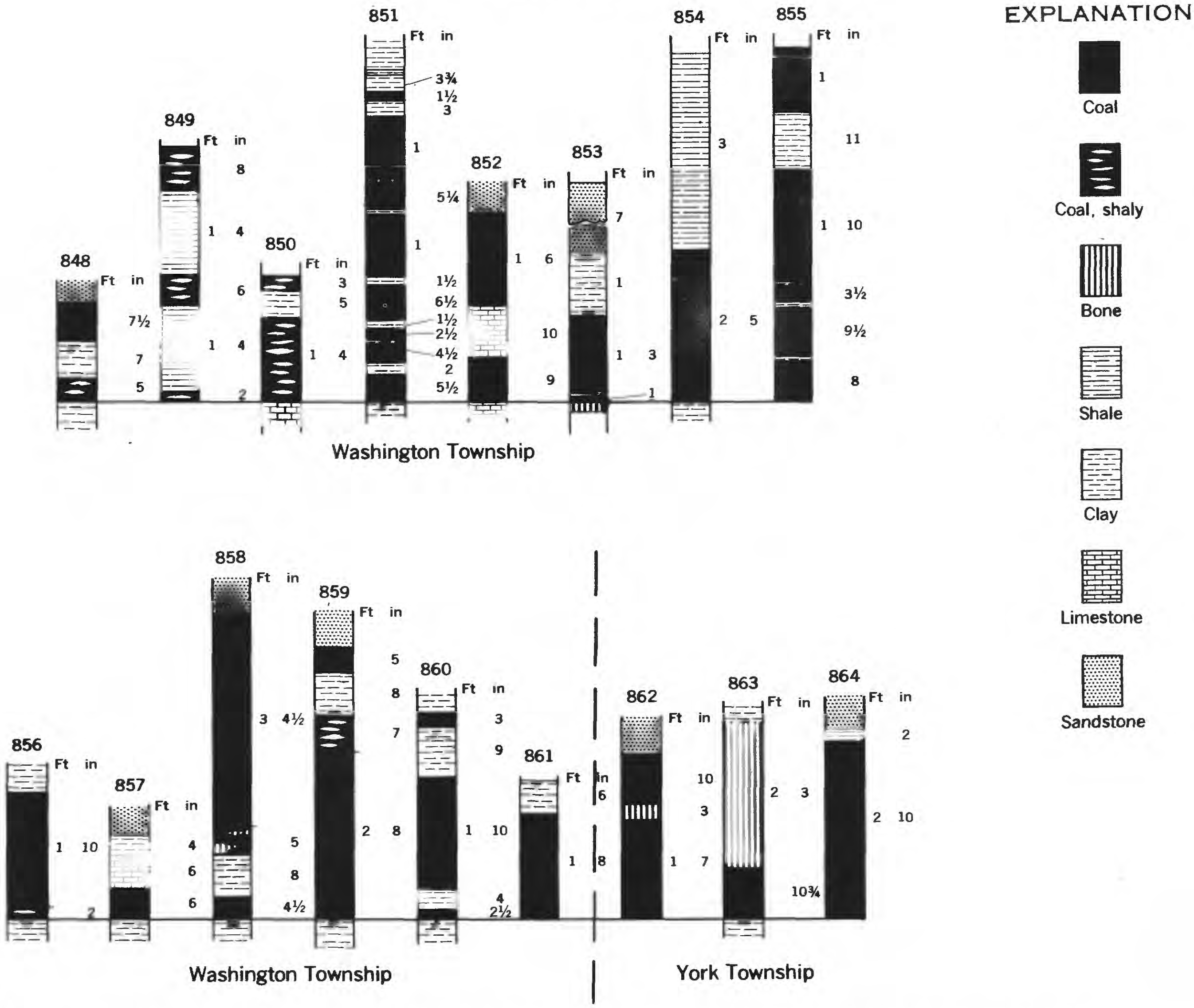

Figure 20.—Sections of the Waynesburg "A" coal bed in Belmont County, Ohio. For geographic location of individual sections see plate 15.

southern Belmont County in Wayne, Somerset, and southern Goshen Townships, the bed consists of thin bands of coal or coaly shale interbedded with clay or shale. The bed is absent in secs. 30 and 36, Wayne Township, secs. 25 and 31, Goshen Township, and secs. 1 and 2, Warren Township, where the overlying Mannington and underlying Waynesburg sandstone members coalesce. Throughout Mead, Smith, northern Goshen, Union, Richland, Pultney, Pease, and Colerain Townships, the place of the coal is taken by gray to greenish-gray clay containing thin bands of carbonaceous clay or coaly shale. The gray underclay beneath the carbonaceous bands contains thin layers of reddish shale or reddish clay.

Annularia-like forms of fossil plants were found in the clay and shale partings of the bed in several places along Crabapple Creek in southwestern Washington Township.

No analyses of the Waynesburg "A" coal in Belmont County have been made, but the relatively large number of clay and shale partings indicate a probable high content of ash. The bed has been mined for home use in Washington Township.

MANNINGTON SANDSTONE MEMBER

The Mannington sandstone was named by Grimsley (1909, p. 440–441) for its exposure near Mannington, Marion County, W. Va., where the sandstone occupies the interval between the Waynesburg "A" and the Little Washington coal beds. Stauffer and Schroyer (1920, pl. 9) correlated the sandstone between the Waynesburg "A" and Washington coal beds in Ohio with the Mannington sandstone of West Virginia. In most of Belmont County the Mannington sandstone lies between the Waynesburg "A" and Washington coal beds but in places the top of the member is separated from the Washington coal bed by an underclay, and in other places both the underclay and the Bristol limestone member lie between the sandstone and the coal. In Mead and eastern Smith Townships, the Little Washington coal bed is present beneath the Washington coal bed and the Mannington sandstone is restricted to the interval between the Waynesburg "A" and Little Washington coal beds. Plate 24 shows the stratigraphic position of the member and its relation to associated strata.

The member ranges in thickness from 21 feet in eastern Richland Township (pl. 24, section 8) to more than 50 feet locally in Wayne and York Townships (pl. 24, sections 2 and 6).

The Mannington sandstone member varies from massive channel sandstone to shale containing beds of impure limestone. The member is massive channel sandstone in the southwestern part of Belmont County, where it forms a sinuous band from 2 to 4 miles wide that trends northwestward across central Wayne Township, the southwestern corner of Goshen Township, the southeastern and south-central part of Warren Township, and the northeastern and north-central part of Somerset Township. The most prominent exposure of the channel facies of the Mannington sandstone is at Raven Rocks along Piney Creek in the southeastern corner of Wayne Township. There the sandstone is more than 50 feet thick and forms a waterfall and vertical walls along a narrow gorge. This massive sandstone also caps Sandy Ridge in secs. 1, 2, 3, and 9, Warren Township, secs. 31 and 32, Goshen Township, and secs. 30 and 36, Wayne Township; the ridges south of Barnesville in secs. 13, 14, 19, and 20, Warren Township; and the ridge that trends northwestward from sec. 5 to sec. 24, Somerset Township. Along Sandy Ridge and in parts of secs. 17, 23, and 24, Wayne Township, and in sec. 36, Washington Township, the Mannington and underlying Waynesburg sandstone members join. In the bank of the road that extends up the nose of the ridge in the northeastern part of sec. 36, Washington Township, the Mannington sandstone member appears to rest disconformably on the Waynesburg sandstone member.

In other parts of the county, the Mannington sandstone member is composed of shaly to flaggy sandstone, siltstone, and some shale. In parts of eastern Belmont County in Mead, eastern Smith, and eastern Richland Townships (pl. 24, sections 5, 7, and 8), lenticular beds of limestone and limestone nodules are in the member. Mudstone and clay form the upper part of the member in places in southeastern Belmont County.

The massive channel Mannington sandstone member in southwestern Belmont County is irregularly bedded, crossbedded, and has an undulatory base. The shaly to flaggy sandstone in other parts of the county commonly contains massive lenticular layers of crossbedded sandstone, but in places the sandstone grades laterally to platy siltstone or shale. Ripple marks were seen at outcrops in the cut of U.S. Highway 40 in the northwestern part of sec. 21 E., Richland Township. The massive facies of the sandstone is medium to coarse grained, micaceous, poorly sorted, and friable. The shaly and flaggy sandstone is generally fine grained, micaceous, and poorly sorted. The overall lithologic character of the Mannington sandstone member is shown in plate 24.

The beds of sandstone and siltstone are olive gray, but they weather rusty brown. Weathered surfaces of the sandstone are stained by sulfates and iron oxide in some places.

Casts of logs and carbonized plant debris are in the basal part of the massive channel sandstone in the southwestern part of the county.

LITTLE WASHINGTON COAL BED

The Little Washington coal bed was named by Stevenson (1876, p. 54) for its presence about 15 feet below the Washington coal bed in Washington County, Pa. In Belmont County the Little Washington coal bed is from 10 to 17 feet below the lower bench of the Washington coal bed in Mead, eastern Smith, and south-central Richland Townships. Elsewhere in the county it is absent. (See pl. 24 for its stratigraphic position.)

The thickness of the Little Washington coal bed ranges from a few inches to 20 inches, but generally averages less than 12 inches. It is impure, consisting mainly of shaly coal, bone, and clay partings and in many places entirely of shaly bone. The following detailed section, measured in the bank of the road along the nose of the ridge in the northwestern part of sec. 2, Mead Township, shows the lithologic character of the Little Washington coal bed and its relation to associated strata:

	Thickness Ft.	In.
Dunkard group, Washington and Greene formations undifferentiated:		
Washington coal bed:		
Coal, weathered, slumped; total thickness not seen (upper bench)	2	0+
Clay		6
Mudstone, dark-gray to black, shaly; contains *Lingula permiana* near top		7
Shale; highly encrusted with iron oxide	1	1

Dunkard group, Washington and Greene formations undifferentiated—Continued	Thickness Ft.	In.
Washington coal bed—Continued		
Ironstone concretions, discoid-shaped; contain *Myalina* sp		2
Shale, carbonaceous; contains what seem to be small pelecypods (also seen at localities in the eastern and southeastern parts of the county)		7
Coal, shaly, impure (lower bench)		3
Washington sandstone member:		
Siltstone, shaly; upper part is almost mudstone	8	1
Sandstone, laminated, even-bedded, micaceous; consists of flaggy to massive layers	5	0
Mudstone, highly weathered	3	5
Little Washington coal bed:		
Coal, shaly, impure		3
Clay, dark-gray to black; upper 2 in. stained with iron oxide		8
Coal and coaly shale, interbedded		10
Clay, stained by iron oxide	1	0
Bottom of ditch along edge of road.		

WASHINGTON SANDSTONE MEMBER

The Washington sandstone member was named by Stevenson (1876, p. 53) for its exposures in Washington County, Pa., where it lies between the Little Washington and Washington coal beds. In Belmont County the Washington sandstone member also occupies the interval between these two coal beds or, more precisely, the interval between the Little Washington coal bed and the underclay and limestone beneath the Washington coal bed and, like the underlying Little Washington coal bed, is present only in Mead, eastern Smith, and south-central Richland Townships (pl. 24). The Washington of eastern Belmont County is equivalent in age to the upper part of the Mannington sandstone member in other parts of the county.

The Washington sandstone member is 10 to 17 feet thick in Belmont County. It is generally composed in part of laminated, micaceous sandstone, and in part of siltstone. Mica and much carbonized plant material are concentrated along the bedding planes, and these impurities form laminae within the sandstone and cause it to split into thin shaly plates. The sandstone is light gray, and weathered surfaces are stained rusty brown by iron oxides. The sandstone is fine grained and like other Pennsylvanian and Permian sandstones is poorly sorted. The measured section given in the description of the Little Washington coal bed shows the typical lithology of the Washington sandstone member.

BRISTOL LIMESTONE MEMBER

The Bristol limestone member was named by Hennen (1912, p. 165–169) for outcrops at Bristol, Harrison County, W. Va.

The Bristol limestone member, with one exception, occurs only in eastern fourth of Belmont County where it lies between the Washington sandstone member and the underclay beneath the Washington coal bed; it was also seen at one locality in sec. 8, Wayne Township, in the south-central part of the county. The member appears to be most persistent in Pease Township in the northeastern corner of the county (pl. 24).

The thickness of the Bristol limestone member ranges from a few inches to about 7 feet, and averages about 1 foot. It is lenticular and occurs in one layer or several layers separated by thin lenticular beds of clay.

The best outcrop in Belmont County is in the bank along the north side of the baseball field in the Memorial Park at Martins Ferry in the SW¼ sec. 24, Pease Township (pl. 24, section 9). There the member consists of two beds of limestone separated by 3 feet of calcareous shaly clay containing limestone nodules. The upper bed of limestone, which at this locality is 26 inches thick, is highly argillaceous and conglomeratic. The high clay content, conglomeratic character, and nodular bedding are typical of the member; and because of the high clay content, the limestone weathers very rapidly.

The color of the freshly exposed limestone was not seen, but the weathered limestone is yellowish gray to grayish yellow.

The Bristol is separated from the overlying Washington coal bed by several feet of plastic impure underclay or clay and shale.

WASHINGTON (NO. 12) COAL BED

The Washington coal bed, which was originally called the Brownsville by White (1874, p. 46–57), was renamed by Stevenson (1876, p. 51) for exposures in Washington County, Pa., where the coal lies about 135 feet above the Waynesburg coal bed. The interval between the Waynesburg and Washington coal beds in Belmont County averages about 100 feet; but because of a rather uniform southward thickening of the rocks between the two coals, the intervening rock thickens from 83 feet in sec. 26, Pease Township, to 138 feet in sec. 5, Washington Township.

The Washington (No. 12) coal bed, the highest of the numbered coals in Ohio, underlies the eastern two-thirds of Belmont County. It has been removed by erosion from Warren, Kirkwood, Flushing, and Wheeling Townships, and occurs only on a few isolated hilltops in Union Township.

The Washington coal bed consists of two benches separated by a parting of variable thickness. The bed is thickest in the eastern part of the county and thins appreciably westward. The combined thickness of the coal and partings ranges from less than 14 inches in Somerset, western Goshen, and Union Townships to as much as 22 feet locally in sec. 18, Pultney Township. Plate 25 is an isopach map showing the thickness of the bed, and plate 26 contains diagrammatic sections showing the lithology of the coal. Because the lower bench of the Washington coal bed is generally impure and less than 14 inches thick, the isopach lines on plate 25 are drawn on the upper bench of the bed, which ranges in thickness from 2 inches in Somerset Township to 8 feet 7 inches in eastern Pease Township. The average thickness of the upper bench is more than 42 inches in the eastern part of Belmont County in Pease, eastern Richland, Pultney, eastern Mead, northern York, and southern Washington Townships. The two benches are separated by a parting of shaly clay 2 inches thick in western Somerset Township, but eastward this parting becomes a tongue of silty mudstone that is 18 feet thick in sec. 18, Pultney Township The average thickness of this tongue in the eastern part of the county is about 4 feet. In Pease Township the upper and lower benches merge.

The lower bench is thin and impure over most of the county. It is generally composed of shaly coal and bone, but in Somerset and Wayne Townships consists of fairly pure coal. Locally in northwestern Goshen Township and along the east side of Crabapple Creek and in places along Peavine Creek in Washington Township, the lower bench of the Washington coal bed is absent.

The thicker upper bench generally has about 12 to 18 inches of good hard coal in the lower part, but the upper one-half to two-thirds is impure, shaly coal in most places. In southern Smith, southern Washington, and southern York Townships, almost all the upper bench consists of good hard coal; but some thin bone, shale, and carbonaceous clay bands are present. Persistent partings were not seen, but one or more partings of clay, shale, and bone are in the upper bench at most places. In Colerain, Pease, and northeastern Richland Townships, the upper bench consists of interbedded laminae of shaly coal and clay.

The main parting or tongue that separates the two benches of coal consists of clayey shale and hard silty shale containing locally discoid ironstone concretions 9 inches or more in diameter. In the southwestern and south-central parts of the county in Somerset, Wayne, and western Washington Townships, the parting is thin and consists of shaly clay but in the central and eastern parts of the county, where the parting is a tongue, it consists mainly of interbedded clayey shale and hard silty shale. The parting is absent in Pease Township in the northeastern part of the county where the two benches join.

An interesting feature of the shale between the benches of the Washington coal bed in Belmont County is the presence of a small linguloid brachiopod that has not been found in any other stratum. Stauffer and Schroyer (1920, p. 143) named the brachiopod *Lingula permiana,* but they found it at only one locality near Alledonia, Washington Township. The writer found *Lingula permiana* at 17 other localities as follows:

Localities where fossils were collected

Township	Sec.	Distance below upper bench of coal bed		Remarks
		Ft.	In.	
Richland	NW¼SE¼SE¼ sec. 10	---	---	Road bank.
Do	NE¼NW¼NE¼SW¼ sec. 8	5	7	400 ft south of house.
Do	NE¼NW¼NE¼ sec 2	5	6	75 ft north of road intersection.
Do	NW¼SW¼SW¼ ses. 27 E	1	0	Road bank.
Do	NW¼NE¼NE¼ sec. 21	---	---	
Pultney	NW¼NW¼SE¼ sec. 18	3	6	Ravine north of road.
Do	SE¼SW¼SW¼SE¼ sec. 6	1	6	Road bank.
Do	SE¼NW¼SW¼ sec. 34	---	9	Do.
Mead	Center of NW¼ sec. 18	3	0	Do.
York	W½NW¼ sec. 15	3	0	Do.
Do	NW¼NW¼ sec. 8	3	0	Road bank at curve.
Do	NE¼NW¼SE¼ sec. 9	4	7	Road bank.
Washington	North-central part of NW¼ NE¼ sec. 35.	---	---	
Do	SE¼NE¼NW¼ sec. 21	---	---	Road bank.
Goshen	SW¼NE¼ sec. 9	---	---	Road bank near abandoned house.
Do	SW¼SE¼SW¼ sec. 29	---	---	Railroad cut at curve.
Wayne	SE¼SE¼NE¼ sec. 11	---	---	Ravine west of abandoned house.

The known areal distribution of *Lingula permiana* is shown in figure 21.

The occurrence of *Lingula permiana* is apparently controlled by the type of sediment because it is generally in the mudstone or clayey shale rather than in the silty shale. One exception to this, however, is the

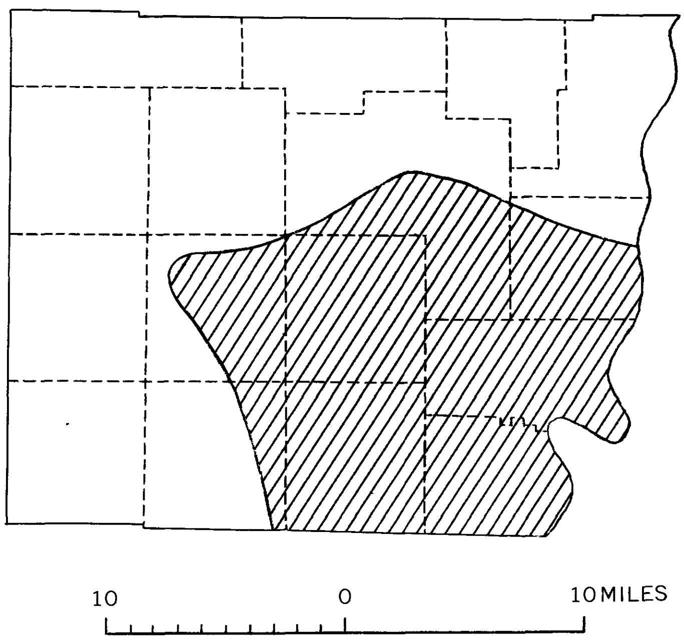

FIGURE 21.—Map of Belmont County showing the known areal distribution of the brachiopod *Lingula permiana* Stauffer and Schroyer, which occurs in the shale separating the two benches of the Washington coal bed.

presence of the brachiopod in disks of ironstone in the railroad cut in sec. 29, Goshen Township. The shale stratum in the Washington coal bed also contains small pelecypods that are found in some places with *Lingula permiana* and in other places where the brachiopod is absent. A specimen of this pelecypod collected from a road cut in the NE¼SE¼ sec. 26, Goshen Township, was identified by Mackenzie Gordon, Jr., as *Myalina* (*Myalinella*) cf. *M. meeki* Dunbar. This pelecypod is found both in the shale and in the ironstone disks and concretions. Concerning the paleoecology of *Lingula*, the following references are cited: Cross and Schemel (1956, p. 51), in describing Permian strata of West Virginia, state that,

> * * * The beds are almost entirely of fresh-water or terrestrial origin. One notable exception is a shale parting in the Washington Coal of the Moundsville-New Martinsville area * * *, which contains *Lingula*, a brackish-water brachiopod, which indicates that marine conditions existed near by, at least this late in the lower Permian time.

Weller (1957, p. 333), in describing Pennsylvanian strata in Illinois, says, "Only a few other genera of apparently brackish-water invertebrates occur in the Pennsylvanian. They are the pelecypods *Anthracomya* and *Niaidites*, the branchiopod *Estheria*, the brachiopod *Lingula*, * * *." Weller states further that *Lingula* most commonly lived under peculiar but probably otherwise normally saline conditions. In Belmont County, *Lingula permiana* probably lived in a marginal brackish-water environment.

The Washington coal is banded and cleated in the purer parts of the bed, but, where shaly and impure, it is not cleated. One analysis for the coal is given in table 11. The ash content on the as-received basis is 21 percent, and the heating value is 10,820 Btu. The sample for the analysis was taken in southern Washington Township where the Washington coal bed contains fewer shaly partings than elsewhere. The ash content is probably higher than 21 percent in most other parts of the county.

The bed has been mined at a few places for home use, but has never been mined commercially.

UNDIFFERENTIATED STRATA OVERLYING THE WASHINGTON COAL BED AND UNDERLYING THE LOWER WASHINGTON LIMESTONE MEMBER

The thickness of the rocks between the Washington coal bed and the overlying Lower Washington limestone member ranges from about 6 feet in the southeastern and northeastern parts of Belmont County to about 28 feet in the central part. Plate 22 shows the stratigraphic position of these strata, which include sandstone, siltstone, shale, clay, and limestone.

Clay, which is commonly shaly and contains thin carbonaceous bands, overlies the Washington coal bed in Belmont County. The clay contains beds of nodular, impure limestone in many places, especially in western Wayne, northeastern Goshen, northwestern Smith, and south-central Richland Townships. In York and southern Mead Townships in the southeastern part of the county and in Pease Township in the northeastern part, the clay occupies the entire interval between the Washington coal bed and the Lower Washington limestone member. Westward, however, a tongue of sandstone and siltstone overlies the clay (pl. 22*A*, sections 2–4). Sandstone and siltstone also overlie the clay locally in northern Mead, Pultney, and eastern Richland Townships.

The sandstone is generally shaly to flaggy but is massive, in places. A name is not proposed at this time for the sandstone because its regional extent is not known. Strata of equivalent age have been removed by erosion to the northwest, but it seems possible that the Lower Washington limestone pinched out to the northwest and that the Lower Marietta sandstone and the sandstone over the Washington coal bed joined. Locally in eastern Richland Township, eastern Belmont County, these two sandstone beds merge to form a thick crossbedded coarse-grained unit whose base rests directly on the Washington coal bed (pl. 22*A*, section 4).

LOWER WASHINGTON LIMESTONE MEMBER

The Lower Washington limestone member was named by Stevenson (1876, p. 50) for exposures in Washington County, Pa., where the limestone is 20 feet thick and is 6 to 8 feet above the Washington coal bed. The member lies 6 to 8 feet above the Washington coal in the southeastern, southwestern, and northeastern parts of Belmont County, but in the central part the interval varies from 8 to 28 feet. The increase in thickness is caused by the unnamed tongue of sandstone discussed in the preceding section of the report. The stratigraphic position and lithologic character of the Lower Washington limestone member are shown on plate 22. The thickness of the Lower Washington limestone member is variable, ranging from 6 inches in southeastern Goshen Township (pl. 22*A*, section 3), central Belmont County, to about 13 feet in Pease Township (pl. 22*B*, section 5), northeastern Belmont County. There the Lower Washington limestone member is overlain locally by the lower tongue of the Middle Washington limestone member. In south-central Belmont County in a ravine west of the road in the southeastern part of sec. 32, Smith Township, the member is 12 feet thick; in the southwestern and southeastern parts of the county the limestone is 3 to 6 feet thick but is absent in the northwestern part of sec. 8, Smith Township.

The member varies from a single bed to several beds separated by thin partings of clay or calcareous shale. The beds of limestone generally contain some clay and silt impurities and are locally conglomeratic. Fresh surfaces of limestone are medium gray to olive gray and weathered surfaces are medium gray to light olive or yellowish gray.

The Lower Washington limestone member is overlain in most places by a thin bed of clay or shale containing carbonaceous bands. At some places where the member consists of several beds separated by clay, each clay layer contains carbonaceous streaks.

The fauna consists of ostracodes, small high-spired gastropods, and fragments of fish remains.

The following detailed section, measured in a ravine about 500 to 600 feet west of the road near the southeastern corner of sec. 14, York Township, shows the lithologic character of the member as well as that of overlying strata:

	Thickness Ft.	In.
Dunkard group, Washington and Greene formations undifferentiated:		
Lower tongue of the Middle Washington limestone member:		
Limestone, olive-gray, silty; weathers greenish gray with slight yellow hue; crumbles to jagged fragments; overlain by 10 in. of shale and thin clay containing carbonaceous bands		7
Shale, grayish-olive; has pale-reddish-brown blotches, heavily stained with iron oxide; contains impure limestone nodules in upper part; cut by joints that resemble large desiccation cracks	12	2
Clay and carbonaceous shale		4
Limestone, olive-gray, laminated, silty; has undulating base; weathers to slabs		7
Covered interval: upper few inches clayey shale	1	0
Limestone, olive-gray, silty; contains argillaceous partings causing the layer to weather multibedded	3	1
Covered interval	2	0
Lower Marietta sandstone member:		
Sandstone, massive, medium- to coarse-grained, micaceous; irregularly bedded; crossbedded; forms cliffs	25	6
Shale, hard; chippy in base, becomes softer in top; contains several carbonaceous bands		6
Lower Washington limestone member:		
Limestone, light-olive-gray, silty; contains shaly partings causing layer to weather into many beds	1	4
Clay, shaly; contains carbonaceous bands		7
Limestone, medium-gray, silty; variable in thickness; forms angular ledge		7
Undifferentiated strata:		
Shale, olive-gray, soft; contains carbonaceous bands; encrusted in places with iron oxide	5	0
Dunkard group, Washington and Greene formations undifferentiated—Continued		
Undifferentiated strata—Continued		
Mudstone, light- to medium-gray; contains carbonaceous bands and a zone of silty limestone nodules near center	3	6
Claystone, slightly shaly, carbonaceous; contains "slickensides"; stained by iron oxide		6
Washington coal bed.		

LOWER MARIETTA SANDSTONE MEMBER

White (1891, p. 35–36) named the Marietta sandstone beds for outcrops just south of Marietta, Ohio. His statement concerning these sandstone beds at Marietta is as follows:

> The Washington "A" is often absent, and the portion of the series for 100 to 125 feet above the Washington coal is then frequently occupied by two or three beds of massive sandstone. These crop out in the hills below Marietta, Ohio, where they have long been extensively quarried for grindstones and building stone, and they have been designated from that locality. There are often three of them, each 25 to 40 feet in thickness, and separated by thin shales, so that in such cases they might be called Upper, Middle, and Lower Marietta sandstones.

In Belmont County three sandstone beds occur in the sequence, 11 to 125 feet above the Washington coal bed. Their stratigraphic positions are shown on plate 22. The lowest lies between the Lower Washington limestone member and the lower tongue of the Middle Washington limestone member and in this report is designated the Lower Marietta sandstone member. The interval between the base of this member and the Washington coal bed ranges from 11 feet in Mead Township (pl. 22*B*, section 2) to 29 feet in Goshen Township (pl. 22*A*, section 3).

The thickness of the Lower Marietta sandstone member ranges from a few inches to 42 feet, averaging about 25 feet. The member is thickest in southeastern Washington Township and southern York Township in the southeastern part of the county and in southeastern Somerset Township in the southwestern part. It thins to the north and is absent where the lower tongue of the Middle Washington limestone member rests on the Lower Washington limestone member in Pease Township (pl. 22*B*, section 5).

The Lower Marietta member consists of sandstone, siltstone, shale, and mudstone. The shaly sandstone and siltstone, which at many places intergrade both laterally and vertically, are commonly irregularly bedded but locally are evenly bedded. Shale generally occurs at the base and top of the member and grades into the clay and mudstone associated with the overlying and underlying limestone members. Locally red or variegated red and green mudstone several feet thick occurs in the upper part of the Lower Marietta member (pl.

22*A*, sections 4 and 5). In northeastern Belmont County the member consists mainly of clayey siltstone.

Massive sandstone makes up the member in parts of York Township in the southeastern corner of the county. The most massive outcrops are in the SE¼SE¼ sec. 14, York Township, where the sandstone is cross-bedded and coarse grained (pl. 22*A*, section 7). A detailed description of this section is included in the discussion of the Lower Washington limestone member.

The sandstone and siltstone are micaceous, poorly sorted, and similar to most other Pennsylvanian and Permian sandstone in Belmont County. They are shades of olive gray, and the intercalated shale and mudstone beds are variegated olive gray and reddish gray.

LOWER TONGUE OF THE MIDDLE WASHINGTON LIMESTONE MEMBER

Stevenson (1876, p. 48–50) named the Middle Washington limestone member for exposures in Washington County, Pa., where it is 15 feet thick and lies 89 feet above the Lower Washington limestone member. Stauffer and Schroyer (1920, p. 20) described the Middle Washington in Ohio as follows:

> This is only occasionally to be found in the Ohio section, although in Pennsylvania it is very persistent and has a thickness of as much as 15 feet. It is massive buff limestone, which, when freshly broken is of a dull flesh color. This same appearance is maintained in the region of its best development in Belmont County.

Unfortunately, Stauffer and Schroyer do not give an average thickness for the interval between the Washington coal bed and the Middle Washington limestone member in Belmont County; however, in the 18 stratigraphic sections in which they recognized the Middle Washington member, its stratigraphic position ranges from 27 to 73 feet above the Washington coal bed. In Belmont County the Middle Washington limestone member consists of two tongues separated by the siltstone, sandstone, shale, and mudstone of the Middle Marietta sandstone member. In each section measured Stauffer and Schroyer gave the name "Middle Washington" to whichever one of the two tongues of limestone was more prominent. This explains the variations in the thickness of the interval between the Washington coal bed and Middle Washington limestone member in their sections.

