Coal Resources of Lawrence County Pennsylvania

By J. A. VAN LIEU *and* ELMER D. PATTERSON

COAL RESOURCES OF WESTERN PENNSYLVANIA

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COAL RESOURCES OF LAWRENCE COUNTY, PENNSYLVANIA

By J. A. Van Lieu and Elmer D. Patterson

ABSTRACT

Lawrence County is in west-central Pennsylvania in the northern part of the Appalachian coal field. The coal-bearing rocks in the county are divided in ascending order into the Pottsville Formation, about 250 feet thick; the Allegheny Formation, about 300 feet thick; and the basal part of the Conemaugh Formation, generally less than 100 feet thick. These rocks dip gently southward; hence, the oldest rocks are exposed in valleys in the northern part of the county and the youngest rocks are exposed on hills in the southeastern part. Most of the northern part of the county is covered by glacial deposits of Pleistocene age.

The sequence of coal-bearing rocks includes 12 coal beds locally more than 14 inches thick. These beds contained original reserves totaling 782 million tons, of which about 28 million tons had been mined or lost in mining as of January 1, 1957. Of the remainder, about 398 million tons is considered to be recoverable. About 62 percent of the reserves is in beds 14 to 28 inches thick, 36.5 percent is in beds 28 to 42 inches thick, and 1.5 percent is in beds more than 42 inches thick. The coal is largely of high-volatile *A* bituminous rank and is high in heat value.

About 70 percent of the reserves is concentrated in the Lower Kittanning, Middle Kittanning, and Homewood coal beds, and most of the mining is concentrated in the Middle Kittanning coal bed. Before 1945, mining in the county was carried on largely by underground methods; since 1945, mining has been largely by stripping methods.

INTRODUCTION

Lawrence County covers an area of 367 square miles in west-central Pennsylvania in the northern part of the Appalachian coal field (fig. 1). New Castle, the county seat, is about 42 miles northwest of Pittsburgh.

Most of the county is underlain by coal, which constitutes an important, largely untapped natural resource. This report, prepared in cooperation with the Pennsylvania Bureau of Topographic and Geologic Survey, is intended to show the distribution, thickness, and

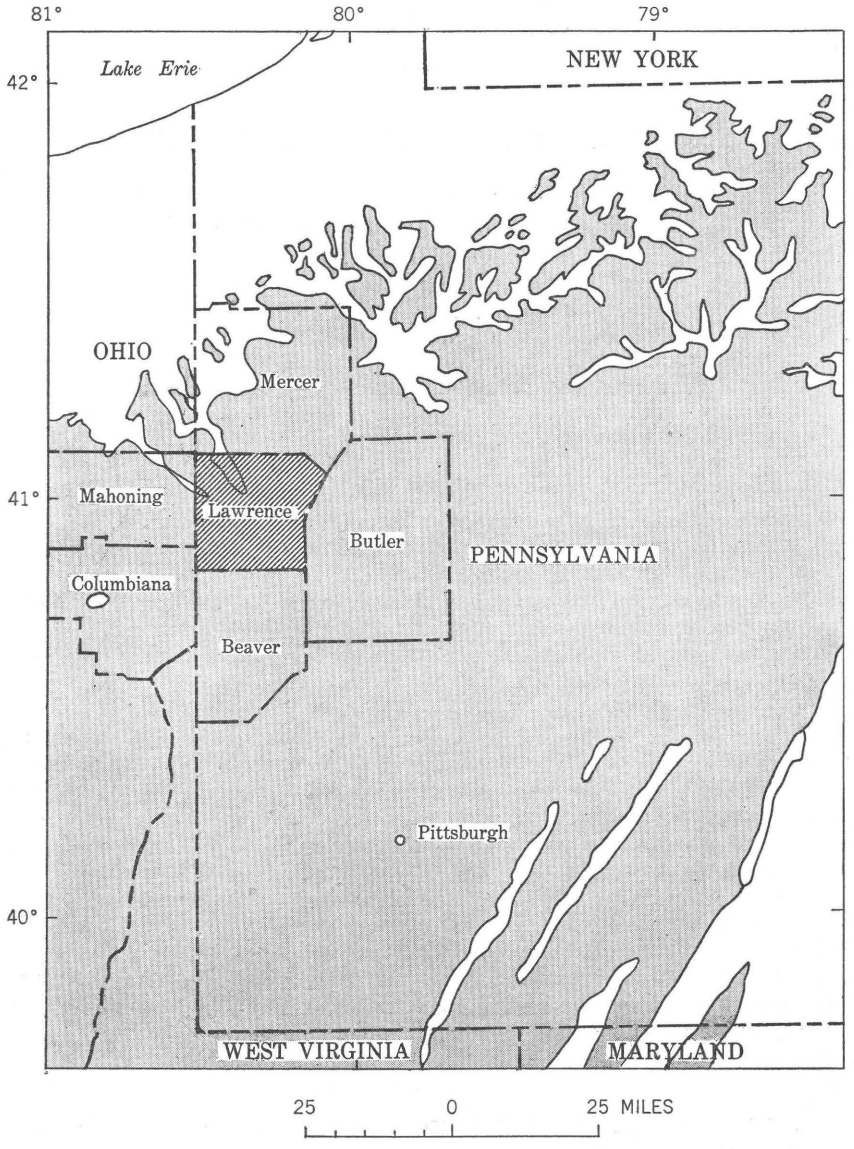

FIGURE 1.—Map showing location of Lawrence County, Pa., in the northern Appalachian coal field (shaded).

reserves of coal as an aid in planning for the future development of western Pennsylvania.

Much of Lawrence County is a broad, moderately dissected upland about 1,100 feet above sea level. Deep valleys have been cut into this upland by the Beaver River and its many tributaries. The

highest point in the county (about 1,450 feet) is 2 miles northeast of Energy; the lowest (745 feet) is in the valley of Beaver River at the southern boundary of the county. Local relief of 300 to 500 feet is common near the major streams. Beaver River, which is formed by the junction of the Mahoning and Shenango Rivers at New Castle, flows southward and joins the Ohio River near Beaver about 25 miles south of New Castle. The main highways and railroads in the county follow these river valleys.

The stratigraphy and structure of Lawrence County were first described by Rogers (1858), Lesley (1875a), Chance (1879), White (1879) and Lesley and Lesquereux (*in* Wrigley, 1875, p. 90–104). These older studies were largely of a reconnaissance nature, and the data were plotted on planimetric maps, which have less utility than modern topographic maps. More recent detailed reports by DeWolf (1929) and Richardson (1936) and data collected by hydraulic engineers of the U.S. Geological Survey were of considerable value in the present study. The areas covered by the more detailed previous reports are shown on figure 2. The coal reserves were estimated previously as part of a statewide study by Reese and Sisler (1928).

As part of the reevaluation of coal reserves in the county, the accompanying geologic map (pl. 1) was prepared to show the distribution of the major coal beds. This map was compiled in part from the sources cited above and in part from detailed mapping by the authors. In particular, the southeast and northwest parts of the county were mapped, and in other parts of the county many outcrop lines of coal beds were adjusted to reflect more recent mining and outcrop information. Additional information was obtained from mine maps and records, aerial photographs, and logs of drill holes.

ACKNOWLEDGMENTS

The writers are indebted to many individuals and organizations associated with the coal-mining industry in Lawrence County who were most helpful in loaning maps and records and in showing mining properties. The Pennsylvania Topographic and Geologic Survey and the Pennsylvania Department of Mines made available the extensive public records of these offices.

D. W. Greenman and C. W. Poth of the U.S. Geological Survey accompanied the writers in the field at the beginning of the fieldwork and gave much useful advice. An unpublished map of the northeastern part of the county by T. E. Hendrix, also of the Geological Survey, was used in compiling the geologic map (pl. 1). Virginia Milewski and W. C. Treon calculated the coal tonnages and prepared the accompanying coal reserves tables.

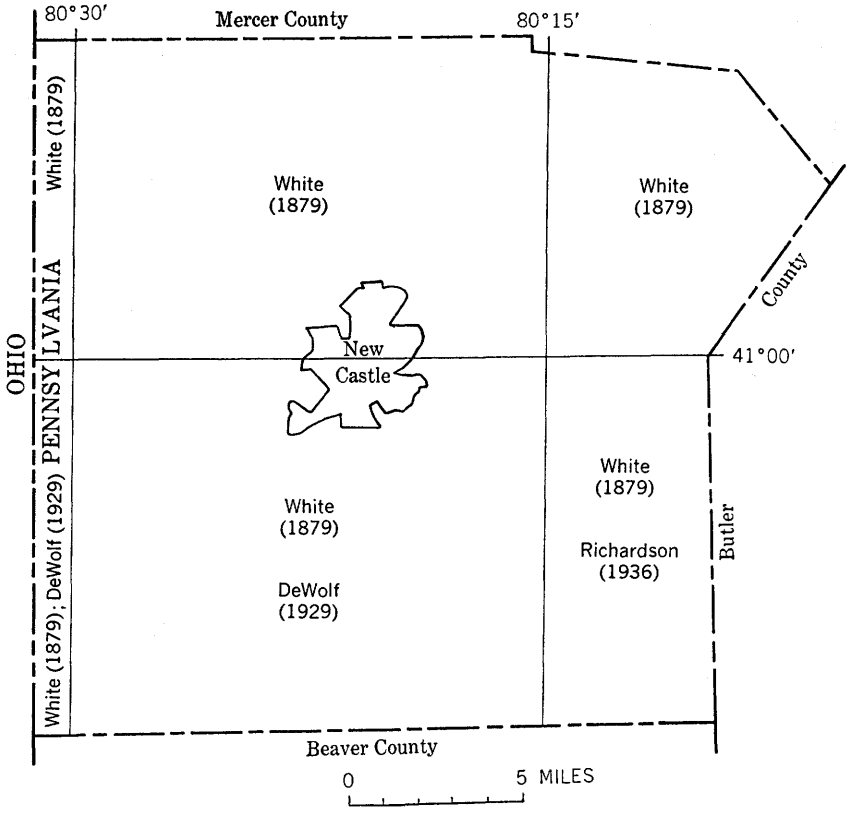

FIGURE 2.—Outline map of Lawrence County, Pa., showing areas covered by previous geologic reports.