The lower tongue of the Middle Washington limestone member as recognized by the author lies from 30 to 40 feet above the Washington coal bed in eastern Belmont County, and the interval increases to the south. In the south-central and southwestern parts of the county, it is commonly between 45 and 55 feet (pl. 22), except in sec. 29, Goshen Township (pl. 22*A*, section 2), where the thickness of the lower tongue is comparable to that in the northeastern part of the county.

The thickness of the lower tongue ranges from 1 foot in the south-central and extreme southwestern parts of Belmont County to 20 feet in the northeastern part. The thickness of individual beds ranges from a few inches to as much as 3 feet.

The number of beds in the lower tongue varies from place to place. In northeastern and east-central Belmont County, several beds are present everywhere and are separated by clay and shale partings; as many as 12 beds were noted locally. The lower tongue thins to the south and southwest, and the number of beds decreases. Only one or two beds are present in most of southern York, Washington, and eastern Wayne Townships (pl. 22). Most individual beds of limestone are lenticular and cannot be traced from one outcrop to another.

The limestone is generally hard and dense. It contains some clay and silt impurities at many places, but locally is pure and is quarried in sec. 32, Pease Township, at the place where the lower tongue of the Middle Washington limestone member rests on the Lower Washington limestone member. The brownish-gray color of the lower tongue of the Middle Washington in Pease Township distinguishes it from the light- to dark-gray color of the Lower Washington. The following stratigraphic section, measured in the quarry, shows the lithologic character of the tongue in northeastern Belmont County:

	Thickness Ft.	In.
Dunkard group, Washington and Greene Formations undifferentiated:		
Lower tongue of Middle Washington limestone member:		
Limestone, slabby, weathered	1	0
Clay, shaly	2	0
Limestone, silty, weathered		11
Clay, shaly; contains thin lenses of limestone	2	0
Limestone, olive to brownish-gray; trifurcated laterally	1	0
Clay; contains thin lense of limestone	1	3
Limestone, light-olive to light-brownish-gray; contains ostracodes	1	9
Limestone, silty		1½
Limestone, light-olive to brownish-gray, conglomeratic; contains ostracodes		6
Limestone, silty		2
Limestone, light-olive to brownish-gray, conglomeratic; contains ostracodes	1	2
Limestone, silty		2
Limestone, light-olive to light-brownish-gray, splits laterally to four beds; contains ostracodes	2	0
Limestone, very argillaceous; weathers shaly; contains fish scales		11
Limestone, light-olive to light-brownish-gray; splits laterally to three beds	1	4

Dunkard group, Washington and Greene Formations undifferentiated—Continued	Thickness Ft.	In.
Upper part of the Lower Washington limestone member?:		
Limestone, dark-gray, silty; weathers shaly		2
Limestone, light-gray, silty; weathers shaly; contains ostracodes and fish scales	1	1
Limestone, dark-gray, silty; weathers shaly		3
Limestone, silty		2
Limestone, silty; weathers shaly		4
Claystone, calcareous		3
Limestone, light-medium-gray, silty	1	2
Floor of quarry.		

The limestone in this quarry was sampled by Lamborn (1951, p. 72) and the analysis is as follows:

	Percent
Silicates	2. 19
Silica	3. 81
Hydrated ferric oxide	. 02
Ferrous carbonate	1. 13
Iron disulphide	. 03
Titanium dioxide	. 07
Calcium phosphate	. 26
Calcium sulphate	. 03
Calcium carbonate	90. 50
Magnesium carbonate	1. 57
Manganese carbonate	. 18
Water	. 29
Organic matter	. 08
Unbalanced components (deficiency CO_2, H_2O)	. 01+

A similar but more complete section showing the merger of the Lower Washington limestone member and the lower tongue of the Middle Washington limestone member was measured at the Ayers quarry in the NW¼ sec. 24, Pease Township (pl. 22*B*, section 6).

The single bed of limestone that represents the lower tongue of the Middle Washington member in most of southern York, southern Washington, and eastern Wayne Townships is massive and forms a ledge. The limestone is hard and dense and appears to be relatively pure. The best exposure in southern Belmont County is a persistent ledge, 3 feet thick, that crops out along a road cut in the NE¼NW¼ sec. 21, Washington Township. Slabs of dark-gray to black impure limestone containing many large fish bones and coprolites lie at the position of the lower tongue along the road in the SE¼SW¼ sec. 26, Washington Township.

At many places the lower tongue of the Middle Washington limestone member is intercalated with red clay or red-mottled shale. Grayish-olive and reddish-brown mottled shale, 12 feet thick, separates the upper bed of the tongue from the lower beds in sec. 14, York Township (pl. 22*A*, section 7). A persistent banded carbonaceous clay overlies the lower tongue in most of Belmont County. This clay possibly is equivalent to the Washington "A" coal bed of Pennsylvania (pl. 21).

Distribution of the thick limestone sequence formed by the merged Lower Washington limestone member and the lower tongue of the Middle Washington limestone member suggests temporary localization during early Dunkard time of a depositional basin whose axis trended roughly N. 65° E. Because of erosion the former northwestward extent of the thick limestone is not known. The generalized area of thick Lower Washington and lower tongue of Middle Washington limestone members and the probable axial trend of the basin are shown on the index maps accompanying plate 22.

As previously stated, members above the Washington coal bed in Belmont County cannot be correlated accurately with members above the Washington coal bed in southwestern Pennsylvania on the basis of available data. The lower tongue of the Middle Washington limestone member in Belmont County, however, does correspond in position to Limestone III of Stevenson (1876, p. 50) (pl. 21, section 10) and the Blacksville limestone of White (1891, p. 36).

The fossil fauna of the lower tongue of the Middle Washington limestone member consists of *Spirorbis*, fish remains, small pelecypods that resemble *Pleurophorus*, ostracodes, and small gastropods.

MIDDLE MARIETTA SANDSTONE MEMBER

The Middle Marietta sandstone member overlies the lower tongue of the Middle Washington limestone member and its base lies from 40 to 60 feet above the Washington coal bed (pl. 22).

The thickness of the member ranges from 10 to 39 feet. It is thickest in the southern part of the county and thins toward the north. In the northeastern part of sec. 14, Mead Township, the Middle and Upper Marietta sandstone members join, and their combined thickness is 61 feet.

Massive crossbedded coarse-grained micaceous sandstone occurs locally in southeastern Belmont County, but elsewhere the Middle Marietta member consists of shaly to flaggy irregularly bedded fine- to medium-grained micaceous sandstone, siltstone, and shale. In parts of southern Washington and eastern Wayne Townships, shale and mudstone make up the member, and in sec. 32, Pease Township, it is a mudstone 10 feet thick (pl. 22*B*, section 5). In areas where the member consists principally of sandstone, the basal and upper parts are usually shale or siltstone. In places the contact between the basal siltstone or shale and the overlying sandstone is abrupt, but in others the contact is gradational.

The sandstone is gray on fresh surfaces and tan on weathered surfaces. The siltstone beds are generally shades of olive gray, and the shale beds vary from olive gray to dusky yellow. Reddish blotches and thin red bands occur locally in the shales.

UPPER TONGUE OF THE MIDDLE WASHINGTON LIMESTONE MEMBER

As previously pointed out on page 59, two sequences or tongues of limestone separated by the Middle Marietta sandstone member occur in the interval from 25 to 90 feet above the Lower Washington limestone member in Belmont County. These two limestone beds, which are separated by the Middle Marietta sandstone member, appear to coalesce in Ohio County, W.Va., and form a unit that may be equivalent in part to Stevenson's (1876, p. 48) "Limestone III" (pl. 21, section 10). In this report the two sequences of limestone are named the lower and upper tongues of the Middle Washington limestone member, and the lower tongue has been described. The position of the two tongues and their stratigraphic relation are shown on plate 22.

The upper tongue of the Middle Washington limestone member is 50 feet above the Washington coal bed in the northeastern part of Belmont County and about 90 feet above the coal in the southern and southwestern parts.

The thickness of the limestone in this member ranges from a few inches to 20 feet. It is thickest in northeastern Belmont County, in Pease, eastern Richland, and northern Pultney Townships and decreases to the south and southwest. The limestone is absent over most of the southeastern and south-central parts of the county where its position is occupied by reddish mudstone and variegated reddish and greenish clayey siltstone and shale of which as much as 24 feet is exposed locally (pl. 22*B*, sections 1–3, 22*A*, sections 4–6).

In northeastern Belmont County the upper tongue consists of several beds of limestone separated by clay and shale partings. In the southwestern part of the county in Wayne, Smith, Goshen, and Somerset Townships, the upper tongue is made up of 1 to 3 thin beds of limestone. Over most of York, Mead, Smith, and Washington Townships, reddish mudstone or variegated olive-gray and reddish-brown clayey siltstone or shale takes the place of the limestone. In the northeastern part of sec. 14, Mead Township, the Middle and Upper Marietta sandstone members coalesce, and the upper tongue of the Middle Washington limestone member is believed to be absent because of nondeposition.

The beds of limestone in the upper tongue are impure in most places and weather rapidly. The best and thickest exposure is in the north bank of U.S. Highway 40 just east of Stillwell's Restaurant in the north-central part of sec. 21 E., Richland Township. There the upper tongue consists of several beds of argillaceous limestone and thin clay, shale, and sandstone partings totaling 20 feet in thickness. The Upper Washington limestone member crops out near the top of this same road bank and is separated from the underlying upper tongue of the Middle Washington limestone member by 9 feet of sandstone and siltstone that make up the Upper Marietta sandstone member (pl. 22*B*, section 4). The following detailed section measured at this locality shows the lithology of the upper tongue of the Middle Washington and also its relation to the overlying Upper Marietta and Upper Washington members:

	Thickness Ft.	In.
Dunkard group, Washington and Greene formations undifferentiated:		
Upper Washington limestone member:		
Limestone, yellowish-gray to grayish-yellow, argillaceous, weathered; consists of several beds separated by thin shaly clay bands	10	0+
Sandstone, fine-grained, micaceous, calcareous	1	9
Limestone; contains lenticular shale partings; weathers to several nodular beds	3	0
Shale, soft, calcareous	2	8
Upper Marietta sandstone member:		
Sandstone, olive to greenish-gray, fine-grained, micaceous, calcareous	6	4
Siltstone, shaly	2	6
Shale, soft, calcareous; has several thin carbonaceous bands that may represent the Washington "A" coal bed	1	7
Upper tongue of the Middle Washington limestone member:		
Limestone, light-brownish-gray with orange hue, argillaceous, shaly	3	0
Limestone, medium-gray, argillaceous; several beds separated by thin bands of soft shale; weathers shaly	5	10
Limestone, medium- to olive-gray, argillaceous	3	0
Limestone, impure, weathered; consists of several beds separated by clay-shale bands	7	6
Road level of U.S. Highway 40.		

Most outcrops of the upper tongue in Wayne, Goshen, and Somerset Townships are weathered and consist of boulders and nodules of argillaceous limestone embedded in clay.

In most of York, Mead, Smith, and Washington Townships, where the limestone is absent, its place is taken by the following sequence: reddish mudstone containing small limy nodules in the basal part, grading to reddish shale, which grades upward to variegated red and green shale and clayey siltstone. Locally the siltstone grades upward into the Upper Marietta sandstone member, but in other places the contact is abrupt. The proportions of mudstone, shale, and siltstone vary from place to place.

Limestone beds of the upper tongue are shades of olive gray on a fresh fracture, but they weather yellowish gray.

Fossils are diminutive forms of gastropods, ostracodes, *Spirorbis* sp., and fish remains.

WASHINGTON "A" COAL BED(?)

White (1891, p. 35) named the Washington "A" coal bed and described its stratigraphic position and lithology as follows:

At 70 to 80 feet above the Washington coal, there occurs a bed of impure coal and coaly shale which is often present in the section along Dunkard Creek.

Bituminous shale is often found at this horizon in Washington and Greene Counties, Pennsylvania, and in Washington County, Ohio, a coal bed 2½ feet thick seems to occur at the same place in the series.

In Belmont County a thin layer of shale and clay that in places overlies the upper tongue of the Middle Washington limestone member may be equivalent to the Washington "A" coal bed of White (pl. 21, sections 5 and 6). It lies about 65 to 75 feet above the Washington coal bed. Plate 21 shows the tentative correlations of this clay with the Washington "A" coal bed of White. White, however, designated a limestone 78 feet above the Washington "A" coal bed as the Middle Washington limestone member in Pennsylvania. Therefore, if the clay above the upper tongue of the Middle Washington in Belmont County is equivalent to the Washington "A" coal bed of Pennsylvania, the Middle Washington of Pennsylvania is not equivalent to the Middle Washington of Ohio.

As previously stated on page 60 a persistent clay with carbonaceous streaks lies above the lower tongue of the Middle Washington limestone member in Belmont County, and conceivably this clay could be equivalent to White's Washington "A" coal. Present data are insufficient to tell which, if either, of these two units is equivalent to the Washington "A" coal bed.

The layer of shale and clay above the upper tongue of the Middle Washington was seen only in northeastern Belmont County where it ranges in thickness from a few inches to about 1½ feet. It is carbonaceous, in part, and in most places contains thin red bands in its upper part.

UPPER MARIETTA SANDSTONE MEMBER

The Upper Marietta is one of three sandstone beds called the "Marietta sandstones" by White (1891, p. 35) for their exposures near Marietta, Ohio.

In Belmont County the Upper Marietta sandstone member is made up of thin-bedded to massive fine- to medium-grained micaceous sandstone, siltstone, shale, or mudstone about 9 to 17 feet thick. The interval between the Upper Marietta and the Washington coal bed ranges from about 65 feet in northeastern Belmont County to about 110 feet in the south-central part (pl. 22). The sandstone is massive in the southeastern corner of sec. 28 E., Richland Township, where its upper surface forms a pavement in front of Tracy's Restaurant on the south side of U.S. Highway 40. The top of the sandstone is also exposed at the Log Cabin Truck Stop on the north side of U.S. Highway 40 several hundred feet east of Tracy's Restaurant. About ½ to ¾ mile to the east, the Upper Marietta sandstone member is exposed in the north bank of U.S. Highway 40. There it consists of 3 feet of shaly siltstone overlain by about 6 feet of sandstone (pl. 22 B, section 4). At most places the sandstone is shaly bedded to flaggy bedded and is crossbedded locally. In parts of York and Washington Townships, variegated reddish and greenish mudstone makes up a part of the member. In the northeastern part of sec. 14, Mead Township, the Upper and Middle Marietta sandstone members coalesce.

The sandstones and siltstones are olive gray, and the shale beds vary from olive gray to dusky yellow.

The Upper Marietta is probably equivalent to the Davistown sandstone of West Virginia (Cross and Schemel, 1956, p. 53, sec. A).

UPPER WASHINGTON LIMESTONE MEMBER

Stevenson (1876, p. 45) named the Upper Washington limestone member for exposures in Washington County, Pa. He states that the limestone is as much as 30 feet thick and lies from 100 to 180 feet above the Washington coal bed in Washington County but is only 4 to 8 feet thick and lies from 135 to 325 feet above the Washington coal bed in Greene County, Pa. A variation of almost 200 feet in interval between the Upper Washington and the Washington coal bed in adjacent counties is anomalous when compared to the relatively uniform intervals between the various members of the Monongahela formation and Dunkard group in most of the northern Appalachian basin. It seems likely that Stevenson miscorrelated the Upper Washington limestone member in parts of southwestern Pennsylvania. As a result, its exact position is in question even in the type area. Plate 21, section 10, shows the stratigraphic position in Washington County, Pa., according to Stevenson.

Stauffer and Schroyer (1920, p. 21) used the name "Upper Washington limestone" in Ohio for the third limestone above the Washington coal bed. They did not mention the thickness of the interval between this limestone and the Washington coal bed, but in stratigraphic sections for Belmont County the position of their Upper Washington varies from 26 to 118 feet above the Washington coal bed. Stauffer and Schroyer did not recognize that the Middle Washington is split into two tongues in Belmont County and therefore, in some places, called the upper tongue of the Middle Washington the Upper Washington. Furthermore, in sec. 8, Wayne Township, they confused the Upper Washington with the Lower Washington, which lies but 26 feet above the Washington coal bed.

In this report the name Upper Washington is given to a limestone member of variable thickness and lithologic character that lies about 85 to 125 feet above the Washington coal bed. The interval is 125 feet in the southeastern and south-central parts of Belmont County in Mead, York, Washington, and Wayne Townships, and thins toward the northeast to 85 feet in eastern Richland, Colerain, and Pease Townships (pl. 22).

The limestone is multibedded and is as much as 17 feet thick in northeastern Belmont County, but it consists of a few nodular beds averaging less than 3 feet in thickness in most of the south-central and southwestern parts of the county. The limestone is absent, and its place is taken by shaly siltstone and mudstone in the southeasternmost part of York Township at the southeastern corner of the county.

The beds of limestone are lenticular and contain clay and silt impurities. Where the member is multibedded, thin layers of impure shaly clay or mudstone separate the beds. In parts of south-central and southwestern Belmont County, where the member contains fewer beds, the basal part is made up of several feet of shaly siltstone or shaly mudstone containing impure limestone nodules.

On a fresh surface the limestone is light olive gray, but it weathers to yellowish gray.

Fossils found are diminutive forms of gastropods, ostracodes, *Spirorbis*, and fish remains.

The two best outcrops of the Upper Washington limestone member are in the northeastern part of the county in secs. 21 E. and 28 E., Richland Township, where the member is thickest. In sec. 21 E. it lies near the top of the north bank of U.S. Highway 40 just east of Stillwell's Restaurant. The upper tongue of the Middle Washington limestone member crops out 9 feet lower in the same road cut (pl. 22*B*, section 4). There the member is more than 17 feet thick and consists of several beds of limestone separated by clay and shale partings. G. W. White (1945, p. 175) erroneously included the Upper Washington at this outcrop, as well as the underlying 9 feet of the Upper Marietta sandstone member, in the Middle Washington limestone member.

In sec. 28 E., three-fourths of a mile west of Stillwell's Restaurant, the Upper Washington limestone member is 17 feet thick and crops out in the bank behind the fruit stand at Tracy's Restaurant, which is on the south side of U.S. Highway 40. Following is a detailed section of the Upper Washington limestone member and the overlying Jollytown "A" coal bed and sandstone at this locality:

	Thickness Ft.	In.
Dunkard group, Washington and Greene formations undifferentiated:		
Aults Run sandstone member:		
Sandstone, massive, fine-grained, micaceous	6	6+
Siltstone, platy; contains thin layers of sandstone in central part	13	0
Jollytown "A" coal bed:		
Coal; lower 4 in. cleated; upper 1 in. shaly		5
Underclay, olive-gray, shaly		8
Upper Washington limestone member:		
Limestone, medium- to light-gray, argillaceous	2	6
Limestone, olive-gray, argillaceous; weathers to several beds; weathered surfaces are yellowish gray to grayish yellow	7	0
Shale, sandy, slightly calcareous	2	7
Limestone, argillaceous; weathers shaly	3	0
Shale, calcareous	2	0
Upper Marietta sandstone member: The even top of this member forms pavement around Tracy's Restaurant.		

JOLLYTOWN "A" COAL BED

The Jollytown "A" coal bed was named by Stauffer and Schroyer (1920, p. 21–22). In discussing the coal bed they state:

> The Jollytown "A" coal, in West Virginia and Pennsylvania, consists of from a few inches to 3 feet of black shale to a fair coal lying immediately above the Upper Washington limestone. In Ohio it is often a mere streak of coal blossom a few inches thick, but it is of more importance in the southern than in the northern part of the field. This is the bed described by I. C. White as the Jollytown coal, but it does not agree in position with the one called Jollytown coal by J. J. Stevenson, since the latter lies some little distance below the Upper Washington limestone. It does correspond, however, to Stevenson's Fish Bed, which he says is a black shale that sometimes becomes a coal. This is a very important horizon in Ohio as it is rather persistent and must be used to separate the Washington from the Greene formation in regions where the Upper Washington limestone is lacking. Hence it seems better to eliminate possible confusion between the two definitions of the Jollytown coal and indicate the one named by White as the Jollytown "A" coal, as it has no real claim on the name of Stevenson's report.

A thin coal bed occurs sporadically in Belmont County just above the limestone designated in this report as the Upper Washington limestone member and from 95 to 128 feet above the Washington coal bed (pl. 22). It is the bed that was called the Jollytown "A" by Stauffer and Schroyer. As previously stated in the general discussion of the Permian stratigraphy on page 47, the Jollytown "A" coal bed of Belmont County may not be the equivalent of the Jollytown coal bed of either White or Stevenson. If the Jollytown "A" coal of Belmont County is present in the

Pennsylvania section, it probably lies considerably below the Jollytown coal.

The Jollytown "A" coal of Belmont County is apparently the same bed that was called the Dunkard coal bed by Grimsley (1907, p. 59) in his report on Ohio, Brooke, and Hancock Counties, W. Va. Grimsley states that the interval between the Washington coal bed and Dunkard coal bed is 105 to 120 feet thick. This corresponds almost identically with the thickness of the interval between the Washington and Jollytown "A" coal beds in Belmont County. The Jollytown "A" coal of Belmont County is probably equivalent to the Hundred coal of Cross and Schemel (1956, p. 53, sec. A) in Marshall County, W. Va.

In Pease Township in northeastern Belmont County the Jollytown "A" coal bed is 95 to 100 feet above the Washington coal bed. The interval thickens southward to about 115 to 128 feet in southeastern and south-central Belmont County (pl. 22).

The Jollytown "A" coal bed is separated from the underlying Upper Washington limestone member by 1 to 2 feet of clay, and ranges from a fraction of an inch to 5½ inches in thickness. The bed is impure coal or coaly shale in parts of York, northwestern Smith, eastern Richland, east-central Mead, northern Pultney, eastern Colerain, and Pease Townships, but elsewhere it is a clay containing thin carbonaceous streaks. The clay is shaly, from a few inches to one foot thick, and everywhere overlain by a layer of reddish shale from a few inches to more than a foot thick. This red shale, which is in the basal part of the overlying Aults Run sandstone member, is a good marker bed for locating the position of the Jollytown "A" zone both because of its color and because it contains in many places small Estheridlike fossils.

The Jollytown "A" coal is well exposed at the following localities. Other outcrops of this bed are shown on plates 22 and 27.

Exposures of Jollytown "A" coal

Township	Sec.	Remarks
Pease	SE¼NW¼ sec. 2	North road ditch at intersection, 1,304 ft elev.
Colerain	NE¼NE¼ sec. 13	Top of east road bank in road cut just northwest of Colerain.
Richland	SE¼SE¼ sec. 28 E	Behind fruit stand at Tracy's Restaurant, south side of U.S. Highway 40.
Do	SE¼SW¼ sec. 2	South bank of road intersection, a few hundred feet west of the abandoned intersection at elev 1,274 ft.
Pultney	South-central edge of the SE¼ sec. 32.	North road bank at intersection.
Mead	NE¼NW¼ sec. 31 E	East road bank east of intersection.
Do	NE¼SW¼ sec. 12	Road bank at point farm road enters from east.
Smith	East-central edge of the NW¼ sec. 29.	Ditch along bed of abandoned road which runs northeast from the intersection at elev 1,274 ft.
York	NE¼NE¼ sec. 13	Road bank several hundred feet east of house.
Do	SW¼NW¼ sec. 7	North road bank at the top of a covered interval.
Do	East-central edge of the NW¼ sec. 9.	Road bank at intersection.

AULTS RUN SANDSTONE MEMBER

D'Invilliers (1895, p. 2573) used the name "Jollytown" for the massive sandstone above the Middle Washington limestone and 70 feet below the Jollytown coal bed along Dunkard Creek, Greene County, Pa., near the mouth of Hoover Run.

Hennen (1909, p. 196–197) applied the name "Jollytown" to the sandstone above the Jollytown coal bed in Wetzel County, W. Va. He described the sandstone as follows:

> In the 30 to 50 feet of measures that intervene between the Dunkard coal and the Jollytown coal next below, there often occurs a massive sandstone, coming 5 to 10 feet above the latter coal, and hence the writer has given it the name, Jollytown Sandstone. It is nearly always present and ranges in thickness from 5 to 30 feet * * *. At the type locality of the Jollytown coal on Dunkard Creek, ½ mile due east of Hero P. O., Greene Co., Pa., this sandstone is 10 to 15 feet thick and quite massive, coming 10 to 15 feet above the Jollytown coal.

Obviously, D'Invilliers and Hennen did not agree on the stratigraphic position of the Jollytown sandstone. Hennen, furthermore, did not indicate whether he was referring to the Jollytown coal of Stevenson or of White, thus further confusing the stratigraphic position of the Jollytown sandstone.

Because the stratigraphic position of the Jollytown coal bed has never been agreed upon, even in the type area, the stratigraphic position of the Jollytown sandstone likewise is not fixed. This is especially true in Ohio, where past correlations of strata of Pennsylvanian and Permian age above the Washington coal bed with strata of Pennsylvanian and Permian age above the Washington coal bed in Pennsylvania are questionable. The sandstone above the Jollytown "A" coal bed in Belmont County will be called the Aults Run sandstone member for outcrops near the summit of the east-southeastward-trending ridge northeast of Aults Run in eastern Richland Township. The type section is the upper 19 feet of the north bank of the new cut for U.S. Highway 40 about 400 feet west of the northeast corner of sec. 27 E., Richland Township. At this locality the member consists of 7 feet of fissile shale overlain by 12 feet of thin-bedded to massive fine-grained sandstone. The upper part of the sandstone is presumably under soil cover on the hillside north of the road bank.

This sandstone is a persistent member of relatively uniform thickness throughout eastern Belmont County. The average thickness is about 24 feet in the northeastern part of the county, but to the south in Washington and York Townships, the thickness is slightly greater, averaging about 30 feet.

In general the member is fine grained, but its composition ranges from medium-grained sandstone to siltstone and mudstone. The proportions of these lithologic types vary considerably from place to place, but shale commonly makes up the basal part of the member, shaly to flaggy, fine-grained sandstone the middle part, and mudstone the upper part (pl. 27).

The basal shale ranges from a few inches to as much as 17 feet in thickness. It is grayish olive to dusky yellow and contains at its base a grayish-red to reddish-brown layer of variable thickness.

Plant remains and small brachiopods occur locally in this basal shale. The best fossil plants are in a road bank just south of the road intersection in the SE¼NW¼ sec. 29, Smith Township, 16 feet above the Jollytown "A" coal bed. Brachiopods that appear to belong to the genus *Orbiculoidea* are in the lower part of the shale, just above the Jollytown "A" coal bed in the road bank in the SW¼NW¼ sec. 7, York Township. As previously mentioned, Estheridlike fossils are in the reddish zone at a number of places.

The sandstone that makes up the middle part of the member is shaly to flaggy bedded, locally crossbedded and micaceous, and ranges from fine to medium grained. It tends to be lenticular and grades into shale and siltstone in many places. In sec. 7, York Township, the central part of the member contains limestone nodules.

The siltstone and mudstone in the upper part of the member are shaly and grade downward into the fine-grained sandstone. Nodules of impure limestone lie in the uppermost part of the siltstone and mudstone, which locally grade upward to limestone.

UNNAMED LIMESTONE

A unit of impure nodular limestone from a few inches to 1½ feet thick lies from 24 to 32 feet above the Jollytown "A" coal in most of eastern and southeastern Belmont County (pl. 27). One or more beds of argillaceous limestone generally make up the unit, but in places it consists of small calcareous nodules embedded in clay. Because of rapid weathering, this unit is inconspicuous and difficult to trace. A thin band of clay separates the limestone from the overlying sandstone, siltstone, and shale. Coal is not associated with this clay at any place in the county, but carbonaceous bands occur in a few places. This limestone and overlying clay may be correlatives of the Jollytown coal and Upper Washington limestone of Cross and Schemel (1956, p. 53) in Marshall County, W. Va., but they do not appear to correspond in stratigraphic position to the Jollytown coal and Upper Washington limestone of either I. C. White or J. J. Stevenson in southwestern Pennsylvania (pl. 21).

UNNAMED SANDSTONE

The limestone and interbedded clay just described are overlain by 23 to 37 feet of sandstone, siltstone, shale, and mudstone (pl. 27). The basal part of the unit is generally shale, which grades upward into siltstone or sandstone.

The sandstone, which is thickest in Mead, Smith, and Richland Townships (pl. 27, sections 3, 7, and 8), is shaly to flaggy bedded and locally crossbedded. It has been quarried on the north side of the road in the NW¼NW¼ sec. 2, Smith Township. Laterally the sandstone grades into siltstone, and at some places mudstone occurs in the upper part of the unit.

The sandstone and siltstone range in color from tan to grayish olive. The shale ranges from grayish olive to reddish brown and is variegated olive gray and reddish brown at some places. The mudstone in the upper part of the unit is also variegated olive gray and reddish brown.

DILLES BOTTOM LIMESTONE MEMBER

A persistent limestone underlies the Big Run coal bed throughout southeastern Belmont County. In this report it is named the Dilles Bottom limestone member for outcrops near the summit of the ridge that lies southwest of Big Run and north and northwest of Dilles Bottom in secs. 6, 7, and 13, Mead Township.

The member, which is 57 to 63 feet above the Jollytown "A" coal bed, ranges in thickness from a few inches to 6 feet, and in most places consists of several beds of limestone interbedded with clay (pl. 27). Good outcrops of the Dilles Bottom limestone member are along the ridge road south of Big Run in southeastern Mead Township, where the limestone is exposed beneath the Big Run coal bed (pl. 27, sections 5 and 7). It is also well exposed near the tops of the ridges in southern Washington and southern York Townships (pl. 27, sections 2, 3, 4, and 6). The limestone is impure and characteristically weathers into small slabs, which fall apart into shaly fragments after prolonged weathering.

The limestone is light olive gray on a fresh fracture and weathers to shades of yellowish gray or very light gray.

Ostracodes were the only fossils seen in this limestone.

BIG RUN COAL BED

A persistent coal bed lies from 64 to 71 feet above the Jollytown "A" coal bed and from about 170 to 195 feet above the Washington coal bed in southeastern Belmont County. Its line of outcrop is shown on plate 1. The interval between this bed and the Washington coal is thickest in the southeastern corner of the county and thins toward the northwest and north (pl. 21). The best exposures of the bed are in the road banks along the ridge crest south of Big Run in secs. 6 and 7, Mead Township, and it is named the Big Run coal bed for these outcrops (pl. 27).

The Big Run coal bed, which ranges from about 1 to 8 feet in thickness, is made up of coaly shale, clay, soft clayey shale, carbonaceous shale, limestone, and sandstone. A parting that separates the coal into two benches is a distinctive feature of the bed. This parting is sandstone in Mead, York, and most of Washington Townships (pl. 27, sections 2, 5, 6, and 7), is limestone at one locality in southwestern Washington Township (pl. 27, section 1), and is absent in sec. 2, Smith Township, and in sec. 2, Richland Township (pl. 27, sections 3 and 8). The thickness of the parting ranges from a few inches to more than 5 feet.

The benches of the coal bed above and below the parting are quite different. Where the parting is sandstone, the lower bench is the thicker of the two and varies in composition from bony coal to coaly shale interbedded with soft, brownish-gray, clayey shale containing plant fragments. Along the top of the ridge south of Big Run the entire lower bench consists of coaly shale. The upper bench is made up of very plastic light-gray clay, which contains carbonaceous streaks in many places. Where the parting is limestone instead of sandstone, the stratigraphic positions of the shale and clay are reversed; the shale and coaly bands occur in the upper bench and the clay in the lower bench.

The Big Run bed consists of 1 foot 9 inches of bony coal in a cut of the abandoned narrow gauge railroad in the SE¼NE¼ sec. 8, Smith Township. Stauffer and Schroyer (1920, pl. IV) erroneously called the coal bed in this cut the Jollytown "A" and the limestone beneath it the Upper Washington.

As stated above, the Big Run coal bed is best exposed in the road banks along the ridge south of Big Run. The bed was uncovered by digging in the road bank a few hundred feet east of the road intersection at elevation 1,226 in sec. 31, Mead Township. Locations of other exposures of the Big Run coal bed are given on plate 27. Because of its persistence and its distinctive character, the Big Run coal bed is a better stratigraphic marker in southeastern Belmont County than the Jollytown "A" coal. This coal bed is probably equivalent to the Dunkard coal of Marshall County, W. Va. (Cross and Schemel, 1956, p. 52, sec. A).

UNDIFFERENTIATED STRATA OVERLYING THE BIG RUN COAL BED AND UNDERLYING THE POWHATAN POINT LIMESTONE MEMBER

The thickness of the strata between the Big Run coal bed and the overlying Powhatan Point limestone member ranges from 66 feet in sec. 7, York Township, to 77 feet in sec. 8, Washington Township (pl. 28). These rocks crop out only near the hilltops in southeastern Belmont County; they are obscured by weathering in most places. The best exposure is west of Powhatan Point along the road which runs southwest from State Highway 7 to the ridge top (pl. 28, section 5).

Shale, from a few inches to several feet thick, overlies the Big Run coal bed and in turn is overlain by shaly sandstone or siltstone 20 to 30 feet thick. Nodular limestone or clay several feet thick generally overlies the sandstone or siltstone. In sec. 6, Mead Township, a thin impure coal bed lies 36 feet above the Big Run coal bed (pl. 28, section 6), but coal was not seen elsewhere at this stratigraphic position. A thin clay represents this coal bed at other places in the county.

Presumably the Fish Creek coal of Cross and Schemel (1956, p. 52) would lie within these undifferentiated strata, but as coal was seen at only one place in Belmont County, that name cannot be logically applied.

The 36- to 55-foot interval between the bed of clay 36 feet above the Big Run coal bed and the Powhatan Point limestone member is occupied by shaly sandstone, siltstone, shale, and mudstone, and beds of nodular limestone. On the ridge west of Powhatan Point in sec. 7, York Township (pl. 28, section 5), these strata are chiefly reddish mottled shale, clayey siltstone, mudstone containing calcareous nodules, and one or two beds of nodular limestone. West of Powhatan Point in sec. 8, Washington Township, the rocks in this interval are almost entirely sandstone and shaly siltstone (pl. 28, section 2) which may be equivalent to the Fish Creek sandstone of West Virginia (Cross and Schemel, 1956, p. 52, sec. A).

North of Powhatan Point, in secs. 6 and 12, Mead Township (pl. 28, sections 6 and 4), where the Powhatan Point limestone member, and some of the underlying strata have been removed by erosion, the 50 feet or more of strata above the Big Run coal bed consist of siltstone, sandstone, mudstone, and small amounts of reddish-brown shale and limestone. The limestone at the top of the outcrop in sec. 12, Mead Township (pl. 28, section 4), appears to be equivalent to the limestone in the central part of the section west of Powhatan Point (pl. 28, section 5).

POWHATAN POINT LIMESTONE MEMBER

The Powhatan Point limestone member is here named for its prominent outcrops west of Powhatan Point along the road cut just north of the saddle where the road crosses the ridge, near the west-central edge of the southwestern part of sec. 7, York Township. This limestone also crops out at a number of places along the ridge tops to the west in Washington Township (pl. 28). The interval between the Washington coal bed and the Powhatan Point limestone member in Belmont County is 265 to 270 feet. In places in Marshall County, W. Va., the Nineveh limestone of Hennen (1909, p. 132–147) is about 310 feet above the Washington coal bed and correlation with the Nineveh limestone would seem possible on the basis of comparable intervals. In other places in Marshall County, W. Va., however, Hennen calls a limestone bed 530 feet above the Washington coal bed the Nineveh. An increase of 220 feet in interval within one county seems excessive for this area, and Hennen probably used the same name for two different limestone beds. According to Cross and Schemel (1956, p. 52–53), the Nineveh limestone lies approximately 400–450 feet above the Washington coal bed in West Virginia. If they are correct, then the Powhatan Point limestone member is probably equivalent to a limestone beneath their Hostetter coal instead of the Nineveh limestone.

The Powhatan Point limestone member ranges from 1½ to 15 feet in thickness and occurs about 265 feet above the Washington coal bed, about 140 feet above the Jollytown "A" coal bed, and about 65 to 76 feet above the Big Run coal bed.

The member is thickest at the type locality west of Powhatan Point, where it consists of three groups of limestone beds separated by shale. The lower bench consists of a single bed, but the middle and upper benches are each made up of several beds. Clayey shale 3 feet thick lies between the lower and middle benches, and 2 feet of shale separates the middle and upper benches. West of that outcrop the member thins (pl. 28) and is absent in sec. 2, Washington Township, and sec. 13, York Township.

The beds of limestone in the Powhatan Point member are commonly impure. On fresh surfaces the rock is olive gray to brownish gray, but it weathers to shades of yellowish gray.

A profusion of *Spirorbis* casts is in the upper bench of the member on the ridge near Powhatan Point and fragments of fish bones, fish plates, and small gastropods were seen in the southeastern part of sec. 32, York Township, where the limestone crops out on the south hillside near the point where a farm lane enters the main road from the south. *Spirorbis* appears to be the most abundant fossil in the Powhatan Point limestone member.

HENDERSHOT COAL BED

A thin impure coal bed overlies the Powhatan Point limestone member near the tops of the hills at an elevation of about 1,300 feet in southern York and Washington Townships (fig. 22 and pl. 28), but is absent at the type locality of the Powhatan Point. The bed is a good stratigraphic marker and is here named the Hendershot coal for outcrops along Hendershot ridge.

The Hendershot coal bed, which is nowhere more than 3 or 4 inches thick, lies about 270 feet above the Washington coal bed, about 150 feet above the Jollytown "A" coal, and about 80 feet above the Big Run coal, and may be equivalent to the Hostetter coal of Cross and Schemel (1956, p. 52). It is a coaly shale that is separated from the underlying Powhatan Point limestone member by an underclay that is a few inches to more than a foot thick.

The best outcrop is in the southeastern part of sec. 32, York Township, in the west road bank at the intersection of a farm lane and the main road where the coaly shale contains fish teeth and dermal plates (pl. 28, section 3). Other exposures are in the road ditch west of the church in the northeastern part of sec. 2, Washington Township, in the road ditch west of the intersection at Hendershot in sec. 2, Washington Township, in the road bank east of the house in the south-central part of sec. 8, Washington Township, in the bank of the abandoned road just north of the intersection at elevation 1,325 in the southwestern part of sec. 8, Washington Township (pl. 28, section 2), and in the road ditch and bank just east of the road intersection in the NW¼NW¼ sec. 18, Switzerland Township, Monroe County (pl. 28, section 1). The Hendershot coal bed apparently is absent along the ridge just west of Powhatan Point.

UNDIFFERENTIATED STRATA OVERLYING THE HENDERSHOT COAL BED

Approximately 106 feet of strata overlies the Hendershot coal bed in a few places in southern York and Washington Townships, but the upper 10 to 20 feet is on the hilltops and could not be examined, because of soil cover.

The most complete outcrop of these strata is in the SW¼NW¼ sec. 13, York Township, along a ravine on the south side of the hill, north of the road (fig. 22). The Hendershot coal bed and Powhatan Point limestone member are absent in the ravine but are exposed on the hillside a short distance to the west. The lower 19 feet above the Hendershot coal bed consists of grayish-olive silty shale, very shaly siltstone, and a layer of clay. The shale and siltstone are overlain by 13 feet of impure friable sandstone containing some shale, which in turn is overlain by 7 feet of silty shale. The rest of the section is deeply weathered and details are obscure. Reddish mudstone and some fragments of sandstone were seen. A disturbed conglomeratic sandstone bed containing limestone pebbles is near the

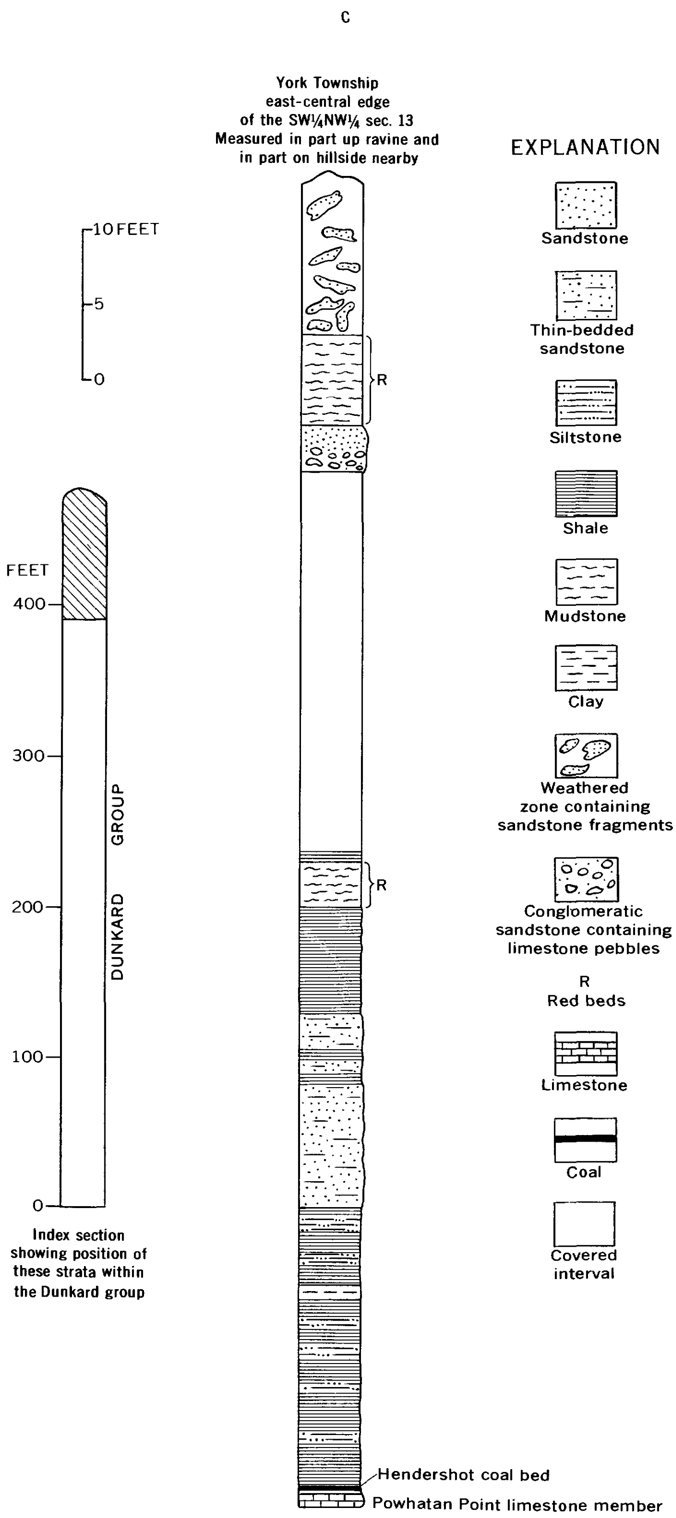

FIGURE 22.—Columnar section of the undifferentiated strata above the Hendershot coal bed.

top of the hill at a stratigraphic position approximately 67 feet above the Hendershot coal bed. This sandstone is overlain by reddish mudstone. The rest of the strata to the top of the hill are covered.

Massive sandstone interbedded with shale overlies the Powhatan Point limestone member in the southwestern corner of sec. 7, York Township (pl. 28, section 5), where the Hendershot coal is absent. There two layers of massive, friable sandstone are 7 feet and 27 feet above the Powhatan Point. The lower and more massive layer is 13 feet thick and is separated from the underlying limestone by dusky-yellow shale. The upper layer, which crops out at the highest point on the road at the ridge top, is more than 10 feet thick and is separated from the lower sandstone layer by 7 feet of variegated olive-gray to reddish-brown shale. Near the center of this shale is a thin band of dark-gray plastic clay. These two layers of sandstone appear to be equivalent to the two sandstone units above the Hendershot coal bed in sec. 8, Washington Township (pl. 28, section 2), and they may be equivalent in part to the Burton sandstone of Cross and Schemel (1956, p. 52, sec. A).

Shaly to flaggy sandstone overlies the Hendershot coal bed in most places in southern York and Washington Townships.

QUATERNARY DEPOSITS

The unconsolidated sand, gravel, and boulders along the streams and stream valleys are the youngest deposits in Belmont County (pl. 1). These unconsolidated deposits include both stream-bed and flood-plain deposits, terrace deposits, and perched deposits of alluvium in the upper or headwater parts of some of the streams. No fossils or other data were found for precise dating of the alluvium, but it is presumed to be of Recent age. The perched alluvium may be of Pleistocene age.

ALLUVIUM

STREAM-BED DEPOSITS

Lenticular deposits of intermixed silt, sand, gravel, and boulders, derived by weathering of the bedrock of the adjacent hills, lie along the beds of all the streams. In general the thickness of these deposits increases towards the mouths of the streams and is greatest along the main courses of Captina, McMahon, and Wheeling Creeks in the eastern half of the county.

Along the lower courses of these three streams, the deposits are silt, sand, fine gravel, and a few cobbles and boulders. Westward toward the headwaters, the silt content of these deposits decreases and the coarse gravel and boulder content increases. The boulder content is not only a function of distance from headwaters but is also related to the local relief, as shown by the abundance of boulders in the easternmost part of the county along the steep ravines. Some boulders have diameters of several feet, but the average in most places is about a foot. The boulders are mostly limestone because the sandstone and siltstone are generally too friable to withstand abrasion.

FLOOD-PLAIN DEPOSITS

Stratified deposits of silt, sand, and fine gravel lie adjacent to the channels of some of the larger streams. These deposits are laid down on the flood plains when the water rises above the bank of the stream channels and spreads laterally across adjacent flat areas.

Because of the youthfulness of the Ohio River system in this area, the flood plains are very narrow. The most extensive flood-plain deposits along the Ohio River are on the concave or slip-off side of the river meanders (pl. 1). Flood-plain deposits are also present along Captina Creek, McMahon Creek, and Wheeling Creek, mainly in the eastern half of the county.

The thickness of the flood-plain deposits is variable because of irregularities on the surface of the underlying bedrock and because of later erosion. The maximum thickness of the flood-plain deposits, as determined from damsite core holes, is 60 to 75 feet. The thickness of these deposits along Captina, McMahon, and Wheeling Creeks is much less than the thickness of the deposits along the Ohio River. Test holes for coal drilled in the northern part of sec. 4, Washington Township, and near the center of sec. 33, York Township, indicate a thickness of about 20 feet for the flood-plain deposits at those localities.

Although the present meandering courses of Captina, McMahon, and Wheeling Creeks are superimposed from a more maturely developed stage that was reached either just before or during the Pleistocene glacial epoch, the narrow flood plains along these streams indicate that they have again reached maturity.

The unconsolidated deposits north of Captina Creek in the northern part of sec. 4 and the southern part of sec. 5, Washington Township, are in part flood-plain deposits and in part abandoned stream channel deposits in a cutoff meander that forms the loop in the south-central part of sec. 5.

TERRACE DEPOSITS

Low terraces in the flood-plain deposits, particularly along the Ohio River, indicate that the Ohio River in this area has been downcutting in the recent past. This process has been arrested in recent years by the construction of dams and locks along the river.

The lowest terrace along the Ohio River has an average elevation above sea level of about 640 feet, or about 30 to 40 feet above the level of the river. This terrace is wide at several places and several cultural features are built on it, including the airport about a mile south of the northeastern corner of the county; the northeastern part of Martins Ferry; the eastern part of Bellaire; and Powhatan Point. This terrace is a part of the present flood plain and is covered by water during floods.

A second terrace, which is less conspicuous and more restricted, is at an elevation of about 680 feet, or about 50 feet above the river. This terrace is widest at Shadyside and the central part of the town is built on it. For a short distance southwest of Shadyside, State Highway 7 lies on this terrace. The northern part of Bellaire opposite Boggs Island is built on the second terrace, and it is also locally present between Aetnaville and Martins Ferry.

The third terrace is at an elevation of about 700 feet, or about 60 to 70 feet above the river. This terrace is well defined in the large meander at the southeastern corner of Mead Township, where State Highway 7 crosses it, and at Martins Ferry, where it appears to be a remnant of an abandoned subsidiary channel of the Ohio River. The elongate area in the central part of Martins Ferry, which has an elevation of about 720 feet, seems to have been an island, and State Highway 7 in Martins Ferry follows the abandoned subsidiary river channel.

Certain features along Captina Creek within a few miles of its mouth indicate that the 700- to 720-foot terrace may represent a previous gradation period for the Ohio River. The elevation of the old channel of Captina Creek in the cutoff meander in sec. 8, York Township, is 720 feet, and the slightly lower abandoned meander in the northern part of section 20 is probably of the same age. Since rejuvenation and readjustment of the course of Captina Creek, the older channel deposits have been largely removed by erosion, but the comparable elevations of the abandoned channels of Captina Creek and of the Ohio River at Martins Ferry indicate that they are time equivalents. The age of the third terrace and the abandoned channels cannot be dated precisely from data gathered in Belmont County but is possibly Pleistocene.

No terrace deposits of comparable elevation were found elsewhere, but the abandoned stream channel in the northwestern part of sec. 3, York Township, at an elevation of just over 800 feet is of interest because it may have been the main channel of Little Captina Creek when the drainage of this area was toward the north rather than toward the south, as it is today. The reversal probably occurred during the Pleistocene epoch.

Gravel-covered terraces of local extent were reported by Leverett (1902, p. 92) to be at an elevation of about 965 feet in the vicinity of Wheeling, W. Va., and Bellaire, Ohio. No terrace deposits were found at this elevation by the writer, but settlement along the Ohio River valley since Leverett's observations has probably obscured them. Leverett also states that a gradation plain lies at an elevation of about 1,000 feet in the same area, and evidence for this plain was found at several places.

Between Bridgeport and Little Captina Creek, at an elevation of about 1,000 feet, are several small flat areas that may be high terraces or perhaps remnants of an old gradation plain. Data positively identifying them as such are lacking, but the soil on these areas seems to be thicker than on other summits nearby and could be in part silt deposits. These surfaces are east of the ridge road just south of Bridgeport; east of Indian Run at Bellaire; east of the Cash Hill road just south of Wegee; and east of the ridge road in sec. 9, York Township. If these areas are remnants of a gradation plain, they are possible early Pleistocene in age.

PERCHED ALLUVIUM

Small patches of alluvium consisting of mixed clay, silt, small boulders, and pieces of tree trunks were found in places along tributaries in the headwaters of the larger streams. These deposits are perched along the sides of the streams and form the upper part of the stream banks, the lower part of the banks and the stream bed being bedrock. A good outcrop of this material showing its relation to bedrock occurs at an elevation of about 1,140 feet near the head of the small ravine that lies east of the road in the southwestern part of sec. 24, Wayne Township. There the alluvial deposit is several feet thick and overlies, in the stream bank, the Waynesburg coal bed which had been partly removed by stream erosion before the deposition of the alluvium. After deposition of the alluvium, the stream resumed degradation, eroding through the alluvium and into the bedrock. This same relation of perched alluvium to bedrock beds of the streams was seen at other places and suggests that the drainage profile or general relief during deposition of the alluvium was more subdued than at the present time. This alluvium is probably of Pleistocene age.

No systematic attempt was made to locate and map all these deposits because of their small extent.

Lithified alluvium consisting of sand, pebbles, and cobbles with a calcareous cement crops out along Glenns Run in the south road cut about two-tenths of a mile east of the road intersection in the southeastern part of sec. 19, Pease Township, at an elevation of about 670 feet. The age of the deposit is not known, but it may be Pleistocene. This is the only lithified alluvium found in Belmont County.

SEDIMENTATION

The sandstone, siltstone, shale, mudstone, clay, limestone, and coal of Belmont County were deposited as sand, silt, mud, and plant remains. Their deposition is a part of the history of the Appalachian geosyncline which covered parts of eastern North America during the Paleozoic era (Schuchert, 1955).

During most of its history, this subsiding geosyncline was covered by an open epicontinental sea that received thick and extensive deposits of sand, shale, and limestone. Near the end of its existence, in Late Pennsylvanian and early Permian times, however, the part of the sea that covered the parts of Ohio and adjacent States that constitute the northern Appalachian basin was a shallow, restricted northeastern embayment fringed by swamps characterized by very luxuriant plant growths. The extent of the swamps fluctuated with periodic oscillations in water level. The water was generally shallow, and following slight drops in its level the swamps spread extensively, but following slight rises large areas of the swamp were drowned and eventually covered by sediments. The intertonguing of the thin sheetlike bodies of sandstone, limestone, and coal is in part a result of fluctuations of the inflow of water into the basin of deposition and in part a result of variations from time to time in the amount and nature of clastic material that was available in the source areas.

The relatively nondiversified diminutive fauna in most of these rocks indicates deposition in one of two possible environments—fresh to brackish or hypersaline water. As evaporites are unknown in the Pennsylvanian and Permian strata of the northern Appalachian basin, the water is presumed to have been fresh to brackish. Furthermore, Weller (1957, p. 333) and Cross and Schemel (1956) have also concluded that *Spirorbis* and *Lingula*, both present in these strata, were not marine forms during Pennsylvanian and Permian time. Water around the margin of the basin was probably fresh because of stream discharge, but water in the central part and in the southwestern part nearer the epicontinental sea was probably brackish. Thin units abounding in marine fossils, however, are interbedded with the nonmarine beds, that indicate that the sea sometimes encroached eastward across the flat, swampy northern Appalachian basin. The periods of marine transgression gradually became less frequent and apparently ceased after middle Conemaugh time. The youngest marine stratum in Belmont County containing unequivocal marine forms is the Ames limestone member of middle Conemaugh age (pls. 1 and 2), but elsewhere the Skelley limestone of Condit (1912) and Birmingham shale member, which lie 25 to 30 feet higher, contain marine fossils.

During Late Pennsylvanian and early Permian times, the northern Appalachian basin seems to have been isolated from the epicontinental sea, or its connection was so narrow, that the volume of fresh water entering from the north and east was much greater than the volume of salt water entering the basin from the southwest. Gradually the basin became completely filled with sediments and there is no evidence of deposition after early Permian in the northern Appalachian basin. Such deposits, if ever present, have been removed by erosion.

The northern Appalachian basin was apparently elongate in a southwest-northeast direction, and the area that is now Belmont County lay to the northwest of the deepest part during most of Late Pennsylvanian and early Permian time. The axis of the basin apparently shifted from time to time, however, because of regional tectonic movements, and Belmont County lay nearer the center at some times than at others.

The repeated fluctuations in the water level and in the amount of sediment entering the basin caused vertical repetition of the various types of sediments in a cyclic pattern that is readily apparent in the generalized sections for the Conemaugh and Monongahela formations, and Dunkard group in plate 29 and also in the many diagrammatic sections included in the discussion on stratigraphy.

DESCRIPTION OF SEDIMENTARY CYCLES

The cyclic character of Pennsylvanian strata was first discussed in detail by Udden (1912, p. 47–50) in a report on the geology of the Peoria quadrangle, Illinois, but it was Weller (1930, p. 97–135) who first propounded the concept of cyclic sedimentation and pointed out the regional extent of these cycles or "cyclothems" which, because of their persistence, he considered to be formations. According to Weller, the typical Pennsylvanian "cyclothem" or formation as developed in Illinois consists of the following members:

Marine:
8. Shale, containing "ironstone" bands in upper part and thin limestone layers in lower part
7. Limestone
6. Calcareous shale
5. Black "fissile" shale

Continental (nonmarine):
4. Coal
3. Underclay, not uncommonly containing concretionary or bedded, fresh-water limestone
2. Sandy and micaceous shale
1. Sandstone

Unconformity

He states: "The succession of beds at any particular locality may be incomplete, or some members may be poorly developed owing to more or less local conditions."

To explain the physical changes responsible for the deposition of individual members and for the recurrence of the cycle or formation, Weller proposed a diastrophic control theory that involved recurring periods of uplift and submergence, both of the basin of deposition and of the source area. The relations between postulated movements and processes in the basin of deposition, source area, and immediate area, according to Weller, are summarized in table 1. In this table he added two more members to the typical cycle as presented in 1930.

TABLE 1.—*Table showing relation between postulated diastrophic movements and processes in depositional basin, intermediate zone, and source area during Pennsylvanian time*

[According to Weller (1956, p. 38)]

	Cyclothem members	Depositional area	Intermediate zone	Source area
Marine hemicyclothem	10. Upper shale	Emergence Rapid deposition Influx of sediment Uplift began	—Uplift→ Increasing gradient —Uplift→	Residual soil removed Erosion rejuvenated Uplift began
	9. Upper limestone 8. Middle shale 7. Middle limestone 6. Lower shale	Maximum submergence Less clastic sediment Deepening water Submergence	Subsidence→ Decreasing gradient Subsidence→	Residual soil developed Erosion almost ceased
Nonmarine hemicyclothem	5. Coal 4. Underclay 3. Lower limestone 2. Sandy shale	Peat accumulated Vegetation decayed Local ponding Slower deposition		Erosion very slow Erosion less effective
	1. Sandstone	Rapid deposition of sheet sands		Subsidence began Active erosion
	Disconformity	Local erosion	— Uplift → Increasing gradient — Uplift →	Maximum uplift
	10. Upper shale	Emergence Rapid deposition Influx of sediment Uplift began		Sand accumulated along shore Erosion rejuvenated Uplift began

In the following tabulations Weller (1956, p. 26, 35) summarizes the interpretations and conclusions upon which the diastrophic control theory is based:

I. The sedimentary sequence is cyclical
  A. It consists of alternating marine and non-marine strata
    1. The lower hemicyclothems are dominantly non-marine
      a. Erosion at the cyclothemic boundaries was subaerial
    2. The upper hemicyclothems are dominantly marine
      a. The invading seas were shallow
  B. The cyclothems are asymmetrical
  C. Many individual members are very widely distributed
  D. Each member accumulated essentially contemporaneously throughout its extent.

II. Subsidence occurred in the basin and uplift in the source area
  A. Subsidence was dominant in basin
    1. Emergence generally was not exclusively the result of basin filling
  B. Uplift was dominant in source area
    1. Intermittent subsidence of source area is indicated by basin sediments
  C. Intermittent movements were synchronous in basin and source area
    1. Corresponding movements occurred in basin and source area
  D. Both types of movement were most pronounced in source area.

Since publication of Weller's report in 1930, other geologists have written about the cyclically deposited strata of the Pennsylvanian and Permian periods, but not all have agreed that their deposition was diastrophically controlled to the degree suggested by him. The most widely known, of several other theories, is that of Wanless and Shepard (1936) who attributed the cyclic sedimentation of the Pennsylvanian and Permian to sea-level fluctuations (base-level control) and climatic changes. Their interpretation involves a more or less continuous subsidence of the sedimentation basin accompanied by rhythmic falling and rising of sea level in a two-phase cycle (transgression-regression). They attributed oscillations of sea level to periodic storing of ocean water on land as continental glaciers or even as interior seas and lakes. According to their theory, sands are assumed to have been deposited during glacial stages as channel fillings and coalescing deltaic fans on a broad piedmont area that lay between source areas and the restricted seas. Beginning with the onset of interglacial periods, when glaciers started melting, extensive swamps formed over the piedmont. As the climate became warmer and the tempo of melting increased, more and more water was carried into the seas, and the sea level rose. Gradually, as sea level rose the swamps were flooded by the transgressing sea, and marine shale and limestone were deposited over them. Rhythmic variations in the earth's atmospheric temperature were presumably responsible for the alternation of glacial and interglacial stages.

In order to explain lateral variations in cyclothems, Wanless and Shepard described three separate types of cyclothems, each of which forms in a given area as a direct result of physiographic location. These three types of cyclothems are defined as follows: (a) piedmont facies, composed largely of nonmarine sediments, (b) delta facies, containing both nonmarine and marine sediments, and (c) neritic facies, consisting predominantly of marine sediments, though containing some nonmarine sediments. Diagrammatic sections of each of the three facies, arranged in its physiographic location relative to the strand line, are shown in figure 23, which is adapted from Wanless and Shepard (1936).