STRATIGRAPHY

The consolidated rocks exposed in Lawrence County are of Mississippian and Pennsylvanian age. The rocks of Mississippian age crop out in the valleys of the Mahoning and Shenango Rivers just above water level, but only about 50 feet of beds in the upper part of the Mississippian are exposed. The overlying rocks of Pennsylvanian age are about 650 feet thick. This sequence includes, from oldest to youngest, the Pottsville Formation, about 250 feet thick; the Allegheny Formation, about 300 feet thick; and the basal part of the Conemaugh Formation, generally less than 100 feet thick and exposed only on a few isolated hills.

Throughout most of Lawrence County, north of a line extending from the middle of the eastern boundary to the junction of Beaver River and Connoquenessing Creek, the rocks of Pennsylvanian age are largely obscured by glacial drift of Pleistocene age. Outwash deposits extend several miles southeast of the drift border.

The distribution of these various rocks in Lawrence County is shown

on the geologic map (pl. 1), and the stratigraphic relations and nomenclature of members and beds in the sequence of Pennsylvanian age are shown on the diagrammatic section (fig. 3).

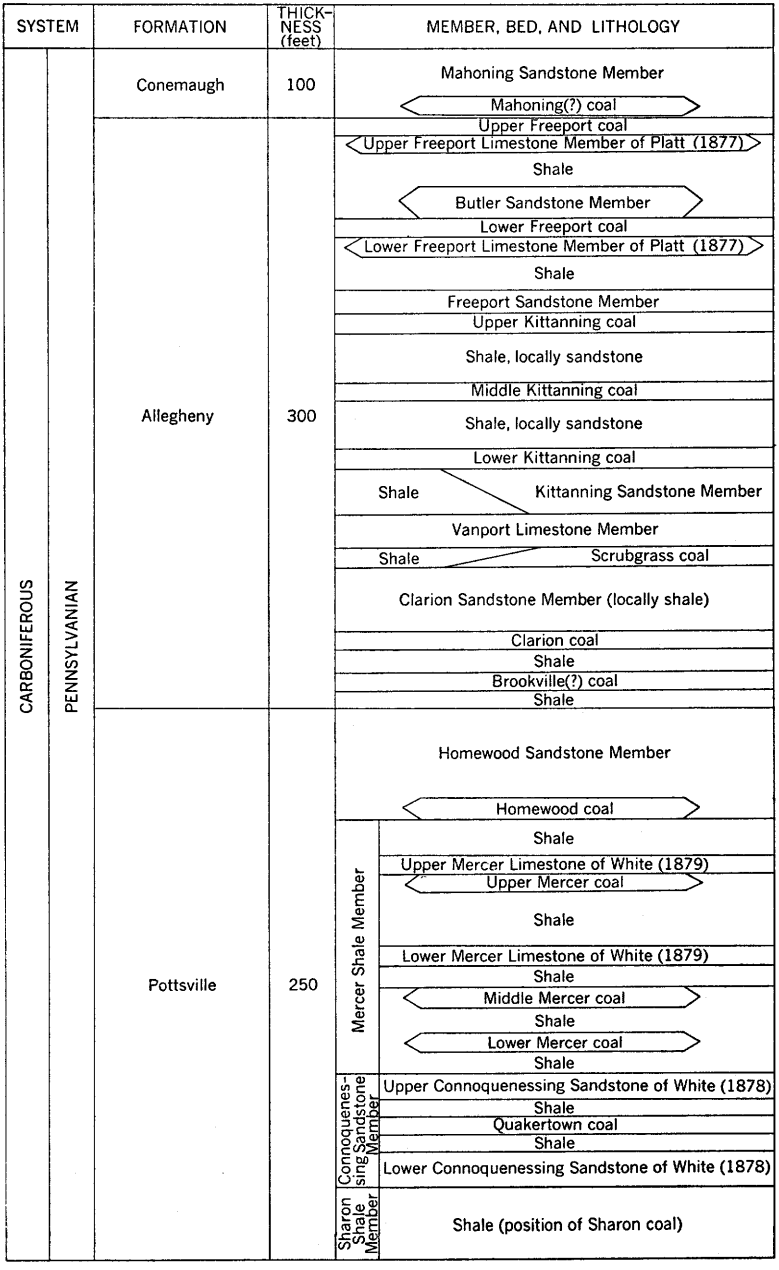

FIGURE 3.—Stratigraphic nomenclature and lithology of rocks of Pennsylvanian age in Lawrence County, Pa.