Wheeler and Murray (1957, p. 1985–2011) modified the Wanless and Shepard glacial theory to include four stages of base-level control which they believe more nearly relates the components of each cycle to glacial and interglacial periods. They, therefore, conclude (p. 2009) that cyclothemic successions have four phases relative to base-level control. They describe these phases as follows:

a—Base-level rapidly and strongly down, with maximum marine withdrawal and regional sub-aerial erosion; local peat accumulation near receded shoreline.

b—Base-level rapidly but moderately up, with non-marine channel sand filling, and moderate marine advance; resumption of marine deposition to basinward and graded fluvial deposits to landward; detrital sedimentation generally precluded peat accumulation even though general humidity favored profuse vegetation.

c—Base-level rapidly but moderately down, with marine withdrawal again to lowest position; relief insufficient for strong erosion; heavily vegetated surface generally decomposed to clay; normal subsidence lowered surface into paludal environment (widespread peat accumulation).

d—Base-level rapidly and strongly up, with maximum marine advance and resumption of marine sedimentation in all but landward margin of basin; landward non-marine sediments of this phase dominated by red fluvial sediments, indicating aridity; both base-level and climate generally unfavorable for vegetal accumulation (minimum peat potential).

Stout (1931, p. 195–216) described in considerable detail cyclic sedimentation in the Pennsylvanian rocks of Ohio. He noted that the ratio of nonmarine to marine strata increased from basal to Upper Pennsylvanian strata and pointed out that the character of the cycles varied because of this. He, therefore, divided the Pennsylvanian system of Ohio into upper, middle,

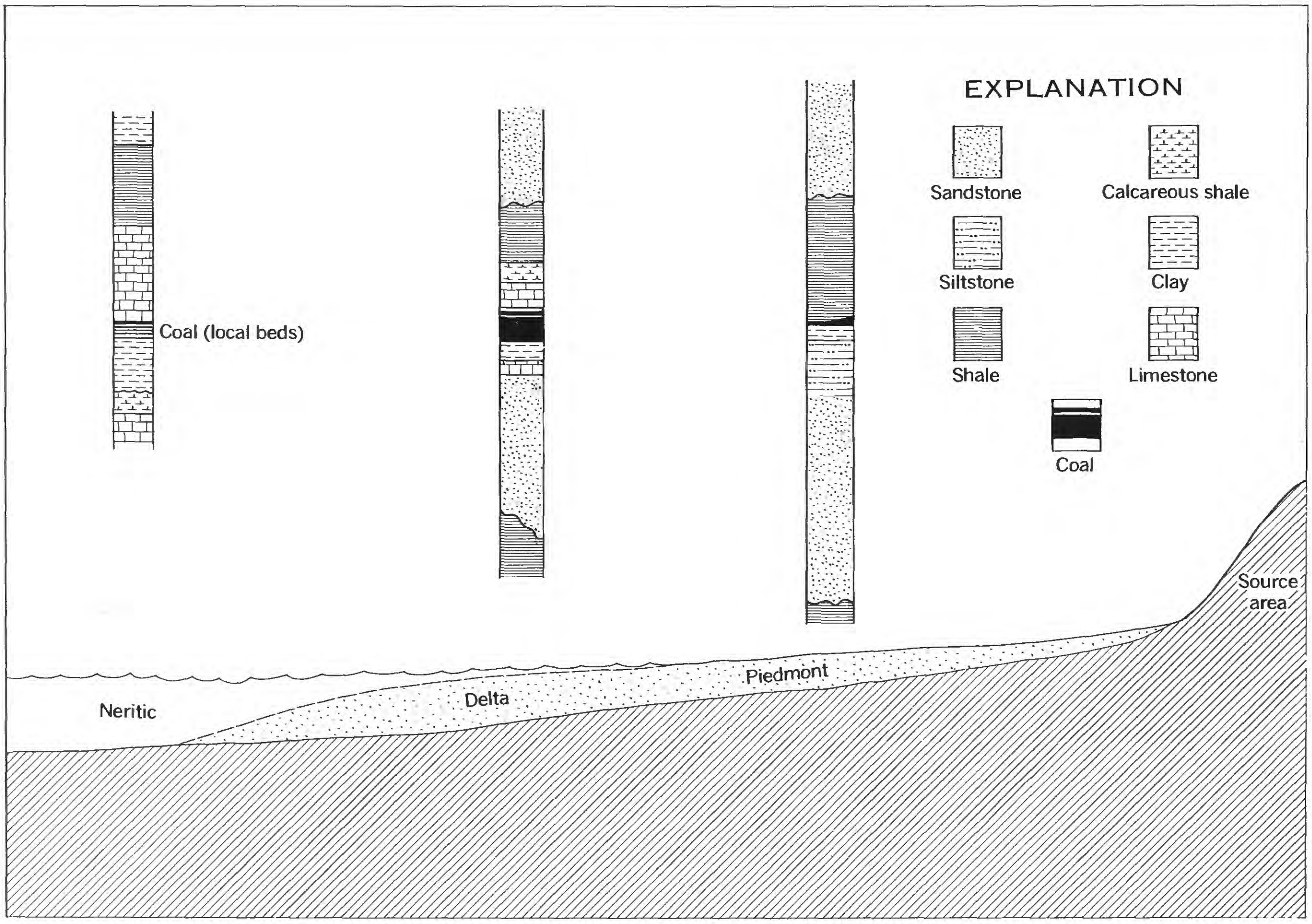

FIGURE 23.—Schematic sections of Midcontinent sedimentary cycles of the piedmont, delta, and neritic facies arranged physiographically. (Adapted from Wanless and Shepard, 1936.)

and lower divisions based on characteristic cycles. He described the three divisions as follows:

3. Upper division—strata from the top of the Skelley limestone to the top of the Waynesburg coal; the beds appear to be entirely of fresh-water origin. (Middle of the Conemaugh formation to top of Monongahela formation.)
2. Middle division—strata from the top of the Strasburg coal to the top of the Skelley limestone; in this section both marine and fresh-water strata are prominent. (Part of Conemaugh formation below the Ames limestone member in Belmont County included in this division.)
1. Lower division—strata from the Harrison ore to the top of the Strasburg coal; throughout this part of the column marine deposits are very prominent. (Strata of this division do not crop out in Belmont County.)

He also recognized several types of cycles within each division. As rocks of the lower division do not crop out in Belmont County cycles for it are not listed. The cycles Stout cited as typical of the upper and middle division are as follows:

Upper division

Type 1. (Top)____ Clay, impure, generally thin, fresh-water
Limestone, fresh-water
Shale and sandstone, fresh-water
Coal, fresh-water

Type 2__________ Clay, thin, local, fresh-water
Limestone and calcareous shale, fresh-water
Coal, fresh-water

Type 3. (Top)____ Clay, thin, local, fresh-water
Shale and sandstone, fresh-water
Coal, fresh-water

Middle division

Type 1. (Top)____ Clay, fresh-water
Limestone, fresh-water
Shale and sandstone, fresh-water
Coal, fresh-water

This type is similar to type 1 of the upper division

Type 2. (Top)____ Clay, thin, impure, fresh-water
Limestone, fresh-water
Shale and sandstone, partially marine
Limestone, marine
Coal, fresh-water

Stout (1931, p. 210–212), in summarizing the character and cause for cyclic sedimentation of the Pennsylvanian system in Ohio, states:

> In Ohio the coal formation cycles are very prominent throughout the entire Pennsylvanian system and also in the overlying Dunkard. In general, the cycles are completed, the strata being on the average about 26 feet thick. The kinds of strata composing the cycle depend on the location of the cycle in the Pennsylvanian system or on the dominant marine or fresh water conditions under which the beds were deposited. The general crustal movement during the formation of the entire system was one of regional and not local subsidence. No disconformities due to elevation and widespread erosion are anywhere apparent. The movement was one of slight but rather rapid depression, followed by a pause, this order being repeated over and over for each succeeding cycle. The surface throughout the great Appalachian syncline was always quite flat, and was never far above or far below water level. In general, the rate of deposition was slow as indicated by the formation of clay, limestone, and coal. The clastic sediments were derived mainly from the piedmont area to the east. Coals and clays were formed under somewhat similar conditions except that in the coals the vegetable matter was partially preserved, whereas in the clay formation, the plant tissue, through decay, gave the chemical reagents for the purification of the infiltrated silts to more kaolinitic sediments. The limestones vary from marine to fresh water and are definite aids in tracing the history of Pennsylvanian sedimentation. On the whole, the cyclical formation of the Pennsylvanian system in Ohio is clear and definite.

In Belmont County both the Pennsylvanian and the Pennsylvanian and Permian strata were deposited in a changing environment that fluctuated cyclically in such a fashion that most rock types are repeated many times and in an orderly sequence or cycle. The cyclic character is much more apparent, however, when the entire succession of strata is viewed grossly than when subjected to close scrutiny. A glance at the sections of the Conemaugh and Monongahela formations, and Dunkard group in plate 29 permits the generalization that in Belmont County a coal bed is underlain by an underclay and limestone and is overlain by shale, siltstone, or sandstone. Detailed studies, as shown in the diagrammatic sections in the discussion of stratigraphy, however, demonstrate that facies changes are the rule rather than the exception, and, as a consequence, the cycles vary not only stratigraphically but areally as well.

Pennsylvanian and Pennsylvanian and Permian strata of Belmont County can be divided into 24 cycles of 6 different types, which are shown in plate 29. These 24 cycles include 17 that are assumed to be regional and 7 thin cycles that pinch out westward in Belmont County. The recognized types of cycles are based upon physiographic position within two basic environments of deposition—deltaic and neritic or basin. The facies relations of the types of sedimentary cycles are shown in figure 24.

The Conemaugh formation contains 2 types of cycles, one (A) that occurs from the base of the formation to approximately the base of the Morgantown sandstone member and another (B) that characterizes the upper part of the formation above the base of the Morgantown. These cycles and their respective environments of deposition are as follows:

Type A—Delta plain

4. Fresh-water clay, impure; variable in thickness but commonly thin.
3. Fresh-water mudstone, reddish; interbedded with siltstone or sandstone and siltstone.
2. Marine limestone, nodular, impure, fossiliferous.
1. Fresh-water clay, lenticular; contains carbonaceous band (coal developed in other parts of Ohio).

Type A is characterized by marine limestone whose position lies just above the carbonaceous clay or coal and by the absence of fresh-water limestone beneath the clay of unit 4. A cycle of this type is associated with the Cambridge limestone member as follows:

4. Underclay beneath Anderson coal (carbonaceous clay).
3. Interbedded reddish mudstone and siltstone ("undifferentiated strata" in this report).
2. Cambridge limestone member.
1. Carbonaceous sandstone and clay (position of Wilgus coal of Condit, 1912).

Type B—Delta plain

5. Clay, impure; variable in thickness.
4. Limestone; one or more beds separated by thin layers of clay.
3. Sandstone; grades upward to shaly siltstone and soft shale; locally grades laterally to siltstone; base locally rests disconformably on siltstone below.
2. Siltstone, shaly; variable in thickness; locally contains thin reddish shale at base.
1. Clay, thin, impure; contains carbonaceous bands.

This type of cycle is characterized by the presence of fresh-water limestone beneath the upper clay and the absence of marine limestone above the basal car-

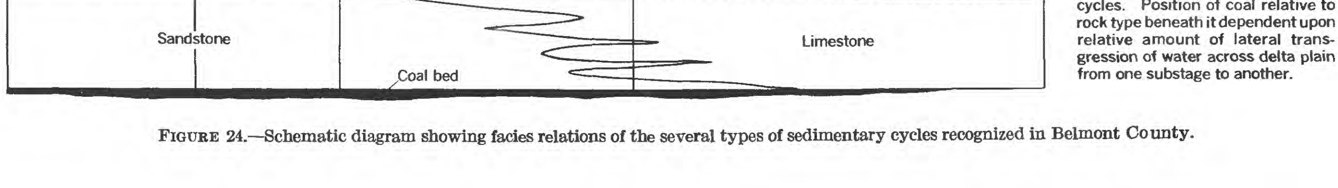

FIGURE 24.—Schematic diagram showing facies relations of the several types of sedimentary cycles recognized in Belmont County.

bonaceous clay. A cycle of type B, which includes the Upper Pittsburgh limestone and Bellaire sandstone members, is as follows:

5. Underclay beneath the Pittsburgh coal bed.
4. Upper Pittsburgh limestone member.
2, 3. Bellaire sandstone member of Condit.
1. Clay, thin; contains several carbonaceous bands (equivalent to Lower Little Pittsburgh coal).

The Monongahela formation contains 4 types of cycles, three of which C, D, and E are laterally equivalent to each other. Type C is similar to type B of the upper part of the Conemaugh formation, differing only in that unit 1 is a thick coal bed. Type C is as follows:

Type C—Delta plain to delta edge

6. Clay, impure; variable in thickness.
5. Limestone, impure; commonly in several thin beds separated by thin layers of clay.
4. Sandstone, coarse-grained; grades upward to siltstone and soft shale; base in many places rests disconformably on siltstone, shale, or clay below.
3. Siltstone, shaly, or shale; relatively thin; locally absent.
2. Clay, thin, locally shaly; commonly contains thin carbonaceous to coaly layers in basal part.
1. Coal, thick; thicker beds commonly consist of a main bench and a lenticular, impure upper bench separated from the main bench by clay; locally a third bench, also thin and impure, underlies the main bench.

The Pittsburgh coal bed and the overlying strata to the base of the Redstone coal bed in parts of western Belmont County form a type C cycle.

Type C cycle

6. Underclay beneath the Redstone coal bed.
5. Redstone limestone member.
4, 3. Pittsburgh sandstone member including lenticular siltstone (unit 3) in basal part.
2. Clay, soft, contains carbonaceous bands.
1. Pittsburgh coal bed.

A second type of cycle in the Monongahela formation, type D, is similar to type C but contains no limestone. The coal is thinner and more impure than in type C. Lithologically, a type D cycle is a delta-plain sequence. It lacks red beds that characterize types A and B and apparently formed around the basinward edge of the delta plain during substages of relatively rapid delta expansion. The sandstone of the type D cycle was apparently deposited fast enough so that surface oxidation did not take place. The following sequence forms a type D cycle.

Type D—Delta edge

5. Clay, impure; variable in thickness but generally thin.
4. Sandstone; variable in grain size, becoming siltstone laterally in some places; upper part is shaly siltstone and soft shale; base locally rests disconformably on underlying unit but generally grades downward into it.
3. Siltstone, shaly, or shale; variable in thickness but generally thin.
2. Clay, partially carbonaceous, thin.
1. Coal; more impure and thinner than in type C.

This type of cycle is represented by the strata from the base of the Uniontown coal bed to the base of the Waynesburg coal bed in the western part of Belmont County.

5. Underclay beneath Waynesburg coal bed.
4, 3. Uniontown sandstone member, including at base shale (unit 3) of variable thickness.
2. Clay, generally very thin.
1. Uniontown coal bed.

The type E cycle, laterally equivalent to both types C and D, contains little or no sandstone, siltstone, or shale, and with one exception is limited to the eastern two-thirds of Belmont County. Its principal units are as follows:

Type E—Basin

4. Clay, impure; variable in thickness.
3. Limestone; multiple bedded, thick; ranges from pure to impure.
2. Clay, calcareous, moderately thick; contains limestone nodules in lower part.
1. Coal; ranges from well-developed to thin and impure.

The Redstone coal bed and overlying Fishpot limestone member form a type E cycle.

4. Underclay beneath Fishpot coal bed.
3. Fishpot limestone member.
2. Clay.
1. Redstone coal bed.

A fourth type of cycle within the Monongahela formation lacks both clay and coal, and consists of only two components, one of which is a fine-grained clastic unit containing ferrous iron. The lithologic character of a type F cycle is shown below:

Type F—Basin

2. Limestone, impure; generally consists of several beds.
1. Siltstone or shale; in most places characterized by distinctive grayish-green color imparted by ferrous iron compounds; sandstone with undulatory base occurs locally.

The Morningview sandstone member and overlying Arnoldsburg limestone member constitute a type F cycle. The significance of the greenish ferrous-iron-bearing siltstone-shale units in the type F cycle is not fully understood, but they probably represent periods of slow sedimentation in a reducing environment.

There are six type B cycles in the upper part of the Dunkard group and three are identical with type B cycles in the Conemaugh. Strata below the Washington coal bed form cycles that are similar in places to type C, and in other places, where the limestone is missing, they are similar to type D. Over most of

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western Belmont County strata between the Waynesburg "A" and Washington coal beds form type D cycles, but in parts of eastern Belmont County, where a fresh-water limestone occurs, these strata comprise type C cycles. Strata above the Washington coal bed in most places form cycles that are similar to type B of the Conemaugh formation. They are characterized by lack of coal in most cases, containing instead bands of carbonaceous or coaly shale, or clay containing carbonaceous bands. The red mudstone beds in the type B cycle of the Conemaugh formation are thicker and more persistent in the Dunkard group and are generally harder and more shaly. Locally in the northeastern part of the county limestone seems to occupy almost the entire interval between the Washington coal bed and the upper tongue of the Middle Washington limestone member. Outcrops are too poor and too few to provide positive proof, but in that area the cyclic repetition of beds may be similar to type E of the Monongahela formation.

The lithology of each unit in the sedimentary cycle is indicative of the sedimentary environment at a given stage during the depositional history of the cycle.

Analysis of the cycles shows clearly that: (1) each cycle represents from 2 to 6 changes in depositional environment, indicating several fluctuations in depth of water; (2) cycles vary in the number of vertical components, indicating fewer fluctuations during some stages of the depositional history than during others; (3) some cycles grade laterally into other types of cycles, for example, type C and type E are time equivalents (pl. 29); and (4) the three basic lithologic components of the cycle—limestone, sandstone, and coal—were deposited in environments so closely related that very minor variations in the rate of subsidence or the volume of water in streams flowing into the basin were sufficient to produce a change in the type of deposit. Change from deposition of one type of sediment to deposition of another was caused largely by fluctuations in inflow of water, which raised base level and caused periodic shifts in the shoreline. Another influencing factor probably was the availability of erosional debris at the source areas, but the factor that most influenced the processes of sedimentation probably was the amount of water available to carry detritus from source area to depositional site. More gradual geomorpholgical changes of a regional nature caused changes in the pattern of sedimentation and in the sedimentary environment that are apparent only when groups of sedimentary cycles are compared. Thus within the cycles of the Conemaugh formation and Dunkard group, sandstone and siltstone are the main units and limestone and coal form relatively minor ones. In the Monongahela formation, however, ratio of sandstone to limestone is more nearly equal, and coal is prominent in many of the cycles. In eastern Belmont County, sandstone is entirely absent from some of the cycles of the Monongahela formation. Figure 25 is a graph that shows the relative abundance, by percent, of each type of lithology within each of the three formations. These percentages are averages and are, therefore, somewhat generalized. Ratio of sandstone to limestone in each of the three formations is somewhat more variable than is indicated in the figure. For example, the upper 100 to 150 feet of the Conemaugh formation is locally made up of sandstone in the northeastern part of the county. The Monongahela formation in a few places in northwestern Belmont County appears to consist almost entirely of sandstone, and the Dunkard group contains more limestone in northeastern Belmont County than elsewhere. These are local conditions, however, and the percentages shown are believed to be representative of the formations as a whole.

Variations in the ratio of sandstone to limestone from one formation to another indicate significant changes in the sedimentary environment. These changes, which were more gradual than the fluctuations causing the cyclic sedimentation, were the result of regional tectonism that caused changes in shape and size of both depositional basin and source areas. Differences in extent and configuration of various lithologic units are the result of adjustments of the depositional agents to the changes caused by tectonic movements.

Although the shape, size, and depth of the basin of deposition changed periodically, the main streams or drainage systems entering the basin appear to have followed the same general courses for long periods of time. Thus, a stream that was probably a distributary of a large delta crossed western Belmont County during all of Conemaugh, Monongahela, and early Dunkard times. This drainage system carried sediments from a source area to the north. At times the channel of the stream itself crossed the area and at other times, when water level was higher in the depositional basin and the shoreline was located farther to the northwest, western Belmont County lay on the basinward edge of the deltaic lobe built by this stream. Positions of the coarse-grained, channel sandstones and the lobate sandstones deposited by this stream at various times are shown in the diagrammatic sections that accompany the discussion of stratigraphy and are also illustrated by the lithofacies maps in figure 26.

The mineralogy of these sandstones as well as that of the associated sheet sandstones signifies something of the nature of regional tectonics during Pennsylvanian

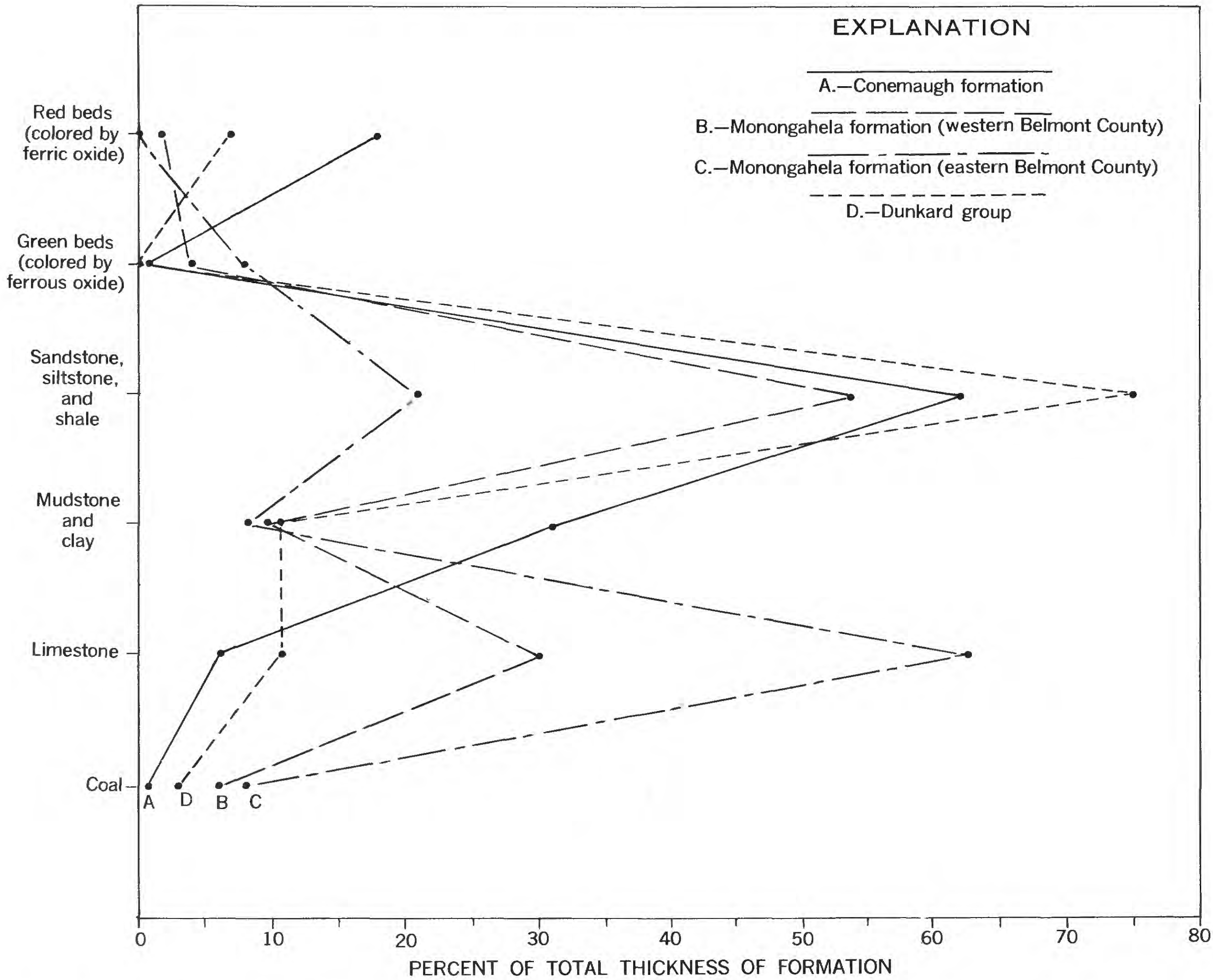

FIGURE 25.—Graph showing principal lithologic types within the Conemaugh and Monongahela formations, and Dunkard group in Belmont County and the percentage of each type in each formation.

and Permian time. All the sandstones are subgraywackes as defined by Pettijohn (1949, p. 255–257).

The subgraywackes of Belmont County are believed to have spread as deltaic sheets into a continuously subsiding basin. The source areas, which lay to the north and east, were uplifted by orogenic movements that appear to have caused a progression of the geosynclinal axis westward or perhaps southwestward during late Paleozoic time.

As already pointed out, the relation of the sandstones and other rock types within the basin is that of interfingering and rhythmic facies. The cyclic sedimentation is believed to have been the result of fluctuations in the amount of water available to transport detritus within a basin undergoing intermittent regional subsidence. This implies rhythmic climatic variations of a regional nature, with accompanying rises and falls of sea level. Periodic increase and decrease in rainfall is not the whole answer, because evaporites presumably would have formed during periods of little or no rainfall. Actually, if red beds are indicative, Conemaugh and Dunkard times seem to have been periods of somewhat lighter rainfall, but not scanty enough to produce evaporites. The theory most applicable is that of fluctuating base level caused by glacial control. This theory is simpler and based on fewer assumptions than others, but even this may not fully explain the perplexing problem of sedimentary mechanics during Pennsylvanian and early Permian time.

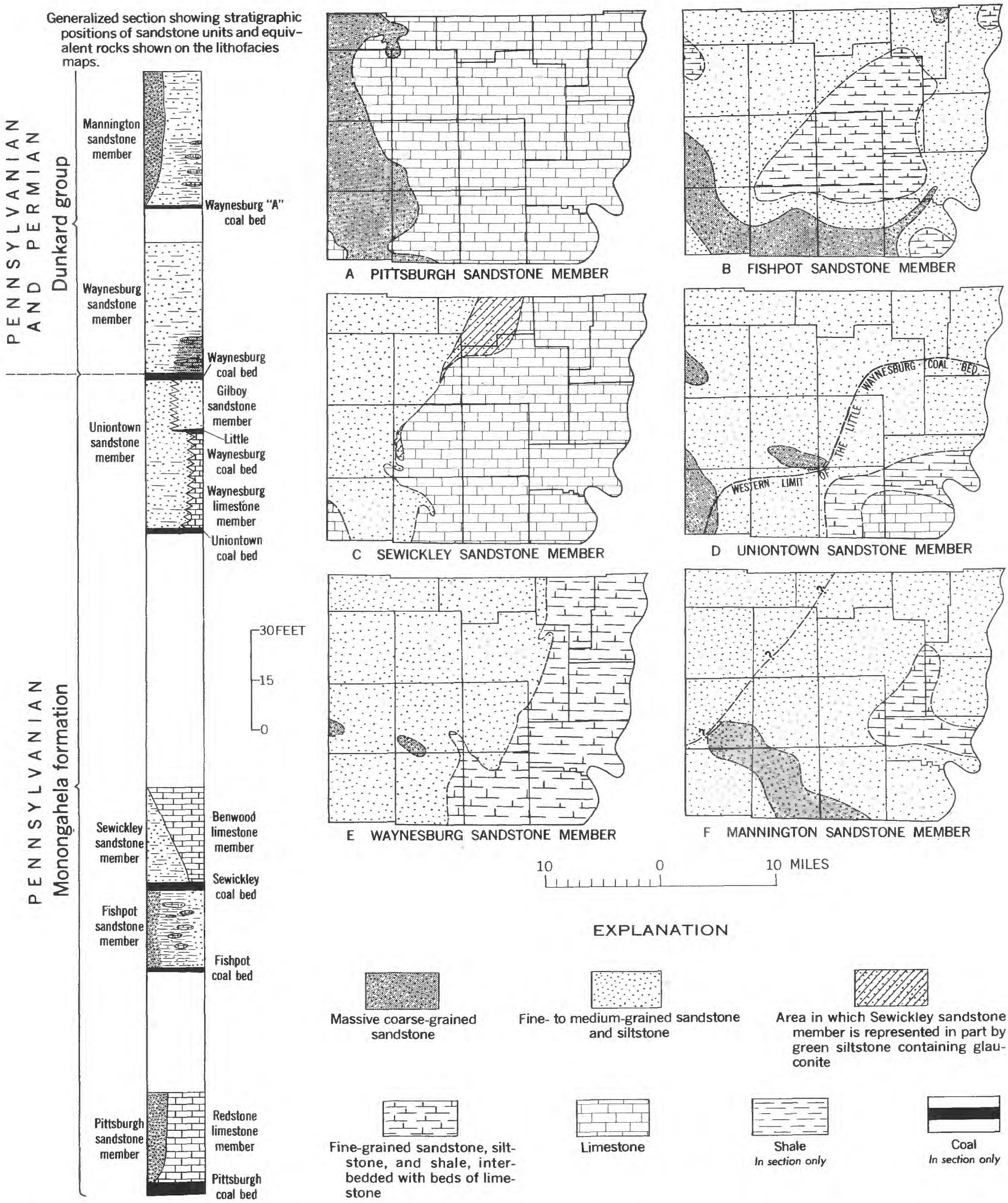

FIGURE 26.—Lithofacies maps of the more prominent sandstone units of the Monongahela formation and lower part of the Dunkard group showing their configuration and distribution. The coarse-grained sandstone in the western and southwestern parts of the county was deposited along the broad channel of a deltaic stream that flowed from the northwest.

DEPOSITIONAL ENVIRONMENT AND PALEOGEOGRAPHY

CONEMAUGH FORMATION

Sedimentary rocks of the Conemaugh formation in Belmont County are deltaic and consist of alternate layers of continental, fresh- to brackish-water, and marine deposits. In contrast to typical wedge-shaped deltas that form in basins where the bottom slopes gradually from shore to deep water, the Conemaugh delta consists of relatively thin, sheetlike deposits that appear to have accumulated mainly in very shallow water. A deltaic environment is indicated by the high percentage of sandstone and siltstone, by the scarcity of coal, and by red beds, whose color may be the result of oxidation in surficial zones. Scarcity of coal and presence of red beds may indicate a relatively dry but not arid climate.

Clastic rocks, including sandstone, siltstone, shale, mudstone, and clay, make up about 93 percent of the formation; limestone about 6 percent; and impure coal an insignificant 1 percent. Approximately 18 percent of the clastic rocks, chiefly the mudstone and shale, are red (fig. 25).