The geologic nomenclature used on figure 3 differs somewhat from that of Carswell and Bennett (1963).

MISSISSIPPIAN ROCKS UNDIFFERENTIATED

Rocks of Mississippian age are poorly exposed along the valleys of the Mahoning and Shenango Rivers. At most places these beds are concealed by glacial deposits, but locally a sequence about 50 feet thick is exposed above river level. The Mississippian sequence includes shale, siltstone, and fine- to medium-grained sandstone in beds ranging in thickness from a few inches to about 3 feet. These rocks very closely resemble the overlying Pennsylvanian rocks in both texture and color.

PENNSYLVANIAN ROCKS

The formations of Pennsylvanian age in Lawrence County consist of interbedded sandstone, siltstone, shale, limestone, coal, and underclay, listed in approximate order of abundance. Sandstone, the most conspicuous rock type, locally forms ledges and cliffs. It is commonly thin bedded and micaceous and weathers brown. Siltstone and shale, which are about equal in abundance, are commonly interbedded and are generally gray to dark gray on fresh surfaces and brown on weathered surfaces. Red and green shale is common in the Conemaugh Formation. Locally the shale contains abundant fragments of carbonaceous material and impressions of leaves and plant stems; nodules and thin beds of ironstone are common in some carbonaceous shale units.

Thin lenticular beds of limestone of both marine and fresh-water origin are present at several places in the sequence. The marine limestone ranges from thin bedded to massive and is generally gray, coarsely crystalline, and fossiliferous. The fresh-water limestone ranges from thin bedded to nodular and is generally gray, microcrystalline, nonfossiliferous, and, in many places, conglomeratic or brecciated.

The coal beds, which generally are less than 3 feet thick and are irregular in thickness, commonly extend throughout the county, but locally grade laterally into coaly shale. Locally, also, the coal beds are cut out by channel sandstone deposits. Underclay, which lies beneath most coal beds, is light to dark gray and commonly contains impressions of roots.

The rocks of Pennsylvanian age were deposited in near-shore and continental environments, and most individual beds are discontinuous and have no diagnostic value as stratigraphic guides in locating coal beds in the field. However, several units are distinctive and continuous and are very useful in determining position in the sequence and in locating coal beds. The Pennsylvanian rocks in Lawrence

County have been divided into three formations—the Pottsville, Allegheny, and Conemaugh Formations—as described below. (See pls. 2–4; fig. 3.)

POTTSVILLE FORMATION

The Pottsville Formation, of Early and Middle Pennsylvanian age, is the oldest of the Pennsylvanian formations exposed in Lawrence County. The name was applied by White (1878, p. 66) to rocks in western Pennsylvania that are stratigraphically equivalent to the Pottsville of the anthracite region of eastern Pennsylvania (Lesley, 1876, p. 221–227). This usage has been continued in Lawrence County and vicinity by White (1878, 1879), Woolsey (1906), DeWolf (1929), Richardson (1936), and the present writers.

The Pottsville Formation in Lawrence County is about 250 feet thick. It has been divided for purposes of mapping and discussion into the following units, listed in ascending order: Sharon Shale Member, including the thin Sharon coal; Connoquenessing Sandstone Member; Mercer Shale Member; and Homewood Sandstone Member. The three members have been divided further into other named and unnamed units as shown in figure 3. Most of the discussion that follows is confined to the coal beds and associated named units, which have diagnostic value in locating coal beds or in determining position in the sequence. Other units, particularly the unnamed units, are composed largely of nonresistant shale and siltstone; these other units are poorly exposed at most places and have little stratigraphic value. For this reason they will not be discussed further. The lithology and range in thickness of all units are shown in the accompanying generalized section.

Generalized section of the Pottsville Formation in Lawrence County, Pennsylvania

	Range in thickness	
	Feet	Inches
Homewood Sandstone Member:		
Shale, siltstone, or sandstone, tannish-white to medium-brown, thin- to medium-bedded	0–4	
Sandstone, tannish-white to reddish-purple, medium- to coarse-grained, quartzose, iron-stained	0–40	
Shale, siltstone, or sandstone, of varying hues of tan through various shades of gray; thin to massive beds; locally contains ironstone concretions	0–10	
Homewood coal		16–60
Underclay, medium-gray	0–10	
Mercer Shale Member:		
Shale or siltstone, medium- to bluish-gray, thin- to medium-bedded; contains a few ironstone concretions	0–27	
Upper Mercer Limestone of White (1879):		
Limestone, dark-gray, fine-grained; contains marine fossils	0–5	
Shale, medium bluish-gray, thin- to medium-bedded	0–10	
Upper Mercer coal		11–38

Generalized section of the Pottsville Formation in Lawrence County, Pennsylvania—Continued