The sandstone and siltstone of the Conemaugh formation are parts of extensive sheets that seem to extend into the county from the northwest and also from the northeast. Individual units or layers are characterized by considerable variation from place to place in both thickness and grain size. In general the thickest parts of these layers are also the parts having the coarsest grain size, indicating that they mark the location of stream channels.

The sandstone units are irregularly bedded, but the siltstone units which accumulated in quieter water are generally even bedded and laminated. The sandstone and siltstone grade into each other in an irregular, and in places, erratic pattern. Lenses of sandstone with cut-and-fill structure are in many places enclosed in even-bedded siltstone. These are fluvial features which resulted from periodic changes in stream velocity, sediment load, and direction of flow. Crossbedding, mostly of the current-bedding type, is present in parts of every sandstone unit, and current ripples are locally present. Interpretation of direction of current flow from orientation of crossbedding and current ripples was hampered by spotty outcrops, but at most places these markings show a random orientation that is the result of frequent shifts in the direction of current flow.

The red beds are principally mudstone and thin shale that grade into nonred siltstone and sandstone. In Belmont County it was not possible to determine whether the red beds are primary deposits or whether the red color results from secondary oxidation of ferrous iron. In the Conemaugh formation the red beds occur in type A and B cycles in association with carbonaceous clays. It may be significant that in the type C and D cycles of the overlying Monongahela formation this part of the cycle is represented by a thick coal and nonmarine limestone. This may indicate greater aridity at the time of deposition of the red beds, resulting in decreased plant growth and increased destruction of plant material by oxidation and accompanying oxidation of minerals containing ferrous iron.

The limestone beds, which make up about 6 percent of the formation, are thin units consisting of one or more beds separated by thin bands of clay. Both marine and fresh- or brackish-water limestone beds are present. The marine limestone units were deposited during periods of rise in sea level that caused the epicontinental sea to spread temporarily northeastward into the northern Appalachian basin covering the sheetlike fluvial deltas. Stratigraphically the marine and fresh- to brackish-water limestone units occupy different positions in the sedimentary cycle. The marine limestone units lie just above the thin carbonaceous clay or thin coal beds, but the fresh- or brackish-water limestone units lie just below similar units. A notable feature of the fresh- or brackish-water limestone is the brecciated upper part of some of the beds. The brecciation is believed to have formed when the process of deposition was interrupted by brief periods of aridity that dried up the lakes or brackish swamps and exposed the limy mud flats to subaerial desiccation, during which sun cracks were formed. The upper cracked and hardened layer of mud was subsequently disturbed and reworked by running water when deposition was resumed. This feature is conspicuous evidence of the shallowness of the depositional basin.

The paleogeography of the part of the Conemaugh delta that covered Belmont County is indicated by the thickness and distribution of the sandstone. Thus, in northwestern Belmont County, a deltaic lobe which had a southeast trend is indicated by the high percentage of sandstone and siltstone. The sandstone and siltstone unit of cycle 2 (pl. 29) represents continuous deposition of clastic sediments in northwestern Belmont County; yet to the northeast in Jefferson County and to the southwest in Guernsey County, the Barton coal bed and Ewing limestone member were deposited during a part of the same period. The thin red shale in the upper half of the sandstone unit of cycle 2 may be roughly a time equivalent of that coal and limestone. Moreover, the general lack of coals in northwestern Belmont County during early and middle Conemaugh time is also indicative of a deltaic lobe, as lenticular coals occur to the northeast in Harrison County and in Jefferson County (Lamborn, 1930), to the southwest in Guernsey County (Condit, 1923), and to the east in West Virginia (Grimsley, 1907), where they have been recorded in drill holes.

During late Conemaugh time the drainage pattern seems to have shifted slightly towards the east because the sandstone units of cycles 5, 6, and 7 (pl. 29) coalesce to form a deltaic lobe that extends from the northeast into the northeastern part of Belmont County and indicates continuous sandstone deposition during three complete sedimentary cycles.

MONONGAHELA FORMATION

Two predominant sedimentary facies are represented in the Monongahela formation of Belmont County. During much of Monongahela time, lime mud was accumulating over the eastern part of the county while sand and silt were being deposited in the western part. The lime mud was laid down in quiet water, probably at some distance from shore. It is a fresh- or brackish-water deposit that corresponds roughly to the neritic or epineritic deposits of the marine environment. The sandstone, siltstone, and mudstone are deltaic deposits. The interfingering of these lithologic units in western Belmont County during early and middle Monongahela time, and across all but the southeastern part of the county in late Monongahela time, is the result of periodic fluctuations in the size of the main delta. As both the bottom of the basin of deposition and the adjacent land were areas of very low relief, changes in water level of only a few feet caused extensive migration of the shoreline. Coal beds that normally overlie the limestone beds represent extensive swamps during periods when the basin of deposition had reached equilibrium and was receiving only small amounts of sediment. The two thickest coal beds, the Pittsburgh and the Sewickley, are persistent in both facies of the formation, but the other beds are more irregular and show thickness trends which appear to be the result of environmental control.

All the sandstone beds of the Monongahela formation in Belmont County are sheet deposits, but the Pittsburgh and Sewickley sandstone members in the lower part of the formation are more lobate and less extensive than the sandstone beds in the upper part of the formation. The configuration, distribution, and stratigraphy of the four most prominent sandstone members are shown in figure 26. The Pittsburgh and Sewickley sandstone members mark the basinward edge of deposits laid down by or closely associated with a delta distributary stream. Although the sandstone bodies are similar in shape, the depositional history of these two sandstone members is different. The Pittsburgh sandstone member is mostly a massive coarse-grained rock that fills a very broad channel that is cut into underlying strata. The Sewickley sandstone member contains a few channel fillings in its basal part but is mostly a laminated, platy deposit containing much carbonized plant debris. It represents a receding deltaic lobe that was gradually transgressed and covered by deposits of limestone.

The sandstone beds in the upper part of the formation also have channel phases in geographic positions similar to those of the Pittsburgh and Sewickley sandstone members, but they are principally fanlike deposits that were spread laterally between distributaries. In the eastern part of the county these sandstone deposits grade laterally into calcareous mudstone and limestone.

Crossbedding of the current-bedding type, small-scale foreset beds, cut-and-fill structural features, and current ripple marks, all indicative of deposition by fluvial action, occur from place to place in all the sandstone units. The foreset beds were found to be reliable indicators of current direction within limited areas, but the orientation of the crossbedding and current ripple marks within a succession of beds at some localities varies as much as 180°.

The sedimentational history of individual units of sandstone involved two main stages of deposition. This is indicated by the relation of the coarse-grained phase within each unit to the fine-grained phase. Sediments deposited during the initial stage consisted mainly of mud, silt, and fine-grained sand that were spread out as sheets. In places these deposits are ferruginous and contain ironstone concretions. The deposition of fine-grained clastic sediments was terminated by stream rejuvenation and channel cutting that eroded away some of the fine-grained silt and sand of the initial stage as well as some of the strata beneath the silt and sand. The channels were eventually filled by coarse-grained sand as a result of aggradation, and deposition of sheet silt and fine sand was resumed. Gradually the clastic sediments became finer grained and most of the sandstone units grade upward into shaly mudstone and impure clay containing limy nodules. The change in the sedimentary processes involved in the two stages of sandstone deposition is illustrated in figure 27.

Several of the sandstone units have basinward facies of mudstone and siltstone that are characterized by their distinctive green color. These green beds are believed to have been deposited in a restricted part of the basin where, because of a deficiency of oxygen, the iron compounds were subject to reduction rather than oxidation.

Thin red beds, whose color is a result of oxidation of iron compounds on surficial parts of a delta, occur locally in the southwesternmost part of Belmont County.

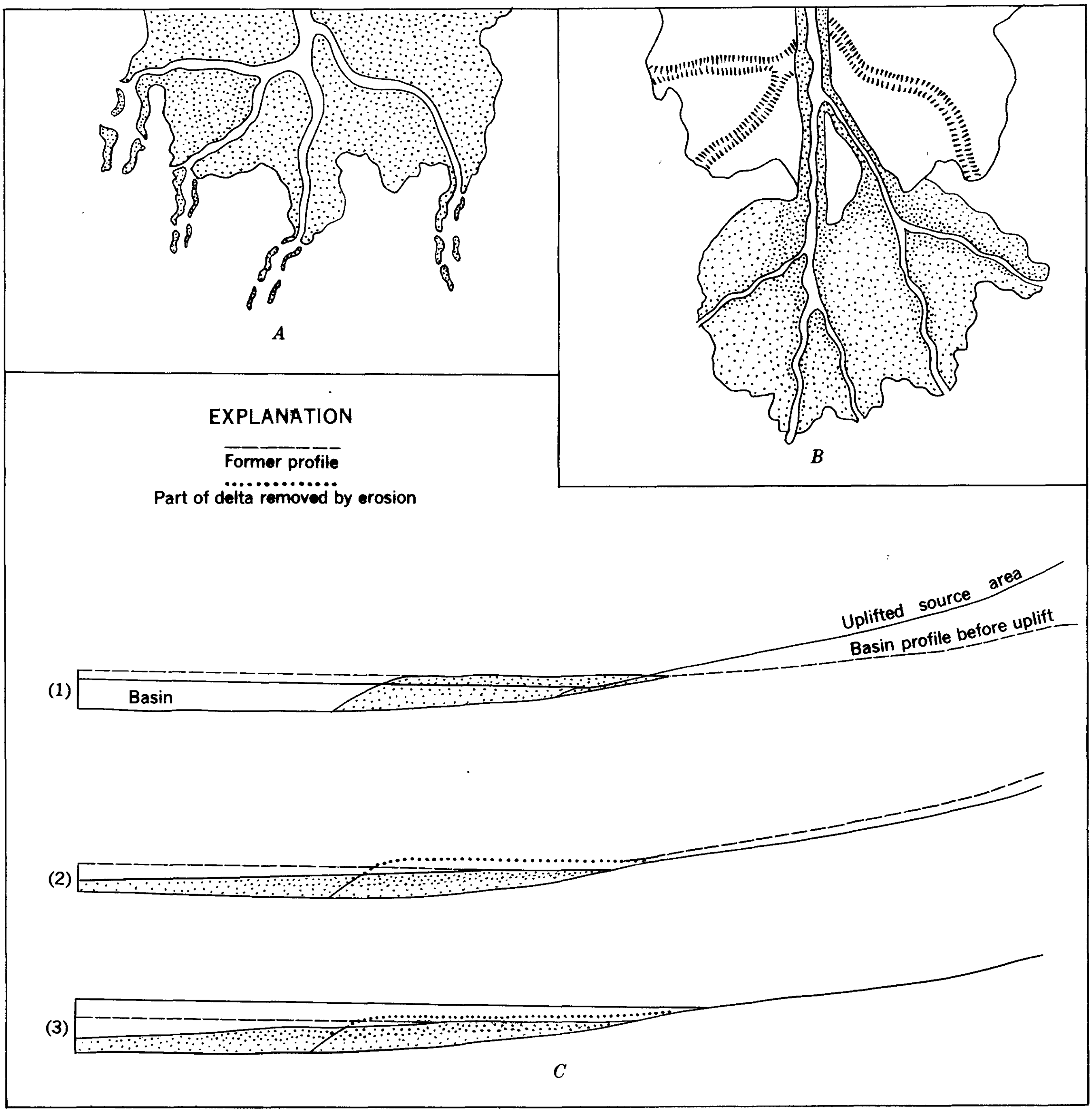

FIGURE 27.—Diagrams showing mechanics of two-phase deposition of some sandstone units in the Monongahela formation and Dunkard group as typified by the Pittsburgh member of the Monongahela formation and the Mannington member of the Dunkard group. *A*, First phase of sandstone deposition: building of delta composed of clay and silt. *B*, Second phase of sandstone deposition: (1) stream rejuvenation and incisement into delta; (2) building of second delta basinward and deposition of coarse sand along incised channels. *C*, Profiles showing effects of stream rejuvenation on distribution of sandstone: (1) elevation of upper part of delta by uplift of source area and by lowering of water level in basin of deposition; (2) incisement of delta and stream course from delta; beveling of first delta and building of a new delta in part from sediments eroded from the older delta and in part from coarse-grained sandstone from the highland source area; (3) gradual rise in water level in part as a result of volumetric displacement by broad deltaic fans, and in part as a result of increased influx of water into the basin.

Limestones in the Monongahela are sheet deposits that thin northwestward across the county; those in the upper part of the formation pinch out northwestward and their place is taken by sandstone. In parts of the county where the sedimentary cycles of the Monongahela formation are complete and contain sandstone, limestone, and coal, the limestone units overlie the sandstone units and are separated from them in most places by a gradational layer of siltstone and mudstone containing limy nodules.

Three features are common to most of the limestones. They are multibedded and relatively impure and lack fossils that are generally associated with a marine environment. The beds of limestone range from nodular masses to dense persistent layers that are separated by thin layers of impure shaly clay locally containing carbonaceous plant debris. The average thickness of individual beds is about 1 foot, but the range of thickness is from a few inches to several feet. The upper and lower surfaces of most of the beds are somewhat undulatory, but from a distance the limestone units have an even-bedded appearance.

Individual beds in some of the units of limestone are conglomeratic, and the upper parts of some of the beds are sedimentary breccia that formed as a result of exposure to subaerial desiccation. The upper surface of the temporarily exposed lime mud was hardened and cracked, forming loose crusts that were disturbed during subsequent inundation, and recemented following inundation when lime deposition was resumed.

The limestone units in the lower half of the formation were deposited during periods when the shoreline lay some distance to the northwest. During those periods, relatively little clastic sediment reached Belmont County. The bottom of the basin was even and nearly flat. The depth of water probably never exceeded 10–15 feet, and, periodically, extensive parts of the basin bottom that lay adjacent to the shoreline were exposed as mud flats.

Sheets of impure clay (underclay) ranging in thickness from a few inches to several feet overlie the limestone units and separate them from overlying coal beds. Layers of shaly, impure clay commonly containing carbonaceous bands also overlie the coal beds in most places. The clay is generally purest just beneath the coal beds and becomes less pure downward. The lime impurities are most common in the lower parts of the clay, which seems in many places to be gradational into the underlying limestone. Where the limestone is absent, the clay grades almost imperceptibly into the mudstone and silstone of the upper part of the sandstone units. The clay is commonly plastic and contains, in addition to clay minerals, variable amounts of impurities that include grains of quartz, mica, pyrite, limonite, and small limy nodules. Locally, where the percentage of impurities is high, the fine-grained layers beneath the coals consist of friable mudstone rather than clay.

The intimate association of underclay and coal in strata of Carboniferous age has resulted in considerable study of underclay. Theories as to origin generally are divided into two groups—one which considers underclay beds to be ancient soils and the other which considers them subaqueous clay deposits.

For many years the generally accepted concept was that underclay beds were soils on which the coal-forming plants of a peat swamp grew. The principal bases for this opinion were the almost universal occurrence of underclay beneath coal of Carboniferous age and the not uncommon occurrence of root markings or *stigmaria* in the clay.

Stout (Stout and others, 1923, p. 541–545) believed underclay to be accumulations of terrigenous sediments and minerals from plant ash and that the beds represent periods of swamp growth preceding actual coal-swamp development and during which the plant remains were destroyed by oxidation. The general concept of underclay as soil formed by leaching and oxidizing ground waters during a period of prolonged exposure to weathering was developed further by Weller (1930, p. 121), who stated that "* * * all zones of a characteristic poorly drained weathering profile * * *" had been observed in certain underclay beds in Illinois.

Although the depositional or sedimentary concept has developed largely in the last quarter of a century, Gresley (1894) described features of the "slate binders" or clay partings in the Pittsburgh coal bed that suggest a sedimentary origin. He was impressed by the remarkable uniformity of thickness, lithologic character, and spacing of the "twin-partings" near the center of the coal—features that persist over an area of approximately 15,000 square miles. He felt that this implied transport and deposition by water. He further pointed out the "mottled" appearance of these partings and interpreted it as a result of the clastic nature of the clay, accentuated perhaps by some interaction between particles after deposition. It has already been noted in the section on stratigraphy that, in parts of western Belmont County, the underclay of the Pittsburgh coal possesses a mottled or clastic appearance—apparently similar to that described by Gresley. As to the lithologic character of the underclay beneath the Pittsburgh coal, Gresley (1894, p. 364) described it as a calcareous shale containing numerous remains of an aquatic fauna. Except for the fauna, his description can be applied to the Pittsburgh underclay in many parts of Belmont County.

Improved optical methods and X-ray techniques in the study of clays in recent years has increased knowledge of the properties and genesis of clay minerals and has made possible the recognition of some of the physicochemical conditions responsible for the alteration of certain minerals to clays in place and also during transport and at the site of deposition. Likewise, conditions that tend to preserve or protect clay minerals from further alteration after deposition can be postulated. Using optical and X-ray criteria in their study of the petrology of the Pennsylvanian underclays of Illinois, Grim and Allen (1938, p. 1507) concluded that: "Most of the underclays do not appear to have been altered, after accumulation and before burial, by any processes similar to those forming modern soils." They also stated that (p. 1501): "There is no indication of any vertical variation due to long-continued selective weathering." They believed that Illinois underclays formed as subaqueous deposits with enough temporary exposure after deposition to allow some vertical redistribution of calcite, organic material, and limonite but not enough for the alteration of the clay minerals. In a similar but much more extensive study that included the Appalachian, Illinois, and Midcontinent basins, Schultz (1958) paid particular attention to the distribution and interlayering within underclays of the various clay minerals—illite, montmorillonite, kaolinite—as well as quartz, chloritic minerals, and feldspar. He found not only that feldspar does not decrease nor kaolinite increase in amount toward the top of the profile, as would be expected if intensive weathering had taken place, but that chlorite, a mineral easily destroyed by weathering, occurs in the upper part of many underclays. Schultz concluded that (p. 391):

> The relationships between underclays and coals indicate that the underclays formed before the coals were deposited. Furthermore, lack of a soil profile similar to modern soils and similarity of the mineralogy of all rock types below the coals indicate that underclay materials are essentially as they were transported into the basin.

The general problem of the origin of underclay is beyond the scope of this discussion of the geology of Belmont County; however, in Belmont County, field observations show a marked gradational relation between underclay and underlying rocks regardless of whether those rocks are limestone or siltstone. This type of gradation would be expected to develop under conditions of sedimentation as a result of a gradual change in the nature of sediments entering the basin. Furthermore, sedimentary structural features, such as thin lenses of limestone or siltstone, are present in the underclay beds but *stigmaria* and tree stumps are not common. Most of the underclay beds of Belmont County, therefore, are believed to be sedimentary deposits and not ancient soils.

The coal beds represent periods when there were extensive swamps in which tremendous quantities of dead plant debris were preserved in very shallow water in a reducing environment. As living organisms, the plants were highly susceptible to changes in water level and to changes in the amount of sediment entering the basin. The geographic distribution of a coal bed, its thickness, its purity, and its relation to associated rocks, therefore, are excellent indicators of both the paleogeography and the sedimentary processes of a particular period.

Coal beds of the Monongahela in Belmont County have several features that show the influence of environment upon the swamp: in general the beds thin toward the west and toward the southwest, most of them are benched, and most have a higher ash content and lower heating value in the western part of the county.

The thickness of most coal beds varies from place to place. If the coal is autochthonous the variation in thickness may be attributed either to: (1) more abundant plant growth in some parts of the swamp than in others, or to (2) better preservation of the plant debris at some places. Actually, both factors probably influenced coal formation to some degree. The significant feature of most of the Monongahela coals is that they thin westward and southwestward across a deltaic lobe. Figure 28 (parts *A–F*) contain isopach maps of five of the Monongahela coal beds superimposed on lithofacies maps of the underlying rocks, excluding the underclay. It is apparent from these maps that, in general, the bed is thinnest where the coal overlies massive coarse-grained sandstone that was deposited along a distributary channel. This seems to indicate that, during swamp development and plant growth, the drainage pattern remained unchanged and water continued to enter the swamp through the same passageways. This conclusion is further substantiated by the fact that the thinner coal above the channel sandstone beds contains more impurities than other parts of the bed and also by the fact that the thin parts of the beds are alined approximately parallel to the trend of the underlying channel sandstone. The Sewickley coal bed (fig. 28*D*) and the Waynesburg coal bed (fig. 28*F*) show a marked coincidence of the thinner parts of the bed in the southwestern part of the county with the underlying coarse-grained sandstone. Along the main drainage ways plant growth was probably impaired by

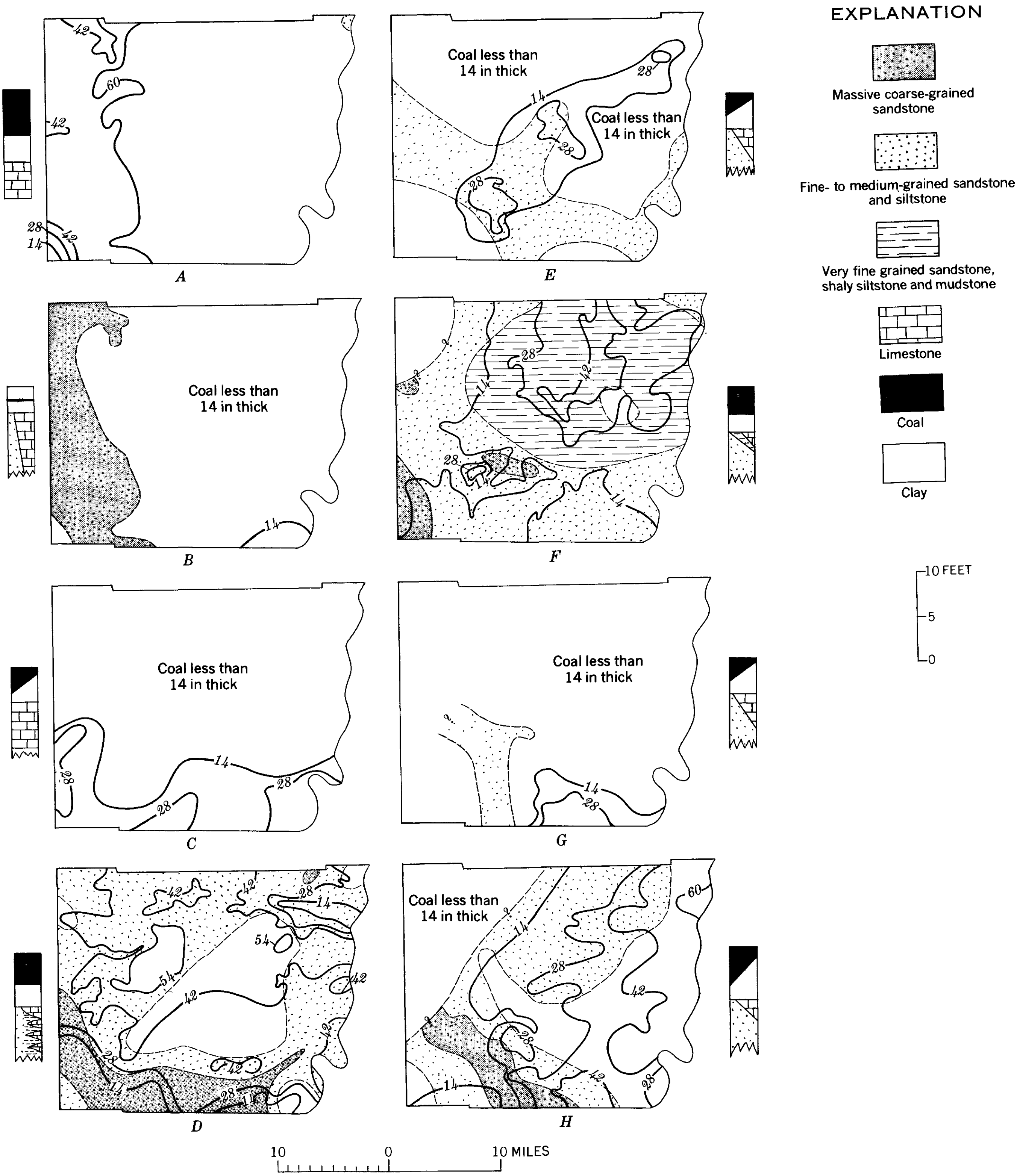

FIGURE 28.—Isopach maps of eight coal beds in the Monongahela formation and Dunkard group superimposed on lithofacies maps of the underlying rocks (excluding underclays) to show the relation of the distribution and thickness, in inches, of the coal to the pre-coal swamp geography. *A*, Pittsburgh coal bed and underlying Upper Pittsburgh limestone member; *B*, Redstone coal bed and underlying Redstone limestone and Pittsburgh sandstone members; *C*, Fishpot coal bed and underlying Fishpot limestone member; *D*, Sewickley coal bed and underlying Fishpot sandstone member; *E*, Uniontown coal bed and underlying Uniontown limestone and McKeefrey siltstone members; *F*, Waynesburg coal bed and underlying Gilboy and Uniontown sandstone members; *G*, Waynesburg "A" coal bed and underlying Mount Morris limestone and Waynesburg sandstone members; *H*, Washington coal bed and underlying Bristol limestone and Mannington sandstone members.

stream currents which also may have periodically removed and rafted some of the dead debris farther out into the swamp.

The thickest parts of the coal bed in general lie above areas where limestone or very fine grained clastic sediments were deposited before swamp development. This characteristic is shown in figure 28, which also shows that the thickest parts of some of the beds form elongate areas oriented northeastward. The general trend of the thickness is believed to approximately parallel the shoreline that lay to the northwest. Except for the Pittsburgh bed, the coals in general thin both eastward toward the basin and westward toward the delta. The Uniontown coal bed shows this feature very clearly (fig. 28*E*). Westward toward the delta and southeastward toward the basin the coal thins appreciably, and in the southeastern corner of the county is entirely absent except for carbonaceous streaks in clay. Locally toward the basin the coal contains a lenticular limestone parting.

The Monongahela coal beds of Belmont County tend to be benched as a result of periodic influxes of appreciable quantities of silt and clay-sized particles that temporarily terminated plant growth. The two most prominently benched coal beds are the Pittsburgh and Sewickley. Figure 29 shows the areal extent of the benches of the Pittsburgh coal bed and their stratigraphic relation, and figure 30 shows the areal extent and stratigraphic relation of the benches of the Sewickley coal.

The benches of the Pittsburgh bed, although markedly different from each other in thickness and purity, are similar in distribution. The interval between the benches never varies more than about 1 foot, indicating a very flat and even-bottomed swamp floor.

The more irregular distribution of the subordinate benches of the Sewickley bed is a result of a more uneven swamp floor. The lower bench is a split from the main or middle bench, which bifurcated locally in

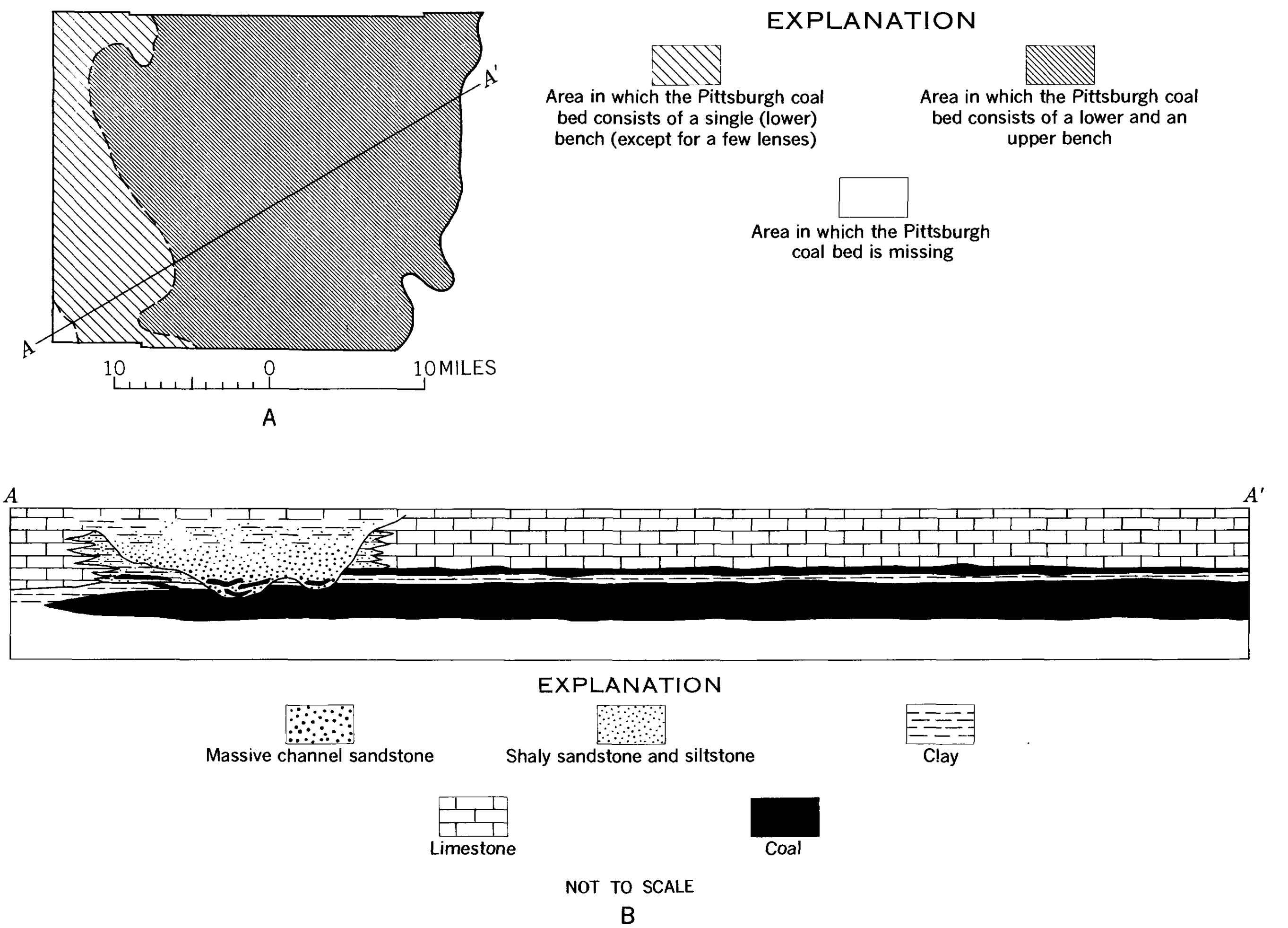

FIGURE 29.—Map of Belmont County and diagrammatic section showing the areal distribution and stratigraphic relation of the two benches of the Pittsburgh coal bed to the overlying rocks.