	Range in thickness	
	Feet	*Inches*
Mercer Shale Member—Continued		
Underclay, medium-gray	0–2	
Sandstone, light- to medium-gray; contains plant debris	0–2	
Shale, light-gray to dark-gray; contains ironstone concretions and thin beds of buff to tan sandstone; locally contains marine fossils in the shale and concretions	0–35	
Lower Mercer Limestone of White (1879):		
Limestone, medium to dark olive-gray, fine-grained; contains marine fossils	0–3	
Shale, black, fissile	0–4	
Middle Mercer coal		6–21
Underclay, medium-gray	0–2	
Shale, siltstone, and sandstone; varying hues of tan, brown, or gray; usually thin bedded	0–20	
Lower Mercer coal		4–42
Underclay, medium-gray		0–6
Shale and sandstone, light- to dark-tan, thin-bedded	2–28	
Connoquenessing Sandstone Member:		
Upper Connoquenessing Sandstone of White (1878):		
Sandstone, white through various hues of tan to light-brown or reddish-purple, medium- to coarse-grained, massive	10–60	
Quakertown Shale of White (1879; 1880):		
Shale, medium-gray to dark bluish-gray, fissile; contains a few ironstone concretions	0–10	
Quakertown coal		0–23
Shale and siltstone, varying hues of tan or gray, thin-bedded	1–10	
Lower Connoquenessing Sandstone of White (1878):		
Sandstone, white through various hues of tan to light-brown or reddish-purple, medium- to coarse-grained, massive	20–100	
Sharon Shale Member:		
Shale, siltstone, and sandstone, light-tan to dark bluish-gray; contains ironstone concretions and the Sharon coal	25–45	
Mississippian rocks undifferentiated.		

As shown in the section, the Pottsville Formation in Lawrence County contains six thin coal beds or coal horizons—in ascending order, the Sharon, Quakertown, Lower Mercer, Middle Mercer, Upper Mercer, and Homewood.

SHARON COAL

The Sharon coal has been mined in Mercer County, Pa. (White, 1880, p. 102), but where observed in Lawrence County it is only a few inches thick. The Sharon coal horizon is near the base of the Sharon Shale Member (fig. 3); it is poorly exposed locally near Pulaski and along the Mahoning River. The conglomeratic zone that lies below the Sharon coal in Mercer County (White, 1880, p. 56) is not present in Lawrence County.

QUAKERTOWN COAL

The Quakertown coal, named by White (1880, p. 65) from exposures at Quakertown Falls, lies between the Lower and Upper Connoquenessing Sandstones of White (1878) about 65 feet above the Sharon coal horizon; it is exposed along the Mahoning and Shenango Rivers and along Connoquenessing Creek. Although only a few inches thick in most parts of the county (see figs. 2 and 3), this coal is 23 inches thick at field observation point MA–1[1] (pl. 1) about 1 mile north of Robinson and, according to White (1879, p. 197), it is 36 inches thick near the head of Coffee Run. The Quakertown coal has been mined only locally and on a small scale.

MERCER COALS

The Lower, Middle, and Upper Mercer coals are associated with two thin marine limestone beds near the center of the Mercer Shale Member. The Upper Mercer Limestone of White (1879), the more persistent of the two, is as much as 4 feet 8 inches thick, but it is absent locally, especially in the eastern part of the county. The Lower Mercer Limestone of White (1879) ranges in thickness from 6 inches to about 3 feet; it is poorly exposed and is also locally absent. The average interval between the two limestones is about 25 feet.

Lower Mercer coal.—The Lower Mercer coal is generally 15–20 feet below the Lower Mercer Limestone. Where observed, it ranges in thickness from 4 to 28 inches but it is absent locally. According to White (1879, p. 63), it is 42 inches thick about 1 mile west of New Wilmington. The Lower Mercer coal has been mined only locally and on a small scale because of variability in both thickness and quality.

Middle Mercer coal.—The Middle Mercer coal lies just below the Lower Mercer Limestone, and from 2 to 20 feet but about 14 feet, on the average, above the Lower Mercer coal. Where the Lower Mercer Limestone is absent, the Middle Mercer coal may be mistaken for the Lower Mercer coal. The Middle Mercer coal ranges in thickness from 6 to 21 inches and averages about 18 inches. It was not observed in the northwestern part of the county. The Middle Mercer coal has been mined only locally and on a small scale.

Upper Mercer coal.—The Upper Mercer coal lies 0–10 feet below the Upper Mercer Limestone. Where observed, the coal ranges in thickness from 11 to 38 inches and averages about 12 inches. According to White (1879, p. 56 and 189), the coal is 56–60 inches thick near Edinburg. The coal has a high sulfur content and is mined only locally and on a small scale.

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[1] Letter prefix indicates political township in which the locality occurs.

HOMEWOOD COAL

The Homewood coal lies at the base of the Homewood Sandstone Member, which commonly forms cliffs or resistant ledges. The coal can usually be identified by its position in the sequence between the Homewood Sandstone Member and the Upper Mercer Limestone. The Homewood coal ranges in thickness from 16 inches at field observation WL–1 (pl. 1) about half a mile south of New Wilmington to 43 inches at field observation point MA–3 (pl. 3) about a mile southeast of Frizleburg. According to DeWolf (1929, p. 51), it is 60 inches thick about 1½ miles northwest of Moravia. The average of the measured thicknesses is about 26 inches.