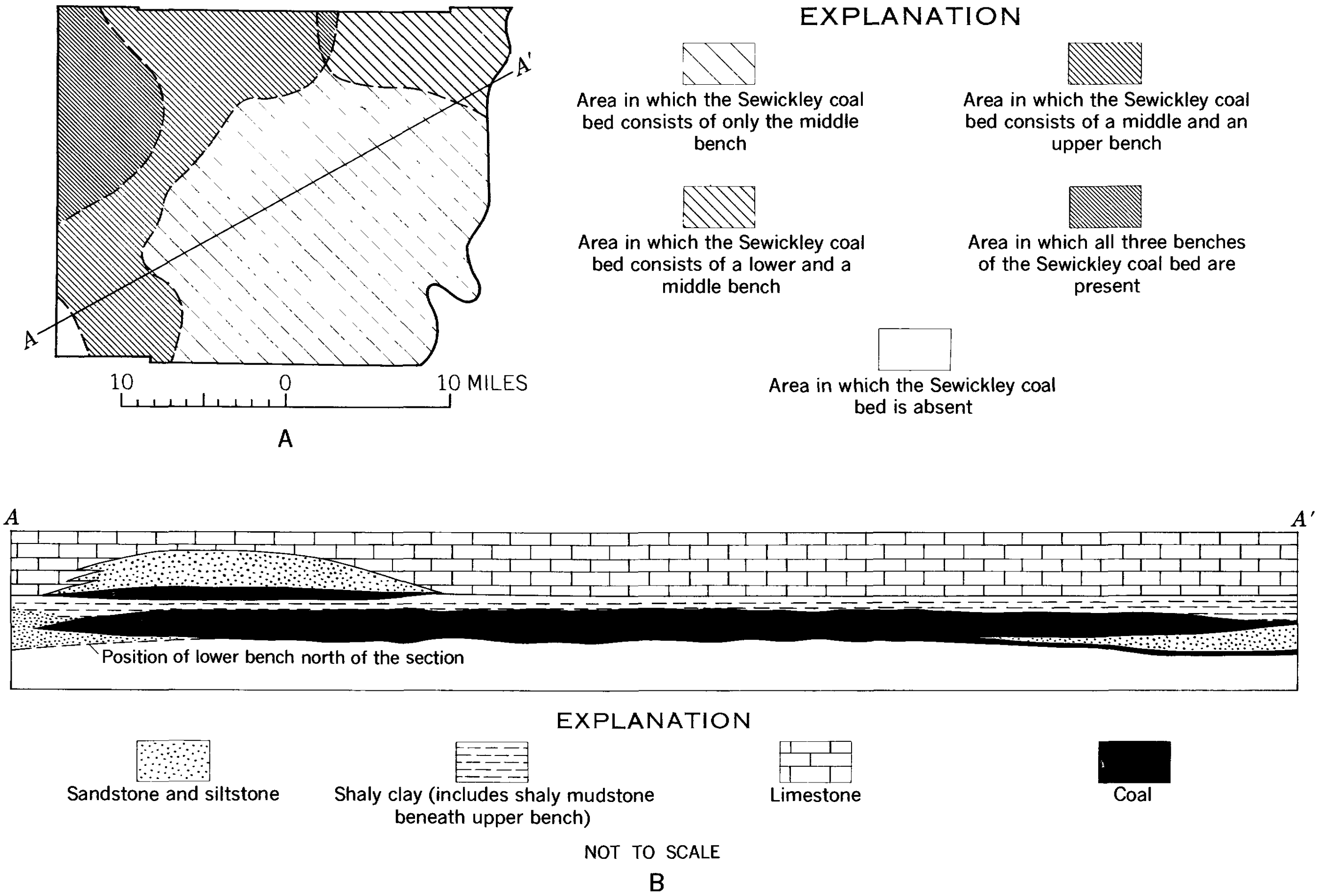

FIGURE 30.—Map of Belmont County and diagrammatic section showing the areal distribution and stratigraphic relation of the three benches of the Sewickley coal bed to the overlying rocks.

slightly deeper parts of the swamp where the influx of silt temporarily halted plant growth. Formation of the main bench was brought to a close by a rise in water level and subsequent influx of sediments. While the depth of water in the eastern two-thirds of Belmont County remained too deep for plant growth, a deltaic lobe formed in the western part, and upon this lobe swamp development was temporarily resumed and the upper bench of coal formed.

Most of the coal in western Belmont County has a higher ash content than coal farther east, because the part of the coal swamp in which it accummulated was near the main delta and received larger quantities of silt.

The chief paleogeographic features of Belmont County were a basin of deposition and a delta that lay to the north and to the west. The general regional relation of the basin to the delta is believed to have been somewhat similar to that depicted by Pepper, de Witt, and Demarest (1954) for certain parts of Early Mississippian time. Figure 31, adapted from Pepper, de Witt, and Demarest, shows the probable paleogeography of the western part of the Appalachian basin during Monongahela time.

A distributary lobe of the main delta extended into western Belmont County during early Monongahela time and the geographic position of this lobe remained relatively unchanged throughout deposition of the Monongahela formation. The position of this lobe is shown in figure 26. Gradually during Monongahela time the delta grew in size, and in late Monongahela time it spread farther eastward across the county.

The source area for most of the Monongahela sediments is believed to have been to the north, but source areas to the east and southeast probably supplied some sediments. The Morningview and Arnoldsburg sandstone members and McKeefrey siltstone member and the sandstone separating the lower and middle benches of the Sewickley coal bed in the eastern part of the county seem to have come in part from the north and in part from the east or southeast. The predominance of fine-grained rocks and lack of conglomerate are a result of deposition some distance from the source areas.

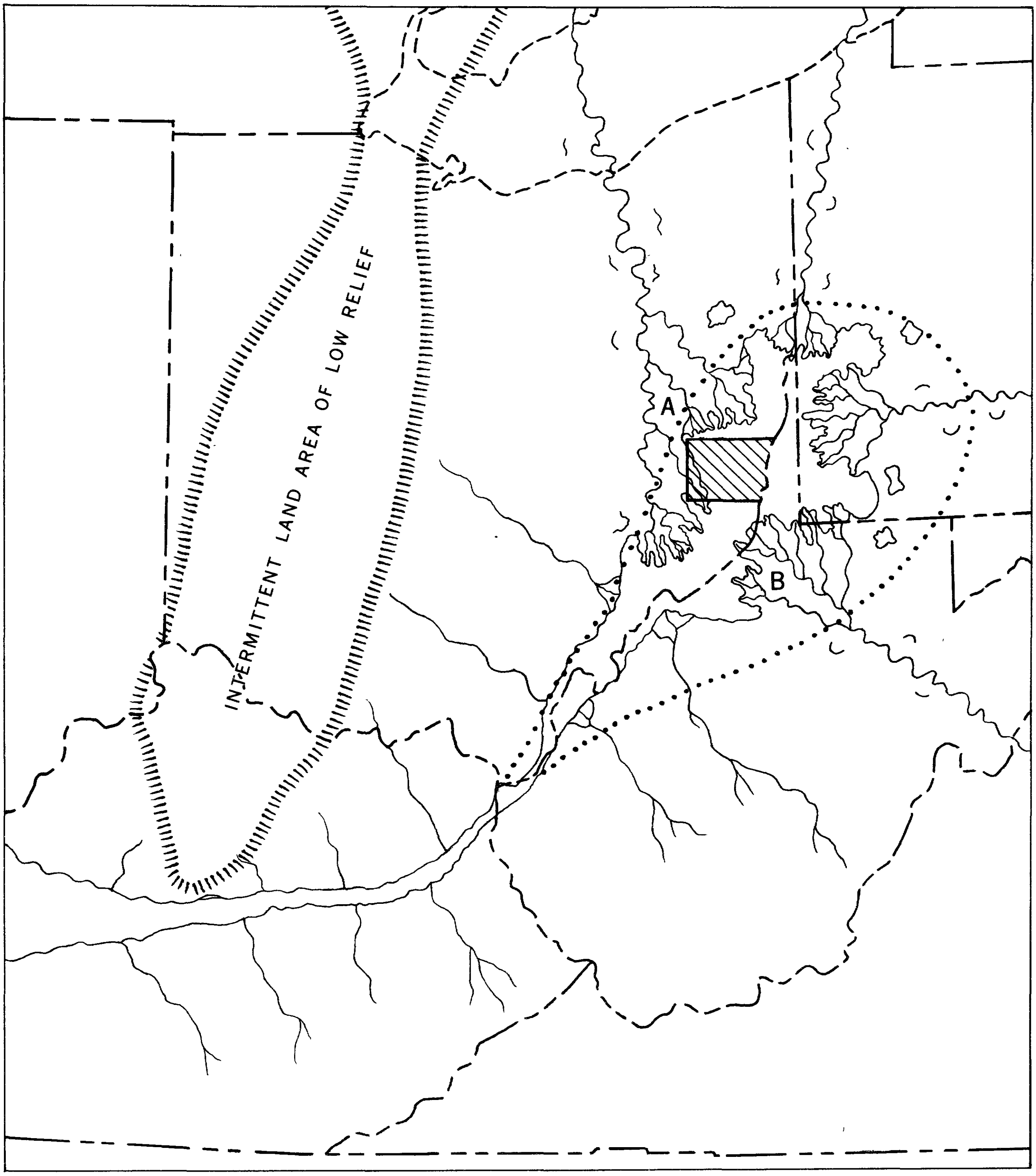

FIGURE 31.—Generalized paleographic map showing the position of Belmont County, Ohio, in relation to the northern Appalachian basin of Monongahela and Dunkard times. Delta A was the main way for sediments entering Belmont County during Monongahela and early Dunkard times and delta B after early Dunkard time. The dotted line marks the approximate outer limits of thick accumulation of limestone during Monongahela time.

The thick lower limestone members in the Monongahela of eastern Belmont County, in contrast to the predominantly clastic rocks, red beds, and poor coal beds of the upper part of the Conemaugh formation, indicate a probable westward shift of the center of the depositional basin during Monongahela time. During late Monongahela time, however, the basin either became shallower and smaller or the center shifted slightly back toward the east.

DUNKARD GROUP

The pattern of sedimentation during early Dunkard time was very similar if not identical to that of late Monongahela time. Thin deltaic sheets of sand were spread southeastward periodically to the easternmost part of Belmont County where they interfingered with limy mud. Twice during early Dunkard time extensive coal swamps developed, and the Washington coal bed, the uppermost of the two coal beds formed during early Dunkard time, is as thick and persistent as most of the Monongahela coal beds.

The configuration of the basin and delta changed somewhat after formation of the Washington coal bed and limy mud was more extensively deposited, especially in the northeastern part of the county. Red beds formed extensively in the county again and thick and persistent coal beds, which are characteristic of Monongahela and early Dunkard times, are absent.

Deposition above the thin and lenticular Jollytown "A" coal bed consisted mainly of fluvial clastic sediments but included also thin red beds and thin impure limestone. These rocks contain very little coal and resemble the rocks in the upper half of the Conemaugh formation.

The sandstone units in the Dunkard group are in general more sheetlike and less lobate than those of the Monongahela formation. The distribution and configuration of the Waynesburg and Mannington sandstone members in the lower part of the formation, however, are similar to the upper sandstone members of the Monongahela, and the Mannington has a prominent channel facies that crosses the southwest part of the county as do the channel facies of both upper and lower sandstone units of the Monongahela. Locally in southwestern Belmont County, the Waynesburg and Mannington sandstone members coalesce. Both of these members interfinger eastward with impure limestone.

The Marietta sandstone members are sheet deposits that thin and become finer grained northward. The sandstone units above the Jollytown "A" coal bed have been removed by erosion over most of the county, so that depositional trends based on thickness and character cannot be determined; but in general, they are more massive in the southeastern part of the county than elsewhere, indicating a pattern of deposition similar to that of the Marietta sandstone members.

All the sandstone units are irregularly bedded, but locally the siltstone facies is even bedded. Current crossbedding, small-scale foreset bedding, cut-and-fill structures, and current ripple marks—all indicative of fluvial action—are present in parts of all the sandstone units.

The limestone units below the Washington coal bed pinch out westward, but those above are in general more extensive. The normal stratigraphic position of the limestone units is just below the coal beds from which they are separated by impure underclay of variable thickness.

Most of the limestone units contain clay and silt impurities in all parts of the county except in the northeastern part where the limestone units between the Washington and Jollytown "A" coal beds are not only purer locally but also thicker. Beds in the lower and upper parts of the units of limestone tend to be nodular and seem to grade into the units of sandstone below and into the underclay above. Locally the beds of limestone are conglomeratic, and in a few places the upper part is brecciated. The limestone units of the Dunkard, which interfinger laterally with deltaic sandstone, are fresh-water deposits that formed in a shallow basin having a relatively flat and even bottom. Their relative impurity is a result of deposition in a general deltaic environment.

With the exception of the Washington bed, coals of the Dunkard group are thin and impure. The two thickest coal beds, the Washington and the Waynesburg "A," are in the lower third of the group. Both thin toward the west and contain several thick clay and mudstone partings, indicating that appreciable quantities of clay and silt were periodically carried into the Washington and Waynesburg "A" coal swamps. As was true of the Monongahela coal beds, the thickness trends of the Washington and Waynesburg "A" coals show a relation to the associated strata. The thickest parts of both beds overlie limestone and fine-grained clastic sediments and both beds thin toward the delta that lay to the northwest. The Washington coal bed is thinnest where it overlies the coarse-grained channel facies of the Mannington sandstone. These features are shown in figure 28, parts *G* and *H*. Throughout the existence of the Washington coal swamp, plant growth was continuous in the northeastern corner of the county, but toward the west and southwest plant growth was interrupted for a time by the deposition of clay and silt. This sheet of clastic rock, which, in places is more than 10 feet thick, separates the bed into two benches. The lower pinches out toward the northwest in the direction of the delta. The relation of the two benches to associated strata is shown in figure 32. The Washington coal swamp had an early stage of plant growth during which the material forming the lower bench was deposited. This was terminated in all except the northeastern part of the county by subsidence and transgression of deeper water over the swamp. The water that flooded the swamp was probably brackish, as indicated by the presence of *Lingula permiana* Stauffer and Schroyer in the clay and silt that gradually filled the basin to the level where plant growth was resumed.

The coal beds above the Washington bed are thin and lenticular. In most places they are only thin carbonaceous bands interbedded with clay. Apparently after formation of the thick and persistent Washington coal, the periods of swamp growth were short and the environment that of a deltaic surface with limited plant growth.

The red beds above the Washington coal bed further indicate a delta upon which intermittent surficial oxidation occurred. The red beds are in part plastic clayey mudstone and in part shale or shaly mudstone. Most of the red beds lie stratigraphically above the coal, but locally they are interbedded with mudstone below the limestone, and in places they take the place of limestone. During periods of aridity and reduced sedimentation, oxidation produced red beds; but when sedimentation was more rapid, much of the sediment was buried before oxidation of the enclosed iron compounds could occur.

The paleogeography of Belmont County during early Dunkard time was very similar to that of late Monongahela time. A depositional basin lay to the east with its margin in the eastern part of the county on the slope of a large delta, which lay to the north and northwest. The lower part of the Dunkard group contains interfingering deposits representing both en-.

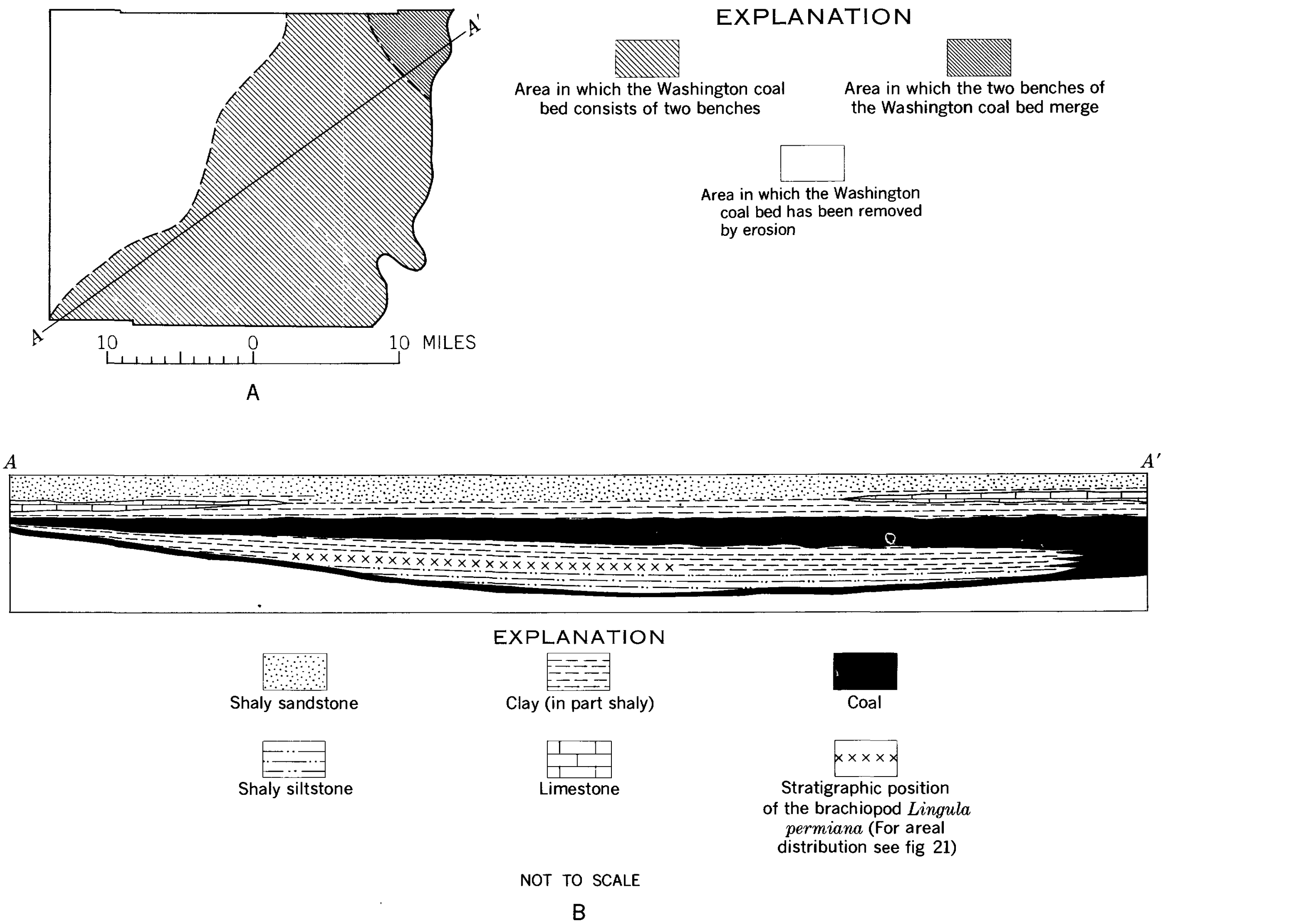

FIGURE 32.—Map of Belmont County and diagrammatic section showing the areal distribution and stratigraphic relation of the two benches of the Washington coal bed to the overlying rocks.

vironments. The distributary channel, which persisted throughout Monongahela time across southwestern Belmont County, was still a prominent feature during early Dunkard time.

After formation of the Washington coal bed, however, the center of the basin apparently shifted westward and thick limestone beds were deposited in the northeastern corner of Belmont County. The westward or northwestward shift in the basin was accompanied by a northwestward migration of deltas from the southeast into the county, as indicated by deltaic sands above the Washington coal that apparently had a source to the south or southeast. Removal of these strata by erosion in western Belmont County precludes determining whether appreciable quantities of sediments continued to come from the north. The Washington coal bed is significant not only because it is the last thick and persistent coal to form, but also because the paleogeography changed after its formation. The northern delta, which was a prominent feature throughout Monongahela and early Dunkard times, apparently became subordinate to a delta that lay to the southeast. The hypothetical position of this delta is shown in figure 31. Inasmuch as multiple provenances are postulated for sediments entering the northern Appalachian basin during Late Pennsylvanian and early Permian times, the sediments forming certain strata in western Belmont County probably came from a different source area than did their correlatives to the east in West Virginia.

ECONOMIC GEOLOGY

COAL

The 15 coal beds that crop out in Belmont County are shown in figure 33 together with the intervals between them. Of these coal beds, the Pittsburgh and Sewickley (Meigs Creek) are now mined commercially and contain the largest quantities of reserves. The Waynesburg and Washington coal beds also contain large reserves but are not mined commercially at present, mainly because they contain relatively large quantities of ash. The Fishpot, Uniontown, and Waynesburg "A" coals are sufficiently thick in places to be minable, but these coals are generally thin and impure over much of the county.

The outcrops of these seven coal beds are shown on the geologic map (pl. 1), and maps showing outcrop and thickness and plates containing diagrammatic sections have been prepared for each bed (pl. 4–26). The other eight coal beds are lenticular, less than 14 inches thick, impure, and cannot be mined.

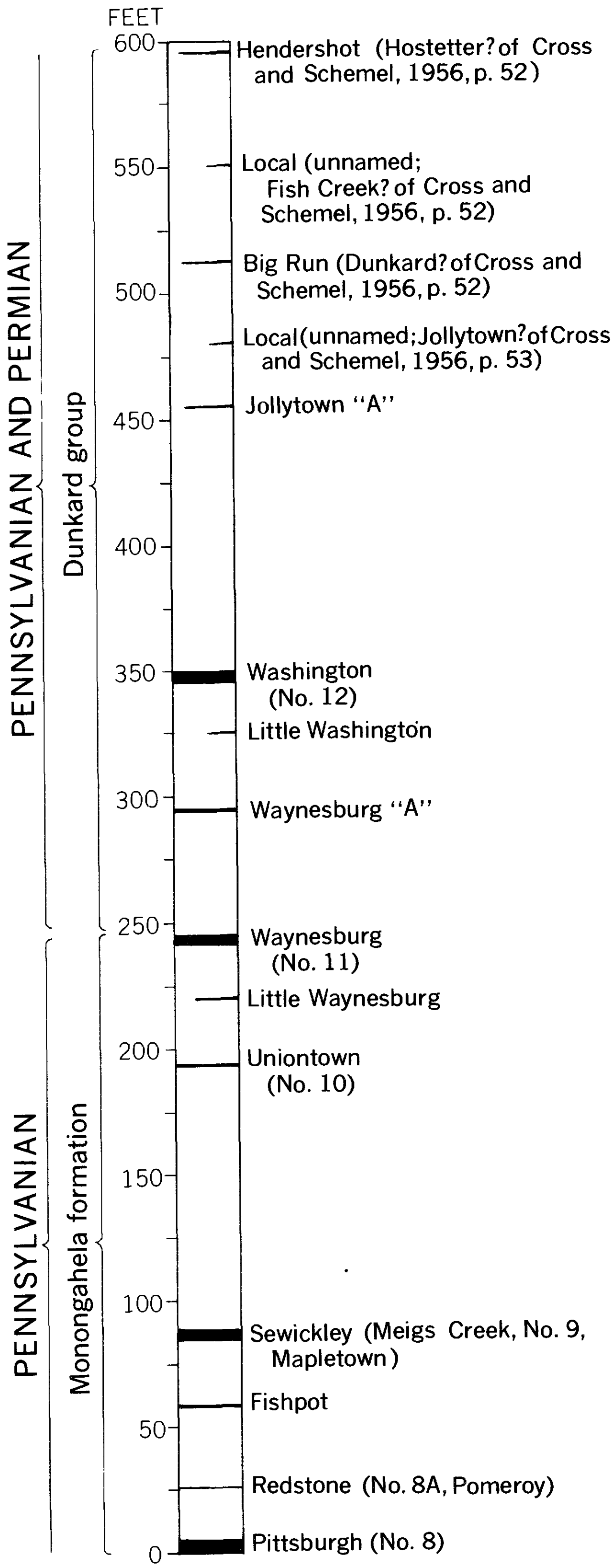

FIGURE 33.—Generalized columnar section showing the coal beds that crop out in Belmont County, Ohio.

METHODS OF PREPARING ESTIMATES OF RESERVES

Any estimate of the coal reserves of an area must be based on assumptions as to thickness, areal extent, correlation of the coal beds, and weight of the coals. The value of an estimate depends on understanding the definitions and procedures used in its preparation. In addition, the usefulness of estimates of coal reserves is increased if they are arranged into categories based on the characteristics of the coal and on the abundance and reliability of the information used in preparing the estimate. The criteria used in preparing the estimate in this report and the categories into which the estimate is divided are described in the following paragraphs.

In the present report the quantities of coal in the ground are described in 12 different categories according to the thickness of the beds, the abundance and reliability of information used in preparing the tonnage estimates, and other purely physical factors, which are timeless in their applicability but which must be integrated with other factors to determine economic availability. Some of these categories contain coal of immediate economic interest; others do not. In this report, therefore, the term "reserves" will be used uniformly to refer to quantities of coal in the ground, regardless of thickness, grade, accessibility, or economic value, and any additional special meaning that is required will be carried by modifying phrases as defined in subsequent paragraphs.

CLASSIFICATION ACCORDING TO CHARACTERISTICS OF THE COAL

Characteristics considered in calculating coal reserves are rank, thickness of beds, and thickness of overburden. Weight of the coal, an essential factor in computing tonnage, is largely a function of rank and ash content.

RANK

American coals are ranked in accordance with the standard classification of the American Society for Testing Materials (table 2). Most of the coal in Belmont County is of high-volatile A bituminous rank. At a few places in western Belmont County, the coal is of high-volatile B bituminous rank.

TABLE 2.—*Classification of coals by rank*

Explanation: FC, fixed carbon; VM, volatile matter; Btu, British thermal units. This classification does not include a few coals which have unusual physical and chemical properties and which come within the limits of fixed carbon or Btu of the high-volatile bituminous and subbituminous ranks. All these coals either contain less than 48 percent dry mineral-matter-free fixed carbon or have more than 15,500 moist mineral-matter-free Btu.

Class	Group	Limits of fixed carbon or Btu mineral-matter-free basis	Requisite physical properties
I. Anthracitic	1. Meta-anthracite	Dry FC, 98 percent or more (dry VM, 2 percent or less)	
	2. Anthracite	Dry FC, 92 percent or more and less than 98 percent (dry VM, 8 percent or less and more than 2 percent).	
	3. Semianthracite	Dry FC, 86 percent or more and less than 92 percent (dry VM, 14 percent or less and more than 8 percent).	Nonagglomerating.[1]
II. Bituminous [2]	1. Low-volatile bituminous coal	Dry FC, 78 percent or more and less than 86 percent (dry VM, 22 percent or less and more than 14 percent).	
	2. Medium-volatile bituminous coal	Dry FC, 69 percent or more and less than 78 percent (dry VM, 31 percent or less and more than 22 percent).	
	3. High-volatile A bituminous coal	Dry FC, less than 69 percent (dry VM, more than 31 percent); and moist [3] Btu, 14,000 [4] or more.	
	4. High-volatile B bituminous coal	Moist [3] Btu, 13,000 or more and less than 14,000 [4]	
	5. High-volatile C bituminous coal	Moist Btu, 11,000 or more and less than 13,000 [4]	Either agglomerating or nonweathering.[5]
III. Subbituminous	1. Subbituminous A coal	Moist Btu, 11,000 or more and less than 13,000 [4]	Both weathering and nonagglomerating.
	2. Subbituminous B coal	Moist Btu, 9,500 or more and less shan 11,000 [4]	
	3. Subbituminous C coal	Moist Btu, 8,300 or more and less than 9,500 [4]	
IV. Lignitic	1. Lignite	Moist Btu, less than 8,300	Consolidated.
	2. Brown coal	Moist Btu, less than 8,300	Unconsolidated.

[1] If agglomerating, classify in low-volatile group of the bituminous class.
[2] It is recognized that there may be noncaking varieties in each group of the bituminous class.
[3] Moist Btu refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.
[4] Coals having 69 percent or more fixed carbon on the dry mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.
[5] There are three varieties of coal in the high-volatile C bituminous coal group, namely, variety 1, agglomerating and nonweathering; variety 2, agglomerating and weathering; variety 3, nonagglomerating and nonweathering.

WEIGHT

The average weight of bituminous coal of low to medium ash content, as determined by many specific gravity determinations, is about 1,800 tons per acre-foot (Averitt, Berryhill, and Taylor, 1953, p. 7). This weight was used in calculating the reserves of coal in Belmont County.

THICKNESS

In order to provide as much information as possible on the distribution of reserves, estimates prepared by the U.S. Geological Survey are divided into three categories according to thickness of the coal. These categories are termed "thin," "intermediate," and "thick." "Thin" coal is 14 to 28 inches thick; "intermediate" coal is 28 to 42 inches thick; and "thick" coal is more than 42 inches thick. These thickness categories are based primarily on the following mining practices: 14 inches is approximately the minimum thickness of coal mined by hand; 28 inches is the minimum generally considered for machine mining and hand loading; and 42 inches is the approximate minimum thickness required at present for completely mechanized

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mining. Results of this study show that throughout much of Belmont County, the Pittsburgh coal bed is either just a little more or less than 60 inches thick. Therefore, another category was added in order to show the reserves of coal more than 60 inches thick in the Pittsburgh bed in Belmont County.

OVERBURDEN

The usual procedure followed by the U.S. Geological Survey in classifying reserves is to separate the coal into categories based on the depth of burial or amount of overburden. The thicknesses of overburden considered are: surface to 1,000 feet; 1,000 to 2,000 feet; and 2,000 to 3,000 feet. In Belmont County, however, all the known commercial coals lie at depths of less than 1,000 feet, so no overburden breakdown is included in the tables showing reserves. In fact, the Pittsburgh, Sewickley, Waynesburg, and Washington coal beds are under so little overburden in many places that they can be mined by stripping methods. The general range of overburden for each of these beds is as follows: Pittsburgh coal, 0 to a maximum of about 600–665 feet in the central and southeastern part; Sewickley, 0 to a maximum of about 575 feet; Waynesburg, 0 to about 445 feet; Washington, 0 to about 345 feet. Maximum depth of the Allegheny formation coal beds, which do not crop out, is probably about 1,350 feet for the Lower Kittanning bed and about 1,115 feet for the Lower Freeport bed. Along Trail Run in northwestern Belmont County and along Deep Run at the northeastern corner of the county, the Lower Freeport coal, if present, probably does not lie much more than 300–315 feet below the surface.