ALLEGHENY FORMATION

The name Allegheny was first used by Rogers (1840, p. 150) for all rocks cropping out along the Allegheny River between Pittsburgh and Warren, Pa. Stevenson (1873, p. 16) defined the Allegheny as the sequence of beds between the top of the Pottsville Formation and the base of the Mahoning Sandstone Member. This usage has been followed by most subsequent writers. As used in this report, the term Allegheny Formation refers to the sequence between the base of the underclay of the Brookville(?) coal and the top of the Upper Freeport coal (fig. 3); this usage accords very closely with Stevenson's definition.

The Allegheny Formation in Lawrence County is about 300 feet thick. It is at or near the surface in most parts of the county, and it contains the thickest and best coal in the county.

For purposes of mapping and discussion, the Allegheny Formation has been divided into 21 named and unnamed units as shown on figure 3. For the most part, the named units are either coal beds or associated beds that have value in locating coals or in determining position within the sequence. The unnamed units, for the most part, are nonresistant shale and siltstone that have little stratigraphic value. For this reason, the discussion is confined primarily to the named units The lithology and range in thickness of all units are given in the accompanying generalized section.

Generalized section of the Allegheny Formation in Lawrence County, Pennsylvania

	Range in thickness	
	Feet	*Inches*
Upper Freeport coal		0–24
Underclay, gray	0–2	
Shale, dark-gray	0–3	
Upper Freeport Limestone Member of Platt (1877):		
Limestone, light to medium bluish-gray, nodular; of fresh-water origin	0–1	

Generalized section of the Allegheny Formation in Lawrence County, Pennsylvania—Continued

	Range in thickness	
	Feet	Inches
Shale, siltstone, or sandstone, in thin to massive beds. Butler Sandstone Member (0–30 ft thick) usually forms part of sequence. Rest of sequence may include dark-gray fissile shale containing many ironstone or cherty concretions	20–60	
Lower Freeport coal		0–48
Underclay, usually tannish-gray to bluish-gray	0–3	
Lower Freeport Limestone Member of Platt (1877):		
Limestone, light to medium bluish-gray; of fresh-water origin	0–5	
Shale, siltstone, or sandstone; locally near base includes the conspicuous Freeport Sandstone Member, 0–60 ft thick	50–80	
Upper Kittanning coal		0–26
Shale, siltstone, or sandstone, brownish- to grayish-tan; includes a bed of buff to tan sandstone 0–20 ft thick	10–60	
Middle Kittanning coal		10–53
Underclay, tan to gray	0–3	
Shale or siltstone, brownish-gray to light-gray; contains ironstone concretions; locally includes a thick bed of tan to brown sandstone	40–80	
Lower Kittanning coal		0–36
Underclay, light bluish-gray; pillowy appearance when freshly exposed; breaks into irregular shardlike pieces	5–15	
Shale or siltstone, dark-gray to tan; includes few ironstone concretions in shale. Locally includes conspicious Kittanning Sandstone Member—a bed of tan, medium-grained sandstone, 0–3 ft thick. When freshly exposed this sandstone is speckled	10–15	
Vanport Limestone Member:		
Limestone, light- to dark-gray; may exhibit cone-in-cone structure when shaly or thin; contains marine fossils	0–25	
Shale, dark-gray, fissile	0–6	
Scrubgrass coal		0–36
Clarion Sandstone Member:		
Sandstone, fine-grained, light-gray or tan to buff; thin platy to medium beds; grades locally to shale or siltstone	20–50	
Clarion coal; two or more beds separated by shale		0–37
Underclay, shale, siltstone, and sandstone	4–20	
Brookville(?) coal; locally two or more beds separated by gray shale		0–36
Underclay	0–1	

In the Allegheny Formation the Vanport Limestone Member is an easily identified unit and is used as a marker for coal beds below and above. The Vanport was defined and named by White (1878, p. 60) from exposures near the town of Vanport in Beaver County, and the name has been continued in use by all subsequent writers. The Vanport ranges in thickness from 6 inches to 25 feet. Where thick,

it consists of several distinct beds, individually 1–5 feet thick, and is conspicuously fossiliferous. (See Richardson, 1936, p. 19.) Where thin, it is argillaceous and commonly exhibits a characteristic cone-in-cone structure. The Vanport is quarried at many places in the county, particularly near Hillsville, Bessemer, and New Castle.

As noted in the generalized section, the Allegheny contains eight coal beds—in ascending order, the Brookville(?), Clarion, and Scrubgrass coals, which are below the Vanport Limestone Member; and the Lower, Middle, and Upper Kittanning coals, and the Lower and Upper Freeport coals, which are above the Vanport Limestone Member.