CLASSIFICATION ACCORDING TO ABUNDANCE AND RELIABILITY OF DATA

According to the abundance and reliability of data upon which the estimates are based, estimates of coal reserves prepared by the U.S. Geological Survey are divided into three categories termed "measured," "indicated," and "inferred."

Measured reserves.—Measured reserves are those for which tonnage is computed from the thickness of the coal beds revealed in outcrops, trenches or prospect openings, mine workings, and drill holes. Points of observation are so closely spaced and thickness and extent of coal so well defined that computed tonnage is considered to be within 20 percent of true tonnage. Although spacing of points of observation necessary to demonstrate continuity of coal varies in different regions according to character of the coal beds and geologic structure, points of observation are, in general, about half a mile apart.

Indicated reserves.—Indicated reserves are those for which tonnage is computed partly from specific measurements and partly from assumptions based on available data and on geologic evidence. In general, points of observation are about 1 mile apart, but they may be as as much as 1½ miles apart in beds of known geologic continuity.

Inferred reserves.—Inferred reserves are those for which quantitative estimates are based on a broad knowledge of the character of the bed or region and for which there are few, if any, measurements. Estimates are based on an assumed continuity of coal bed for which there is good geologic evidence. In general, inferred coal lies more than 2 miles from points of observed thickness.

DISTINCTION BETWEEN ORIGINAL, REMAINING, AND RECOVERABLE RESERVES

Coal reserves are further classified as original, remaining, and recoverable. Original reserves are reserves that were present in the ground before mining began. Remaining reserves are reserves in the ground as of the date of appraisal. For large areas such as States, these figures are generally obtained by subtracting recorded production plus an allowance for mining losses from original reserves. However, in estimating reserves of coal in Belmont County, sufficient mine information was available to plot the extent of both the coal bed and the mined-out areas and to measure the remaining coal and the mined-out areas separately. Accuracy of measurements of the mined-out areas is believed to be such that calculated tonnages for these areas are within 20 percent of the actual tonnages, and may, therefore, be placed in the measured category.

Recoverable reserves are reserves in the ground, as of the date of appraisal, that can actually be produced in the future. The amount of these reserves is obtained by subtracting estimated future losses in mining from remaining reserves. Recoverability of coal from any property depends on the method of mining, the geologic structure, the thickness and nature of the roof rock, the thickness and quality of the coal, and other engineering and geologic factors. Consequently, the percentage of recoverability differs markedly from one area to another. Nevertheless, the average, long-term recoverability in Belmont County can be calculated from data at hand.

Reported coal production in Belmont County from 1816 to January 1, 1953, is 399,178,668 tons. The total coal originally present in the mined-out areas as calculated from mine maps amounts to 844 million tons. The reported coal production divided by the amount of coal originally present in the mined-out areas gives an average recoverability factor of 47 percent in Belmont County, which is comparable to the frequently assumed nationwide average recoverability of 50 percent (Averitt, Berryhill, and Taylor, 1953, p. 12). Assuming 47 percent recoverability, the recoverable reserves of coal in Belmont County, as of January 1, 1953, is estimated to be 2,051 million tons. Technological advances that result in greater efficiency in mining will doubtlessly increase the percentage of recoverability.

The recent and current increase in strip mining, where under favorable conditions as much as 90 percent of the coal originally in the ground may be recovered (Koenig, 1950, p. 28), is increasing the average percentage of recoverability. This increase can be observed by comparing the percentages of recoverability from the Pittsburgh and Sewickley coal beds in Belmont County. The recoverability factor is 47 percent for the Pittsburgh bed and 70 percent for the Sewickley bed. The reason for this difference is that most of the coal produced to date from the Pittsburgh bed has come mainly from underground mines, whereas about 50 percent of the production from the Sewickley bed has come from strip mines. The production from the Sewickley bed has been so small in comparison with production from the Pittsburgh bed, however, that the higher percentage of recoverability for the Sewickley bed has had little effect to date on the recoverability figure for the county as a whole.

METHODS OF RECORDING DATA AND MAKING CALCULATIONS

Exposures of coal beds were located in the field by planetable and alidade, surveying altimeter, or hand level and tape, and the locations were plotted on topographic maps of Belmont County. The lateral extent of the coal was determined from the outcrop, drill-hole, and mine data. Thickness lines were drawn on the basis of plotted information, dividing the coal into four categories: 14 to 28 inches, 28 to 42 inches, 42 to 60 inches, and more than 60 inches. Other lines were drawn, dividing the bed into measured, indicated and inferred categories on the basis of spacing of the data.

Within each thickness category shown on plates 4, 9, 10, 15, 20, 25, a weighted average thickness for the coal was obtained by using all measurements from outcrops, mines, and drill holes. The figures used are the thicknesses of the coal minus partings more than three-eighths of an inch thick, except where the partings exceed half the total thickness of the coal bed. Where more than half of the coal bed or layer is made up of partings, the coal is not considered to be commercially minable and, therefore, is excluded from the estimate.

Areas thus outlined were measured with a planimeter to obtain the acreage underlain by coal in the different categories of thickness and reliability. The tonnage was calculated by multiplying the number of acres by a weighted average thickness of the coal to the nearest tenth of a foot, by 1,800 (the assumed weight of bituminous coal in tons per acre-foot). The figures were tabulated by townships and by beds and placed in categories according to thickness of coal and reliability of information (tables 3 to 10). All figures were rounded to the nearest 100,000 tons, but for convenience in reading are recorded in the tables in millions of tons.

SUMMARY OF COAL RESERVES

Original reserves of coal in Belmont County total 5,668 million tons, of which 1,584 million tons is classified as measured, 3,213 million tons as indicated, and 870 million tons as inferred. Included in the 1,584 million tons of measured coal is 844 million tons of coal mined out and lost in mining, leaving remaining measured reserves of 740 million tons as of January 1, 1953.

Remaining measured reserves of 740 million tons plus indicated reserves of 3,213 million tons and inferred reserves of 870 million tons give total remaining reserves of 4,823 million tons as of January 1, 1953.

The distribution of these reserves in the 16 townships in Belmont County is given in table 3.

PITTSBURGH COAL BED

Original reserves of coal in the Pittsburgh bed total 2,757 million tons, of which 1,335 million tons is classified as measured and 1,422 million tons as indicated (table 4). Included in the 1,335 million tons of measured coal is 827 million tons of coal mined out and lost in mining, leaving remaining measured reserves of 508 million tons as of January 1, 1953. Figure 34 shows the areas in which the Pittsburgh coal bed has been largely mined out.

TABLE 3.—*Estimated reserves of coal (not including subsurface coal beds), in millions of short tons, in Belmont County, by township*

Township	Original measured reserves					Original indicated reserves					Original inferred reserves					Total original reserves	Total mined and lost in mining as of Jan. 1, 1953	Total remaining reserves as of Jan. 1, 1953
	Thickness of beds, in inches				Total	Thickness of beds, in inches				Total	Thickness of beds, in inches				Total			
	14 to 28	28 to 42	42 to 60	More than 60		14 to 28	28 to 42	42 to 60	More than 60		14 to 28	28 to 42	42 to 60	More than 60				
Colerain	-------	4.8	1.3	137.2	143.3	14.3	58.4	9.5	-------	82.2	4.1	1.6	7.9	-------	13.6	239.1	104.2	134.9
Flushing	-------	15.7	54.5	-------	70.2	1.9	4.8	49.9	-------	56.6	-------	-------	-------	-------	-------	126.8	14.1	112.7
Goshen	0.3	5.4	28.8	1.5	36.0	39.0	55.0	156.0	120.7	370.7	32.9	23.4	4.8	-------	61.1	467.8	4.9	462.9
Kirkwood	-------	4.8	23.0	-------	27.8	-------	10.4	88.7	-------	99.1	-------	-------	-------	-------	-------	126.9	1.7	125.2
Mead	.5	3.2	4.6	161.0	169.3	39.8	97.0	15.6	30.2	182.6	7.3	34.1	40.2	-------	81.6	433.5	126.9	306.6
Pease	1.2	2.0	1.0	145.5	149.7	21.4	48.7	12.7	-------	82.8	9.4	3.9	24.3	15.8	53.4	285.9	82.6	203.3
Pultney	-------	3.4	7.7	143.8	154.9	14.6	63.7	48.1	-------	126.4	8.6	-------	48.2	-------	56.8	338.1	118.1	220.0
Richland	.1	5.4	44.8	219.5	269.8	9.2	85.9	253.9	100.2	449.2	47.4	32.2	18.6	-------	98.2	817.2	170.1	647.1
Smith	.7	3.3	37.0	-------	41.0	9.8	107.6	100.1	138.8	356.3	63.0	59.3	16.0	-------	138.3	535.6	11.4	524.2
Somerset	.6	1.0	7.4	-------	9.0	51.6	26.7	125.6	-------	203.9	1.6	-------	-------	-------	1.6	214.5	.1	214.4
Union	.2	5.0	96.3	2.0	103.5	13.3	10.2	220.8	-------	244.3	-------	-------	-------	-------	-------	347.8	38.0	309.8
Warren	.3	7.8	36.9	-------	45.0	6.2	44.0	162.7	-------	212.9	-------	-------	-------	-------	-------	257.9	6.4	251.5
Washington	.4	4.3	7.5	27.0	39.2	28.4	80.2	3.8	194.4	306.8	80.5	41.8	17.7	-------	146.0	492.0	5.2	486.8
Wayne	.7	8.1	3.6	.7	13.1	36.5	57.9	66.9	112.7	274.0	39.1	67.1	2.5	-------	108.7	395.8	.1	395.7
Wheeling	-------	6.6	174.1	-------	179.7	.4	4.8	52.5	-------	57.7	-------	-------	-------	-------	-------	237.4	73.1	164.3
York	.2	5.8	-------	126.9	132.9	26.0	44.6	6.2	31.1	107.9	22.3	55.7	32.5	-------	110.5	351.3	87.1	264.2
Total	5.2	86.6	528.5	965.1	1,584.4	312.4	799.9	1,373.0	728.1	3,213.4	316.2	325.1	212.7	15.8	869.8	5,667.6	844.0	4,823.6

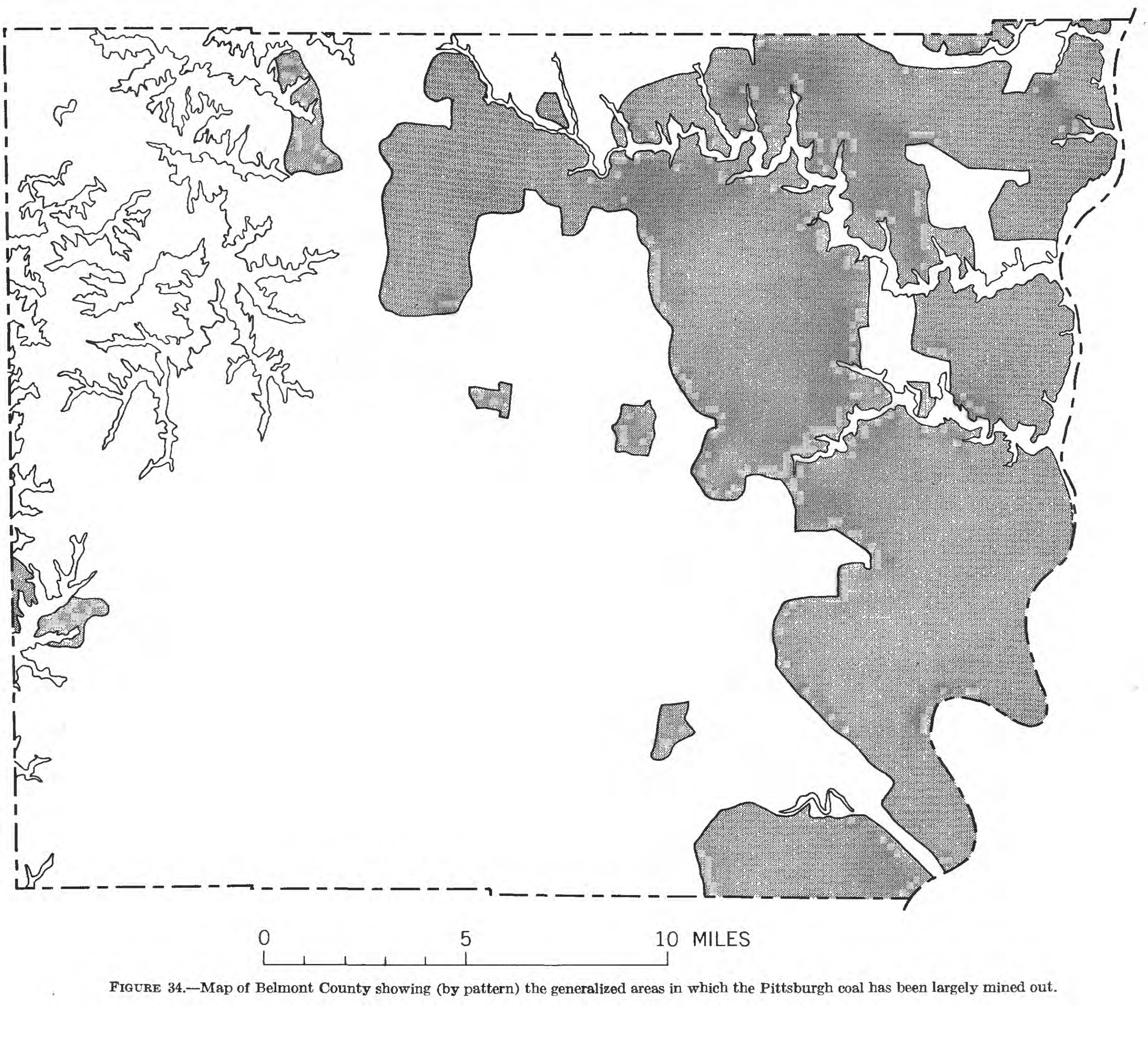

FIGURE 34.—Map of Belmont County showing (by pattern) the generalized areas in which the Pittsburgh coal has been largely mined out.

TABLE 4.—*Estimated reserves of coal, in millions of short tons, in the Pittsburgh bed in Belmont County, by township*

[All tonnage estimates based on lower bench; upper bench or "roof coal" excluded from estimate]

Township	Original measured reserves				Original indicated reserves					Total original reserves	Total mined and lost in mining as of Jan. 1, 1953	Total remaining reserves as of Jan. 1, 1953
	Thickness of beds, in inches			Total	Thickness of beds, in inches				Total			
	28 to 42	42 to 60	More than 60		14 to 28	28 to 42	42 to 60	More than 60				
Colerain			137.2	137.2						137.2	104.2	33.0
Flushing	13.8	32.3		46.1		3.7	33.7		37.4	83.5	8.9	74.6
Goshen	.4	5.5	1.5	7.4		4.7	67.5	120.7	192.9	200.3	1.3	199.0
Kirkwood	.6	19.3		19.9		4.5	69.5		74.0	93.9	1.6	92.3
Mead			161.0	161.0				30.2	30.2	191.2	126.9	64.3
Pease			145.5	145.5						·145.5	82.6	62.9
Pultney			143.8	143.8						143.8	118.1	25.7
Richland		14.2	219.5	233.7			5.8	100.2	106.0	339.7	168.0	171.7
Smith		31.0		31.0			43.7	138.8	182.5	213.5	11.4	202.1
Somerset		6.6		6.6	4.2	6.2	124.1		134.5	141.1	.1	141.0
Union		79.0	2.0	81.0			109.4		109.4	190.4	37.1	153.3
Warren		28.9		28.9			124.5		124.5	153.4	6.0	147.4
Washington			27.0	27.0				194.4	194.4	221.4	5.2	216.2
Wayne	.4		.7	1.1		14.9	63.3	112.7	190.9	192.0		192.0
Wheeling		137.7		137.7			13.9		13.9	151.6	68.2	83.4
York			126.9	126.9				31.1	31.1	158.0	87.1	70.9
Total	15.2	354.5	965.1	1,334.8	4.2	34.0	655.4	728.1	1,421.7	2,756.5	826.7	1,929.8

Remaining measured reserves of 508 million tons plus the indicated reserves of 1,422 million tons give total remaining reserves of 1,930 million tons as of January 1, 1953.

FISHPOT COAL BED

Original reserves of coal in the Fishpot coal bed total 276 million tons, all classified as inferred (table 5).

Mining of the Fishpot coal bed has been limited to a very small production for home use. Remaining reserves, therefore, are virtually the same as original reserves.

TABLE 5.—*Estimated reserves of coal, in millions of short tons, in the Fishpot bed in Belmont County, by township*

[No original, measured, or indicated reserves in this bed]

Township	Original inferred reserves			Total original reserves	Total remaining reserves as of Jan. 1, 1953
	Thickness of beds, in inches				
	14 to 28	28 to 42	Total		
Goshen	0.7		0.7	0.7	0.7
Mead	6.7	0.8	7.5	7.5	7.5
Smith	9.7		9.7	9.7	9.7
Somerset	38.2	4.6	42.8	42.8	42.8
Warren	19.1	4.5	23.6	23.6	23.6
Washington	61.2	13.3	74.5	74.5	74.5
Wayne	18.1	40.5	58.6	58.6	58.6
York	13.2	45.6	58.8	58.8	58.8
Total	166.9	109.3	276.2	276.2	276.2

SEWICKLEY COAL BED

Original reserves of coal in the Sewickley bed total 1,469 million tons, of which 219 million tons is classified as measured and 1,250 million tons as indicated (table 6). Included in the 219 million tons of measured coal is 17 million tons of coal mined out and lost in mining, leaving remaining measured reserves of 202 million tons as of January 1, 1953.

TABLE 6.—*Estimated reserves of coal, in millions of short tons, in the Sewickley bed in Belmont County, by township*

[All tonnage estimates based on middle bench; upper and lower benches excluded from estimate. No original inferred reserves]

Township	Original measured reserves				Original indicated reserves				Total original reserves	Total mined and lost in mining as of Jan. 1, 1953	Total remaining reserves as of Jan. 1, 1953
	Thickness of beds, in inches			Total	Thickness of beds, in inches			Total			
	14 to 28	28 to 42	42 to 60		14 to 28	28 to 42	42 to 60				
Colerain		4.5	1.0	5.5	9.9	30.8	7.3	48.0	53.5		53.5
Flushing		1.9	22.2	24.1		1.1	16.2	17.3	41.4	5.2	36.2
Goshen		4.1	23.3	27.4		41.6	88.5	130.1	157.5	3.6	153.9
Kirkwood		4.2	3.7	7.9		5.9	19.2	25.1	33.0	.1	32.9
Mead		2.6	4.0	6.6		89.4	13.5	102.9	109.5		109.5
Pease	1.2	.9	.6	2.7	17.1	10.2	11.1	38.4	41.1		41.1
Pultney	2.6	7.6		10.2		34.5	47.6	82.1	92.3		92.3
Richland		3.3	21.4	24.7		18.8	198.8	217.6	242.3	2.1	240.2
Smith		.5	3.0	3.5		84.4	49.1	133.5	137.0		137.0
Somerset		.2	.8	1.0	22.2	9.2	1.5	32.9	33.9		33.9
Union		4.4	17.3	21.7		3.2	111.4	114.6	136.3	.9	135.4
Warren	.2	7.8	8.0	16.0	2.4	44.0	38.2	84.6	100.6	.4	100.2
Washington		3.3	7.5	10.8	9.6	80.2	3.8	93.6	104.4		104.4
Wayne		6.2	3.6	9.8	11.1	21.5	3.6	36.2	46.0	.1	45.9
Wheeling		6.5	35.1	41.6		2.2	36.4	38.6	80.2	4.9	75.3
York		5.5		5.5	7.1	41.7	6.2	55.0	60.5		60.5
Total	4.0	63.5	151.5	219.0	79.4	518.7	652.4	1,250.5	1,469.5	17.3	1,452.2

Remaining measured reserves of 202 million tons plus the indicated reserves of 1,250 million tons give total remaining reserves of 1,452 million tons as of January 1, 1953.

UNIONTOWN COAL BED

Original reserves of coal in the Uniontown bed total 216 million tons, all classified as inferred (table 7). Mining of the Uniontown coal bed has been limited to small production for home use, and remaining reserves are, therefore, virtually the same as original reserves.

TABLE 7.—*Estimated reserves of coal, in millions of short tons, in the Uniontown bed in Belmont County, by township*

[No original measured or indicated reserves in this bed]

Township	Original inferred reserves				Total original reserves	Total remaining reserves as of Jan. 1, 1953
	Thickness of beds in inches			Total		
	14 to 28	28 to 42	42 to 60			
Colerain	4.1			4.1	4.1	4.1
Goshen	22.7	19.4	2.9	45.0	45.0	45.0
Mead	.6			.6	.6	.6
Pease	9.4	3.9		13.3	13.3	13.3
Pultney	8.6			8.6	8.6	8.6
Richland	45.9	9.6		55.5	55.5	55.5
Smith	36.4	20.2		56.6	56.6	56.6
Washington	2.2	3.8		6.0	6.0	6.0
Wayne	8.8	17.6		26.4	26.4	26.4
Total	138.7	74.5	2.9	216.1	216.1	216.1

WAYNESBURG COAL BED

Original reserves of coal in the Waynesburg bed total 581 million tons, of which 31 million tons is classified as measured, 541 million tons as indicated and 9 million tons as inferred (table 8). The amount of coal mined from the Waynesburg bed is negligible as mining has been limited to very small production for home use. Remaining reserves, therefore, can be considered to be the same as original reserves, and total 581 million tons

TABLE 8.—*Estimated reserves of coal, in millions of short tons, in the Waynesburg bed in Belmont County, by township*

Township	Original measured reserves				Original indicated reserves				Original inferred reserves; beds 14 to 28 in. thick	Total original reserves	Total remaining reserves as as Jan. 1, 1953
	Thickness of beds, in inches			Total	Thickness of beds, in inches			Total			
	14 to 28	28 to 42	42 to 60		14 to 28	28 to 42	42 to 60				
Colerain		0.3	0.3	0.6	4.4	27.6	2.2	34.2		34.8	34.8
Flushing					1.9			1.9		1.9	1.9
Goshen	0.3	.9		1.2	39.0	8.7		47.7	1.4	50.3	50.3
Mead	.5	.6	.6	1.7	39.8	7.6	2.1	49.5		51.2	51.2
Pease		1.1	.4	1.5	4.3	38.5	1.6	44.4		45.9	45.9
Pultney		.8	.1	.9	14.6	29.2	.5	44.3		45.2	45.2
Richland	.1	2.1	9.2	11.4	9.2	67.1	49.3	125.6		137.0	137.0
Smith	.7	2.8	3.0	6.5	9.8	23.2	7.3	40.3	5.4	52.2	52.2
Somerset	.6	.8		1.4	25.2	11.3		36.5		37.9	37.9
Union	.2	.6		.8	13.3	7.0		20.3		21.1	21.1
Warren	.1			.1	3.8			3.8		3.9	3.9
Washington	.4	1.0		1.4	18.8			18.8		20.2	20.2
Wayne	.7	1.5		2.2	25.4	21.5		46.9	2.6	51.7	51.7
Wheeling	.1	.3		.4	.4	2.6	2.2	5.2		5.6	5.6
York	.2	.3		.5	18.9	2.9		21.8		22.3	22.3
Total	3.9	13.1	13.6	30.6	228.8	247.2	65.2	541.2	9.4	581.2	581.2

WAYNESBURG "A" COAL BED

Original reserves of coal in the Waynesburg "A" coal bed total 58 million tons, all classified as inferred (table 9). Mining of the Waynesburg "A" coal bed has been limited to a little production for home use. Remaining reserves are, therefore, virtually the same as original reserves.

TABLE 9.—*Estimated reserves of coal, in millions of short tons, in the Waynesburg "A" bed in Belmont County, by township*

[No original measured or indicated reserves in this bed]

Township	Original inferred reserves				Total original reserves	Total remaining reserves as of Jan. 1, 1953
	Thickness of beds, in inches			Total		
	14 to 28	28 to 42	42 to 60			
Washington	10.1	30.7	5.8	46.6	46.6	46.6
York	7.4	3.9		11.3	11.3	11.3
Total	17.5	34.6	5.8	57.9	57.9	57.9

WASHINGTON COAL BED

Original reserves of coal in the Washington bed total 403 million tons, all classified as inferred (table 10). A small amount of coal has been removed from the Washington bed for home use. Remaining reserves, therefore, can be considered to be the same as original reserves, which total 403 million tons.

Reserves of the Washington bed are classified as inferred only because the weathered condition of the bed did not permit as many accurate measurements of the thickness as are required for classification as indicated. The bed is persistent, but because it is near the ridge tops over much of the county, it is highly weathered in most places.

TABLE 10.—*Estimated reserves of coal, in millions of short tons, in the Washington bed in Belmont County, by township*

[No original measured or indicated reserves in this bed]

Township	Original inferred reserves					Total original reserves	Total remaining reserves as of Jan. 1, 1953
	Thickness of beds, in inches						
	14 to 28	28 to 42	42 to 60	More than 60	Total		
Colerain	1.6		7.9		9.5	9.5	9.5
Goshen	8.1	4.0	1.9		14.0	14.0	14.0
Mead		33.3	40.2		73.5	73.5	73.5
Pease			24.3	15.8	40.1	40.1	40.1
Pultney			48.2		48.2	48.2	48.2
Richland	1.5	22.6	18.6		42.7	42.7	42.7
Smith	11.5	39.1	16.0		66.6	66.6	66.6
Somerset	1.6				1.6	1.6	1.6
Washington	7.0	26.8	11.9		45.7	45.7	45.7
Wayne	9.6	9.0	2.5		21.1	21.1	21.1
York	1.7	6.2	32.5		40.4	40.4	40.4
Total	42.6	141.0	204.0	15.8	403.4	403.4	403.4

SUBSURFACE COAL BEDS

Elsewhere in Ohio several commercially minable coal beds occur in the Allegheny formation, which underlies the Conemaugh formation, and which is deeply buried in Belmont County. The Upper Freeport (No. 7), Lower Freeport (No. 6A), Middle Kittanning (No. 6), and Lower Kittanning (No. 5) coal beds in the Allegheny formation crop out in descending order in the counties to the north, northwest, and west of Belmont County.

Examination of several hundred driller's records of wells drilled for oil or gas in Belmont County revealed coal beds at depth that are probably equivalent to the minable coal beds of the Allegheny formation. Representative well logs that illustrate the stratigraphic positions of these coals are shown in figure 35. All but one of the wells were drilled with standard cable tools and thus provided very little detailed information. Log 15, however, is the record of a core hole drilled at Glenova, just north of Wheeling, W. Va. The uppermost coal bed, which is 556 feet below the Pittsburgh coal bed in this core boring, is probably the Lower Freeport. The coal bed is 45 inches thick. Bownocker and Dean (1929, p. 72) report that a coal bed 29 inches thick occurs 563 feet below the Pittsburgh coal bed in a core hole near Bellaire, eastern Pultney Township (position *A* in fig. 35). This coal bed, which was called Middle Kittanning by Bownocker and Dean, is probably the Lower Freeport. The uppermost coal bed in log 10 is 412 feet below the Pittsburgh coal bed and is probably the Upper Freeport, the uppermost stratum in the Allegheny formation.

The Middle Kittanning coal bed is 623 and 625 feet below the Pittsburgh coal bed in logs 14 and 15 respectively, but the interval decreases slightly to the west.

On the basis of the available data, it is not possible to draw definite conclusions about the thickness or persistence of the coal beds in the Allegheny formation in Belmont County, but the beds seem to be lenticular and sporadic in their occurrence. If the correlations shown in figure 35 are correct, the most widespread and thickest of the coals in the Allegheny formation is the Lower Freeport, which seems to be present in holes 1, 2, 3, 6, 7, and 8 in southern Belmont County, and in all the holes except 13 in the northern part of the county.

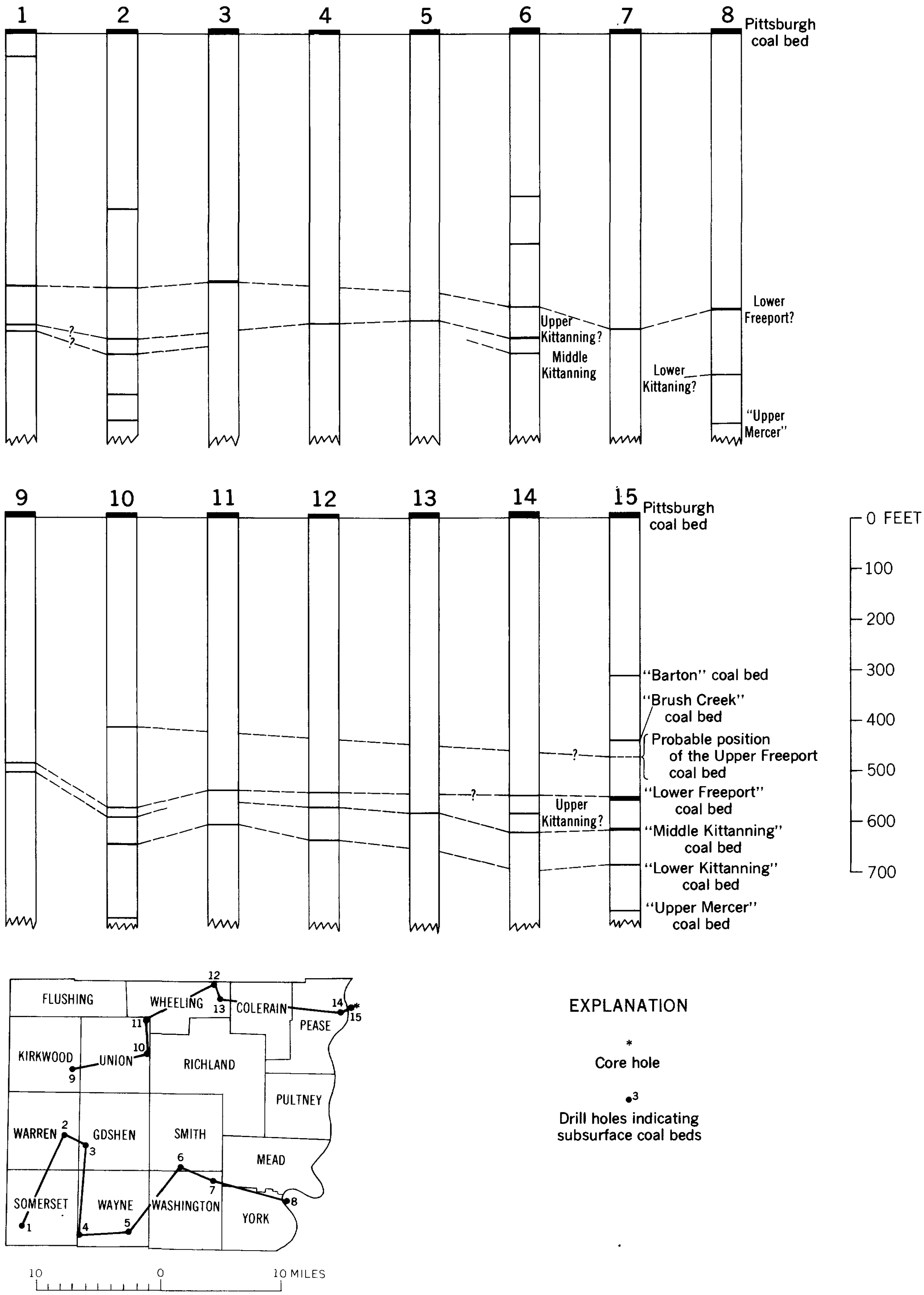

FIGURE 35.—Subsurface coal beds in Belmont County (from well records). See accompanying table in text listing wells.