BROOKVILLE(?) COAL

The name Brookville was first used by Rogers (1858, p. 475) for a coal near the town of Brookville in Jefferson County, Pa. It is not known to which of several coals near Brookville he intended the name to be applied. A coal near Brookville that Platt, (1881, p. 106) designated as the Brookeville was later correlated by Graeber and Foose (1942, p. 50–51) with the Clarion coal. As used in this report, the Brookville(?) coal is stratigraphically the first coal above the Homewood Sandstone Member of the Pottsville Formation.

In Lawrence County, the Brookville(?) coal lies just above the Homewood Sandstone Member and 30–85 feet below the base of the Vanport Limestone Member. The coal is usually less than 14 inches thick, but in some areas, particularly in the northern part of the county, it is as much as 36 inches thick and is mined locally. Commonly the coal is overlain by a black fissile shale, as at section 21 (pl. 3). In places the coal contains a thick clay parting and is known as the Twin Vein. A coal noted at field observation points UN–1, UN–2, and UN–3 (pl. 1), and which was mapped as the Homewood by DeWolf (1929, pl. 4) is believed by the writers to be the Brookville(?).

CLARION COAL

The name Clarion was first used by Rogers (1858, p. 490) for a coal about 25 feet above the Brookville(?) coal in Clarion County, Pa. In Lawrence County, the Clarion coal ranges from a few feet to about 20 feet above the Brookville(?) coal and from 20 to 55 feet below the base of the Vanport Limestone Member. It is generally less than 14 inches thick in southern and western Lawrence County. (See pl. 3, sections 12, 14, 25, and 26; and pl. 4, section 4.) In Washington Township, northeastern Lawrence County, a drill hole penetrated 30 inches of coal at the approximate stratigraphic position of the Clarion (pl. 3, section 29). In Neshannock Township, north-central Lawrence County, the Clarion coal is less than 28 inches thick and is mined locally by stripping methods.

SCRUBGRASS COAL

The Scrubgrass coal was named by Rogers (1858, p. 491) from exposures on Scrubgrass Creek in Venango County. In Lawrence County the Scrubgrass coal is less than an inch to a maximum of 6 feet below the Vanport Limestone Member. The coal ranges in thickness from a film to about 3 feet, but the thicker coal occurs in lenses of small areal extent and is of little economic importance.

KITTANNING COALS

The Lower, Middle, and Upper Kittanning coals have been correlated over large areas in western Pennsylvania. In Lawrence County these coals are readily distinguished by their position between the Vanport Limestone and the Freeport Sandstone Members. The Middle Kittanning bed is the thickest and best coal in the county and is actively mined at many places. For this reason it serves as a marker for the Lower and Upper Kittanning coals.

Lower Kittanning coal.—In Lawrence County the Lower Kittanning coal is 15–30 feet above the Vanport Limestone Member and 40–80 feet below the Middle Kittanning coal. The Lower Kittanning coal is very thin or absent over the eastern part of the county. At field observation point SR–1 (pl. 1), it is only a few inches thick. In the Slippery Rock Creek area at field observation points PE–3, PE–6, PE–8 (pl. 1) and in section 14 (pl. 3), the position of the coal is occupied by a few inches of black shale. The coal thickens toward the south in Beaver County and toward the west in Ohio. In western Lawrence County the Lower Kittanning coal ranges in thickness from 15 to 36 inches and averages about 24 inches. A medial parting of fusain or clay is common.

In many places the Lower Kittanning coal is underlain by a bed of commercially valuable fire clay, which may be as much as 12 feet thick. When freshly exposed, this fire clay is light bluish gray and massive. After exposure to weathering for several months the clay assumes a pillowy appearance, and upon further exposure it breaks or crumbles into small irregular chips or shardlike fragments.

Middle Kittanning coal.—The Middle Kittanning coal, known locally as the Three-foot bed, is the most extensively mined coal in Lawrence County. It is 60–101 feet above the Vanport Limestone Member and 40–80 feet above the Lower Kittanning coal. The Middle Kittanning coal ranges in thickness from 22 to 53 inches and averages about 30 inches. Where the coal bed is thick, it usually contains several thick partings. At field observation point NB–7 (pl. 1), the bed is 53-inches thick and contains several partings, one of which is 14 inches thick. In the southwestern part of the county, the coal usually contains only one or two partings ½–2 inches thick. A bed of clay 0–3 feet thick underlies the coal.

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Upper Kittanning coal.—The Upper Kittanning coal is 10–60 feet above the Middle Kittanning coal, and at most places is only a few inches or a few feet below the Freeport Sandstone Member. This sandstone ranges in thickness from 0 to 60 feet and is typically medium to coarse grained, friable, iron stained, and crossbedded. The Upper Kittanning coal is thin and discontinuous and at many places is represented by coaly shale. In the southwestern part of the county, it is thick enough to mine locally. Near section 2 (pl. 4) it is 11 inches thick, and at Coverdale it is reported to be 26 inches thick (DeWolf, 1929, p. 40).