PREVIOUS ESTIMATES OF THE COAL RESERVES IN BELMONT COUNTY

Three previous estimates of the coal reserves in Belmont County have been made. Clark (1917, p. 90) estimated that the original reserves of the county totaled 7,984 million tons. His estimate included reserve tonnages for the Lower Freeport, Upper Freeport, Pittsburgh, Meigs Creek (Sewickley), Coal No. 10 (Uniontown), Waynesburg, and Brownsville (Washington) beds. In an effort to prepare a complete, total reserve estimate, Clark made statistical allowance for possible tonnages in the Lower and Upper Freeport coal beds. These beds do not, however, crop out in Belmont County and only a few core hole data are available. Consequently, there are no reliable data upon which even an inferred estimate can be based. Excluding reserves of 3,017 million tons estimated for the Lower and Upper Freeport beds, Clark's estimate of original coal reserves totaled 4,967 million tons, as compared to the present estimate of 5,668 million tons. His estimate is smaller than the present estimate for several reasons: he assumed a smaller area underlain by the various coal beds; he assumed a lower average thickness for the Waynesburg and Washington coal beds; and he did not include the Fishpot and Waynesburg "A" beds.

Ray (1929, p. 339) estimated that the original reserves of the Pittsburgh, Pomeroy (Redstone (8A)), and Meigs Creek (Sewickley) coal beds in Belmont County totaled 3,098 million tons. In the present report the coal reserves of the Pittsburgh and Sewickley beds alone are estimated to be 4,227 million tons. Ray's estimate of these reserves is smaller because: he assumed that a smaller area was underlain by the Pittsburgh and Meigs Creek coal beds; he excluded all coal less than 32 inches thick; and he assumed a weight of only 1,500 tons per acre-foot for the coal, presumably to allow for future losses in mining.

Smith, Brant, and Amos (1952, p. 30) estimated that the original reserves of the Meigs Creek (Sewickley) coal bed in Belmont County totaled 1,629 million tons, as compared to the present estimate of 1,469 million tons. Their estimate included 161 million tons of coal in the upper bench of the bed. In the present report, however, the reserve estimate for the Sewickley bed excludes the upper bench.

QUALITY OF THE COAL

Most of the coal in Belmont County is of high-volatile A bituminous rank; some, however, is of high-volatile B bituminous rank (table 11). Rank varies slightly within each bed from place to place and also from one bed to another in the same area. In general, however, the rank tends to decrease slightly from the oldest bed exposed to the youngest. The Pittsburgh bed, geologically the oldest coal exposed in the county, contains the coal of highest rank. The Washington bed, geologically the youngest, contains the coal of lowest rank.

Detailed discussions of the quality of the coal accompany the descriptions of the various coal beds in the section on stratigraphy. Individual analyses by bed are listed in table 11.

LIST OF WELLS SHOWN ON FIGURE 35

No. on section	Property owner	Well No.	Operator	Sec.	Township or district	County	State
1	A. J. Burkhart	1	J. Patterson	SE¼NE¼ 26	Somerset	Belmont	Ohio.
2	J. F. Shry	1	Barnesville Development	NE¼NE¼ 9	Warren	do	Do.
3	Thornbery Heirs	1	do	SW¼SE¼ 33	Goshen	do	Do.
4	E. E. Davis	1	H. Clymer	NW¼NW¼ 33	Wayne	do	Do.
5	W. E. Crum	1	Sale Drilling Co.	SE¼SW¼ 8	do	do	Do.
6	T. H. Mobley	8	Natural Gas Co. of West Virginia.	SE¼NW¼ 19	Smith	do	Do.
7	I. Sindeldecker	2	A. J. West	NE¼SW¼ 6	Washington	do	Do.
8	Solvay	1	Allied Chemical & Dye Corp.		Clay	Marshall	West Virginia
9	A. O. Campbell	1	Bradfield & Havduvde	SW¼NE¼ 2	Kirkwood	Belmont	Ohio.
10	Lillie Gillespie	1	Texas Co.	SE¼SE¼ 4	Union	do	Do.
11	Abner Lodge	1	Venture Oil & Gas Co.	NW¼NE¼ 6	do	do	Do.
12	J. H. Seebert	4	Harrisville Oil & Gas Co.	NE¼NE¼ 9	Wheeling	do	Do.
13	Albert McGrew	1	Ohio Fuel Gas Co.	NE¼SW¼ 2E	do	do	Do.
14	Schweitzer	1	Wheeling Steel Co.	NW¼SE¼ 19	Pease	do	Do.
15	Glenora core test		Wheeling Board of Trade		Richland	Ohio	West Virginia

TABLE 11.—*Analyses of samples of coal from Belmont County, Ohio*

Kind of sample: BM, mine sample collected by U.S. Bur. Mines inspector; GS, mine sample collected by U.S. Geol. Survey geologist; O, mine sample collected by Ohio Geol. Survey geologist; T, sample collected from mine tipple.

Condition of sample: A, as received; B, moisture free (dried at 105° C); C, moisture and ash free.

References refer to publications listed in the "Selected bibliography" in which the mine descriptions and sections from which the samples were taken are listed.

Location of sample	Sample			Analyses, in percent										Heating value		References
				Proximate				Ultimate					Air drying loss			
	Laboratory No.	Kind	Condition	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen		Calories	Btu	
Pittsburgh coal bed																
Armstrong Mills, NE¼ sec. 10, Washington Township, Captina mine (face sample).	9	O	A	2.8	37.9	49.9	9.4	5.1	5.3	69.8	1.1	9.3	------	7,217	12,990	Fieldner, Campbell, and others (1923).
			B	------	39.0	51.3	9.7	5.2	5.1	71.8	1.1	7.1	------	7,422	13,360	
			C	------	43.2	56.8	------	5.8	5.6	79.5	1.2	7.9	------	8,217	14,790	
Baileys Mills, 3½ miles southwest of Barnesville, sec. 31, Warren Township, Cochran No. 2 mine (face of main north face).	20187	GS	A	4.1	42.7	43.9	9.3	4.5	------	------	------	------	2.3	7,072	12,730	Do.
Same as above (face of room, 15 feet west of entry, three-fourths of a mile north of mine mouth.)	20188	GS	A	3.7	43.3	44.4	8.6	4.5	------	------	------	------	1.7	7,194	12,950	Do.
NE¼ sec. 31, Warren Township, Media mine.	10	O	A	4.5	37.5	47.0	11.0	4.7	5.2	67.6	1.1	10.4	------	6,878	12,380	Fieldner, Campbell, and others (1923).
			B	------	39.3	49.2	11.5	4.9	4.9	70.8	1.1	6.8	------	7,194	12,950	
			C	------	44.4	55.6	------	5.5	5.5	80.0	1.3	7.7	------	8,133	14,640	
Bellaire, SE¼ sec. 28, Pultney Township (face of 24 room, 10 entry).	3988	BM	A	3.1	40.8	50.1	6.0	3.4	------	------	------	------	1.1	7,556	13,600	Do.
Bridgeport, NE¼ sec. 28, Pease Township, Aetna Standard Mill mine.	1	O	A	3.4	36.8	51.9	7.9	3.0	5.2	71.5	1.2	11.2	------	7,216	12,990	Do.
			B	------	38.1	53.8	8.1	3.1	5.0	74.0	1.3	8.5	------	7,472	13,450	
			C	------	41.5	58.5	------	3.3	5.4	80.5	1.4	9.4	------	8,133	14,640	
Fairpoint, SW¼ sec. 13, Wheeling Township, Columbiana Coal Co.	6a	O	A	4.3	33.5	51.8	10.4	4.0	5.2	68.2	1.1	11.1	------	6,906	12,430	Do.
			B	------	35.0	54.2	10.8	4.1	4.9	71.2	1.1	7.9	------	7,211	12,980	
			C	------	39.3	60.7	------	4.6	5.5	79.8	1.3	8.8	------	8,083	14,550	
Flushing, south-central sec. 26, Flushing Township, Kennon mine.	2a	O	A	4.2	36.3	50.3	9.2	4.2	5.1	68.8	1.1	11.6	------	7,000	12,600	Do.
			B	------	38.0	52.4	9.6	4.4	4.9	71.8	1.1	8.2	------	7,311	13,160	
			C	------	42.0	58.0	------	4.8	5.4	79.4	1.3	9.1	------	8,089	14,560	
2 miles southeast of Flushing, SW¼, (sec. 7), Wheeling Township, Kennon Coal Co., Black Oak mine (2,000 ft west of shaft).	3985	BM	A	4.0	38.1	48.9	9.0	4.3	------	------	------	------	1.7	------	------	Do.
			B	------	39.7	50.9	9.4	4.4	------	------	------	------	------	------	------	
Same as above (1,500 ft. southwest of shaft).	3986	BM	A	4.1	39.2	48.7	8.0	4.2	------	------	------	------	1.9	7,272	13,090	Do.
			B	------	40.9	50.8	8.3	4.3	------	------	------	------	------	7,583	13,650	
Glencoe, NE¼ sec. 5, Smith Township, Delora No. 1 mine.	7	O	A	3.2	36.8	52.7	7.3	4.3	5.1	71.5	1.1	10.7	------	7,294	13,130	Fieldner, Campbell, and others (1923).
			B	------	38.0	54.5	7.5	4.4	4.9	73.9	1.1	8.2	------	7,539	13,570	
			C	------	41.1	58.9	------	4.8	5.3	79.9	1.2	8.8	------	8,150	14,670	
Laferty, SW¼ sec. Union Township, Wheeling Valley Coal Co.	5	O	A	4.5	36.0	48.7	10.8	4.5	4.9	68.2	1.1	10.5	------	6,906	12,430	Do.
			B	------	37.7	51.0	11.3	4.7	4.6	61.4	1.2	6.8	------	7,228	13,010	
			C	------	42.5	57.5	------	5.3	5.1	80.5	1.3	7.8	------	8,144	14,660	
Martins Ferry, SE¼, Pease Township, Laughlin mine.	34002	BM	A	4.0	39.6	48.3	8.1	3.4	------	------	------	------	2.7	7,222	13,000	Do.
Central sec. 13, Pultney Township, Neff mine 2.	4	O	A	3.8	37.2	50.0	9.0	4.3	5.2	70.6	1.2	9.7	------	7,106	12,790	Do.
			B	------	38.7	52.0	9.3	4.4	5.0	73.4	1.3	6.5	------	7,383	13,290	
Neffs, NW¼ sec. 12, Pultney Township, Neff mine 1.	2095	BM	A	4.0	38.8	49.1	8.1	3.5	------	------	------	------	1.8	7,278	13,100	Do.
			B	------	40.4	51.2	8.4	3.6	------	------	------	------	------	7,583	13,650	
1 mile above mouth of Pipe Creek on Ohio River, SE¼ sec. 6 Mead Township.	8	O	A	2.9	37.9	51.2	8.0	4.3	5.1	73.0	1.0	8.6	------	7,339	13,210	Do.
			B	------	39.1	52.7	8.2	4.4	4.9	75.1	1.1	6.3	------	7,561	13,610	
			C	------	42.6	57.4	------	4.8	5.4	81.9	1.2	6.7	------	8,239	14,830	
Temperanceville, NE¼ sec. 33, Somerset Township, Jeffries mine.	20230	GS	A	3.7	41.0	45.8	9.5	4.6	------	------	------	------	2.0	7,089	12,760	Do.
			B	------	42.6	47.5	9.9	4.8	------	------	------	------	------	7,361	13,250	
Same as above	------	O	A	4.1	37.1	48.2	10.6	5.0	4.9	68.8	1.1	9.7	------	6,931	12,476	Bownocker and Dean (1929).
SE¼ sec. 21, York Township, McIntyre mine.	------	O	A	3.1	41.8	47.7	7.3	3.5	------	------	------	------	1.2	7,306	13,152	Bownocker and Dean (1929).
			B	------	43.5	49.3	7.6	------	------	------	------	------	------	7,540	13,574	
Powhatan Point. NE¼ sec. 7, York Township, Powhatan mine 1.	------	O	A	2.3	42.6	48.4	6.7	3.2	5.2	74.2	1.4	9.3	------	7,456	13,421	Do.
			B	------	43.6	49.6	6.8	3.3	5.1	76.0	1.4	7.5	------	7,628	13,731	
Powhatan Point, NE¼ sec. 7, York Township, Powhatan mine 1 (5¼ miles N. 15° W. of opening, 4 left, D north, No. 5 entry, 12 plus 80 ft.).	E-34227	GS	A	2.8	42.1	46.6	8.5	4.8	5.3	71.2	1.2	9.0	------	------	13,010	(Analyses by U.S. Bureau of Mines.)
			B	------	43.3	48.0	8.7	4.9	5.1	73.2	1.2	6.9	------	------	13,380	
			C	------	47.5	52.5	------	5.4	5.6	80.2	1.4	7.4	------	------	14,660	
NW¼ sec. 36, Smith Township, Loomis mine.	------	O	A	6.0	41.2	44.0	8.8	4.3	5.8	69.0	1.2	10.9	3.7	6,990	12,583	Bownocker and Dean (1929).
			B	------	43.8	46.8	9.4	4.6	5.4	73.4	1.2	6.0	------	7,436	13,386	
SW¼ sec. 25, Union Township, Barr mine.	------	O	A	4.2	41.6	44.0	9.9	4.6	------	------	------	------	1.9	6,973	12,551	Do.
			B	------	43.7	46.0	10.4	4.8	------	------	------	------	------	7,280	13,104	
One-half mile west of Hendrysburg, NE¼ sec. 20, Kirkwood Township, McCartney mine.	------	O	A	3.8	38.0	47.4	10.8	4.8	5.1	67.4	1.1	10.8	3.0	6,865	12,357	Do.
			B	------	39.5	49.3	11.3	5.0	4.9	70.0	1.2	7.6	------	7,132	12,838	

TABLE 11.—*Analyses of samples of coal from Belmont County, Ohio*—Continued

Location of sample	Sample			Analyses, in percent										Heating value		References
				Proximate				Ultimate					Air drying loss			
	Laboratory No.	Kind	Condition	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen		Calories	Btu	
Pittsburgh coal bed—Continued																
Flushing, south-central sec. 26, Flushing Township, Rosemary 1 mine.		BM	A	1.9	39.2	50.0	9.4	4.7						7,194	12,950	Bownocker and Dean (1929).
			B		40.0	51.0	9.6	4.8						7,328	13,190	
Barton, central sec. 24, Colerain Township, Y. and O. Coal Co.		O	A	3.8	36.4	50.8	9.0	4.2	5.1	70.4	1.1	10.2	3.0	7,145	12,861	Do.
			B		37.8	52.8	9.4	4.3	4.9	73.2	1.1	7.1		7,426	13,367	
6 miles northwest of Barnesville, NW¼ sec. 36, Warren Township, Wells Coal Co. strip mine.	E-34224	GS	A	3.4	38.8	48.8	9.0									(Analyses by U.S. Bureau of Mines.)
			B		40.2	50.5	9.3									
			C		44.3	55.7										
Three-quarters mile southwest of Barnesville, NW¼ sec. 20, Warren Township, H. E. Tickhill Coal Co. Black Diamond mine.	E-34226	GS	A	2.5	41.2	45.9	10.4	4.6	5.2	70.6	1.2	8.0			12,950	Do.
			B		42.3	47.0	10.7	4.7	5.1	72.5	1.3	5.7			13,280	
			C		47.3	52.7		5.3	5.7	81.1	1.4	6.5			14,870	
Barton, Colerain Township, Barton mine.	B31915	T	A	3.0	41.6	46.9	8.5	4.4							13,040	Fieldner, Taylor, and others (1952).
			B		42.9	48.4	8.7	4.6							13,450	
East-central sec. 7, Pultney Township, Godaway mine.	C3160	T	A	2.5	43.1	45.4	9.0	5.7	5.3	70.5	1.2	8.3			13,060	Do.
			B		44.2	46.6	9.2	5.9	5.1	72.3	1.2	6.3			13,390	
SW¼ sec. 36, Pultney Township, Schick mine.	B13353	T	A	2.9	41.0	46.3	9.8	4.3							12,890	Do.
			B		42.2	47.7	10.1	4.5							13,270	
Blaine, SW¼ sec. 16, Colerain Township, Lorain Coal and Dock Coal Co., Blaine 21 mine.	C3105	T	A	2.5	41.9	47.4	8.2	4.9							13,180	Do.
			B		43.0	48.6	8.4	5.0							13,510	
Crescent, SE¼ sec. 25, Colerain Township, Lois strip mine.	B66824	T	A	4.1	39.7	46.7	9.5	4.3	5.2	69.5	1.3	10.2			12,710	Do.
			B		41.4	48.7	9.9	4.5	5.0	72.5	1.3	6.8			13,250	
Fairpoint, SE¼ sec. 13, Wheeling Township, Hanna Coal Co. Bradford mine.	C2837	T	A	3.6	37.9	46.2	12.3	3.7	5.2	67.7	1.2	9.9			12.370	Fieldner, Taylor, and others (1952).
			B		39.3	48.0	12.7	3.9	5.0	70.2	1.2	7.0			12,830	
NW¼ sec. 25, Wheeling Township, Camel Run Mine 2.	B32608	T	A	3.4	40.5	48.0	8.1	3.8							13,070	Do.
			B		42.0	49.6	8.4	3.9							13,530	
Flushing, Rice Brothers 1 mine	C2907	T	A	4.4	37.6	46.3	11.7	4.7	5.2	67.1	1.2	10.1			12,290	Do.
			B		39.4	48.3	12.3	4.9	4.9	70.2	1.2	6.5			12,850	
Laferty, SW¼ sec. 11, Union Township, Hanna Coal Co. Laferty 6 mine.	B13864	T	A	3.0	40.8	47.4	8.8	4.5							13,030	Do.
			B		42.1	48.8	9.1	4.6							13,440	
Laferty, SW¼ sec. 6, Union Township, Virginian 44 mine.	B13352	T	A	4.3	38.7	47.2	9.8	4.0							12,630	Do.
			B		40.4	49.4	10.2	4.2							13,190	
Martins Ferry, NW¼ sec. 19., Pease Township, Funari mine.	C2522	T	A	2.4	40.9	48.1	8.6	5.0	5.4	71.7	1.3	8.0			13,180	Do.
			B		41.8	49.4	8.8	5.1	5.2	73.5	1.4	6.0			13,500	
Fishpot coal bed																
SW¼ sec. 32, Mead Township, bed of Wegee Creek.		O	A	2.5	40.8	40.9	15.7	5.0					2.0	6,522	11,739	Bownocker and Dean (1929).
			B		41.9	42.0	16.1									
Sewickley (Meigs Creek) coal bed																
NE¼ sec. 13, Flushing Township, White mine.	4054	GS	A	4.6	33.8	52.6	9.0	2.2					1.7			Fieldner, Campbell, and others (1923).
			B		35.5	55.0	9.5	2.3								
East-central sec. 26, Flushing Township, Flushing Coal Co. mine.	36	O	A	5.0	33.3	48.9	12.8	2.4	5.0	66.3	1.2	12.3		6,650	11,970	Do.
			B		35.1	51.4	13.5	2.5	4.6	69.8	1.3	8.3		7,000	12,600	
SE¼ sec. 31, Goshen Township, Statler mine.	40	O	A	3.4	35.7	46.0	14.9	4.4	4.9	64.8	1.1	9.9		6,578	11,840	Do.
			B		37.0	47.5	15.5	4.5	4.6	67.1	1.1	7.2		6,811	12,260	
SW¼ sec. 24, Goshen Township, Badgertown mine.	4053	GS	A	4.2	36.4	47.9	11.5	3.2								Do.
			B		38.0	50.0	12.0	3.3								
South-central sec. 27, Pease Township, Kanaha mine.		O	A	4.7	36.2	43.0	16.2	3.1	4.7	62.6	1.3	12.1	1.9	6,265	11,278	Bownocker and Dean (1929).
			B		38.0	45.1	17.0	3.3	4.4	65.7	1.3	8.3		6,571	11,828	
Central sec. 28, Pultney Township, local mine.		O	A	3.9	38.8	44.0	13.3	2.7					1.9	6,643	11,958	Do.
			B		40.4	45.7	13.9	2.8						6,911	12,441	
NW¼ sec. 30, Pultney Township, Ward mine.		O	A	4.1	39.6	42.5	13.8	3.4	5.0	65.6	1.2	11.0	1.8	6,584	11,852	Do.
			B		41.3	44.3	14.4	3.5	4.8	68.4	1.3	7.6		6,868	12,363	
SE¼ sec. 32, Richland Township, Dyrdek mine.		O	A	4.7	39.9	43.3	12.2	3.4						6,672	12,010	Do.
			B		41.8	45.4	12.8	3.5						6,999	12,598	

Strip mining, or the digging of coal after first removing the cover of rock or overburden, is not a new development. Some of the first coal mined in the county was obtained by such methods, but the size of earth-moving equipment in existence before World War II limited strip mining to small-scale operations. Development of large power shovels with bucket capacities as great as 50 cubic yards has made possible the economic removal of much thicker overburden.

Some coal operators use horizontal power augers to remove additional coal after some of the coal has been removed by stripping. Augers seen in operation penetrate about 100 feet horizontally into the coal.

COAL PRODUCTION

Although coal mining probably began in 1804, production figures are not available prior to 1816. Yearly production figures from 1816 through 1952 are listed in table 12.

TABLE 12.—*Coal production, in tons, in Belmont County, 1816 to 1953*

[Sources of production figures: 1816–77, Eavenson (1942); 1878–1913, Ohio Div. Mines; 1914–29, Ohio Indus. Comm.; 1929–53, Ohio Div. Labor Statistics]

Year	Total	Underground	Strip
1816	500		
1817	500		
1818	500		
1819	500		
1820	500		
1821	500		
1822	500		
1823	600		
1824	700		
1825	700		
1826	800		
1827	800		
1828	900		
1829	900		
1830	1, 000		
1831	1, 000		
1832	1, 700		
1833	2, 400		
1834	3, 100		
1835	3, 800		
1836	4, 500		
1837	5, 200		
1838	5, 900		
1839	6, 700		
1840	7, 528		
1841	7, 700		
1842	7, 900		
1843	8, 000		
1844	8, 000		
1845	8, 000		
1846	8, 000		
1847	8, 000		
1848	9, 000		
1849	15, 000		
1850	21, 000		
1851	27, 000		
1852	32, 000		
1853	40, 000		
1854	80, 000		
1855	110, 000		
1856	125, 000		
1857	140, 000		

TABLE 12.—*Coal production, in tons, in Belmont County, 1816 to 1953*—Continued

Year	Total	Underground	Strip
1858	138, 000		
1859	135, 000		
1860	133, 000		
1861	130, 000		
1862	128, 000		
1863	125, 000		
1864	122, 000		
1865	119, 000		
1866	115, 870		
1867	90, 972		
1868	69, 626		
1869	97, 000		
1870	123, 900		
1871	120, 000		
1872	116, 776		
1873	115, 571		
1874	164, 158		
1875	213, 955		
1876	199, 834		
1877	274, 720		
1878	385, 000		
1879	420, 000		
1880	452, 754		
1881	500, 000		
1882	500, 000		
1883	576, 326		
1884	643, 129		
1885	744, 446		
1886	533, 779		
1887	721, 767		
1888	1, 108, 106		
1889	814, 699		
1890	827, 568		
1891	1, 259, 570		
1892	1, 249, 423		
1893	1, 277, 540		
1894	1, 193, 329		
1895	963, 367		
1896	1, 082, 964		
1897	905, 378		
1898	1, 168, 567		
1899	1, 259, 520		
1900	1, 595, 369		
1901	1, 544, 832		
1902	2, 058, 066		
1903	2, 612, 025		
1904	3, 283, 189		
1905	3, 871, 846		
1906	4, 467, 295		
1907	6, 355, 582		
1908	5, 591, 719		
1909	5, 993, 418		
1910	8, 336, 428		
1911	8, 040, 333		
1912	9, 316, 850		
1913	10, 454, 795		
1914	2, 624, 023		
1915	4, 403, 754		
1916	10, 553, 088		
1917	11, 156, 626		
1918	12, 030, 431		
1919	9, 999, 648		
1920	10, 953, 668		
1921	11, 634, 028		
1922	6, 802, 199		
1923	13, 295, 035		
1924	10, 022, 265		
1925	9, 263, 176		
1926	9, 128, 799		
1927	3, 694, 788		
1928	3, 815, 155		
1929	7, 187, 338		
1930	6, 919, 036		

TABLE 12.—*Coal production, in tons, in Belmont County, 1816 to 1953*—Continued

Year	Total	Underground	Strip
1931	6, 702, 362		
1932	3, 862, 991		
1933	5, 933, 491		
1934	6, 056, 803		
1935	5, 782, 459		
1936	6, 887, 094		
1937	7, 786, 096		
1938	5, 565, 993		
1939	4, 953, 697	4, 884, 353	69, 344
1940	5, 362, 533	5, 362, 533	
1941	8, 209, 536	8, 135, 530	74, 006
1942	8, 860, 706	8, 552, 671	308, 035
1943	8, 739, 167	8, 291, 140	448, 027
1944	8, 303, 187	7, 797, 717	505, 470
1945	7, 994, 882	6, 860, 426	1, 134, 456
1946	7, 953, 868	6, 739, 887	1, 213, 981
1947	9, 242, 973	7, 550, 731	1, 692, 242
1948	8, 744, 582	7, 130, 802	1, 613, 780
1949	6, 435, 371	5, 405, 995	1, 029, 376
1950	8, 331, 998	6, 343, 185	1, 988, 813
1951	9, 708, 811	7, 498, 892	2, 209, 919
1952	8, 730, 192	6, 412, 193	2, 317, 999
Total	399, 178, 668	384, 573, 220	14, 605, 448

Tonnages before 1859 must be classified as approximate because no official State production records were kept before that time. Between 1859 and 1885 official records were published by the State, but the agency charged with compiling the records was changed from year to year and, therefore, these tonnage figures are probably inaccurate. Production from 1816 through 1885 was probably greater than is indicated. The official records do not contain production from all the many small domestic mines, and for this reason recorded production is slightly less than actual production.

Reported coal production during the period from 1816 to 1953 is 399,178,668 tons. This total includes 386,548,799 tons from the Pittsburgh bed and 12,529,869 tons from the Sewickley bed. Production from these two beds was combined prior to 1945. Since 1945, production from the Sewickley bed has totaled 7,529,869 tons. Production from the Sewickley bed prior to 1945 is estimated to have been 5 million tons. In 1950 Belmont County ranked 18th among 382 coal-producing counties in the United States and produced more coal that year than 22 of the 31 coal-producing States.

Underground mining has accounted for 96 percent of the coal produced to the present time. Strip-mine production, however, constituted 33 percent of total production in 1952.

LIMESTONE

Limestone is abundant in Belmont County, but most of the beds are too impure to be used as sources of high-grade calcium carbonate. In general, limestone beds in the upper part of the Pennsylvanian and in the Permian rocks have relatively high contents of silica, alumina, magnesium, and iron. Only 3 of the 20 named limestone units have been quarried commercially, and these are used mainly for road surfacing and agricultural lime. These are the Upper Pittsburgh member of the Conemaugh formation, the Fishpot member of the Monongahela formation, and the lower tongue of the Middle Washington member of the Dunkard group. Limestone of the Fishpot member from a quarry near Barnesville was once used for making natural rock cement, but the magnesium content of the Fishpot, as well as that of the other limestone beds, is too high for use in making Portland cement. The Fishpot is the most important limestone in the county because of its uniform thickness and comparatively good quality. The lower tongue of the Middle Washington limestone member has a higher carbonate content than the Fishpot, but its thickness is highly variable. The Fishpot limestone member is quarried in sec. 31, Somerset Township, and sec. 24, Wayne Township; the lower tongue of the Middle Washington limestone member is quarried in sec. 32, Pease Township.

Although the Lower Pittsburgh member of the Conemaugh formation and the Redstone limestone member of the Monongahela formation have not been quarried in the past, they are suitable for use as road-surfacing material and as agricultural lime. The Benwood limestone member of the Monongahela formation is the thickest limestone in the county but is too impure to be used even as a source of agricultural lime.

Descriptions and analyses of the limestones are given in the discussions of the individual members in the section on stratigraphy.

SANDSTONE

Most of the sandstones in Belmont County are too irregularly bedded and too friable to be classed as good building stones. An exception is the Bellaire sandstone member of the Conemaugh formation, which was quarried along McMahon Creek for use in the railroad bridge at Bellaire. No sandstone quarries are in operation in the county at the present time.

SHALE AND MUDSTONE

Shale, which varies from hard and fissile to soft and clayey, occurs throughout the county. Most is not thick or persistent enough, however, to be used commercially in the ceramic industry. The only shale quarry in Belmont County is at McClainsville on McMahon Creek. Here the soft clayey shale beneath the Bellaire sandstone is being used for making common brick. Plate 3, section 1, was measured at this quarry. Some of the red mudstone in the Conemaugh formation and

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