FREEPORT COALS

Next above the Upper Kittanning coal are two coals known as the Lower and the Upper Freeport coals (fig. 3). These names are in general use over large areas in western Pennsylvania for coals occurring at or near the same stratigraphic positions. In Lawrence County the Lower and the Upper Freeport coals can be identified by their stratigraphic positions above the Upper Kittanning coal and below the conspicuous Mahoning Sandstone Member at the base of the Conemaugh Formation. The two coals are also distinctive in that both are underlain locally by thin limestone beds known as the Lower and the Upper Freeport Limestone Members of Platt (1877).

Lower Freeport coal.—The Lower Freeport coal is typically 35–80 feet above the Upper Kittanning coal and 20–60 feet below the Upper Freeport coal. Over most of the northern half of the county the Lower Freeport coal is thin and discontinuous or has been eroded. It thickens in a southward direction, and locally in Little Beaver Township in the southwest corner of the county it is more than 42 inches thick. In Perry Township in the southeast corner of the county, it is less than 28 inches thick but is mined locally. Even in the southern part of the county, however, the coal is discontinuous. In places it grades laterally into cannel shale or is cut out by channels formed during deposition of the overlying Butler Sandstone Member. The Lower Freeport Limestone, which lies 0–3 feet below the Lower Freeport coal at many places, ranges in thickness from 0 to 5 feet and averages about 3 feet. However, this limestone weathers rapidly and usually is exposed only in steep roadcuts, strip pits, and a few gullies.

Upper Freeport coal.—The Upper Freeport coal lies from 0 to 30 feet below the base of the Mahoning Sandstone Member of the Conemaugh Formation; locally it is cut out by channels formed during deposition of the Mahoning Sandstone Member. The coal has been eroded over most of the northern part of the county, and it is exposed only in the southern part in Slippery Rock, Shenango, and North Beaver Townships. Measured thicknesses in this area range from 11 to 31 inches. DeWolf (1929, p. 103) reported the coal to be 62 inches

thick about a mile south of Coverdale, but this thickening is believed to be atypical. The Upper Freeport Limestone, which typically lies several feet below the Upper Freeport coal, ranges in thickness from 0 to 1 foot and is rarely exposed.

CONEMAUGH FORMATION

The basal part of the Conemaugh Formation, generally less than 100 feet thick, crops out on the tops of the higher hills in the southeastern part of Lawrence County. At the base of the formation is the Mahoning Sandstone Member, which serves as a marker for the underlying Freeport coals. The Mahoning Sandstone Member is made up of medium- to coarse-grained massive sandstone in beds individually as much as 10 feet thick. Locally, it forms a cliff 50 feet or more in height. In places a thin sequence of fine- to medium-grained even-bedded sandstone or dark-brown silty shale underlies the massive beds of the Mahoning and separates it from the underlying Upper Freeport coal. This sequence locally contains a thin coal, here termed the Mahoning(?) coal.

MAHONING(?) COAL

The Mahoning(?) coal is thin at all exposures and is of no economic importance. This coal, called the Mahoning in Ohio, is probably stratigraphically lower than the Mahoning coal of areas to the south and southeast. In Beaver County, for example, the Mahoning coal lies about 20 feet stratigraphically above a thick massive sandstone, interpreted as the Mahoning Sandstone Member, and it is underlain by a thin limestone bed. In his report on the New Castle quadrangle, DeWolf (1929, p. 32) assigned the local name New Palestine to the coal here termed the Mahoning(?) as a means of emphasizing the uncertainties of regional correlation.

STRUCTURE

Lawrence County lies in the north-central part of the northern Appalachian coal field where the regional dip is southward at angles of 1° or less. In Lawrence County the regional dip is interrupted by several broad gentle northeast-trending anticlines and synclines, which generally can be detected only by preparation of detailed structure contour maps. The maximum change in elevation of a datum across these flexures rarely exceeds 100 feet, and local dips rarely exceed 2° or 3°.

Homewood anticline.—The Homewood anticline is the largest and most pronounced of several flexures. The axis of this anticline extends northeastward across Beaver County to Ellwood City on the southern boundary of Lawrence County. From Ellwood City, the axis trends north-northeastward across Lawrence County in the direction of Energy, then continues northeastward to a point 1 mile

south of Slippery Rock in Butler County. Throughout its extent in Lawrence County, the anticline is characterized by low dips, and the axis can be traced only with careful study.

West New Castle anticline and Covert syncline.—The West New Castle anticline and the Covert syncline lie in the New Castle quadrangle northwest of the Homewood anticline. These two structures were identified by DeWolf (1929, pl. 5, sheet 5) by means of structure contours drawn on the Middle Kittanning coal. They were not observed by the writers outside the New Castle quadrangle.

Other structural features.—An unnamed syncline is present in southeastern Lawrence County, southeast of the Homewood anticline, between Slippery Rock Creek and Camp Run; a sequence of beds about 100 feet thick at the base of the Conemaugh Formation is preserved in this syncline. Other minor synclines and anticlines, approximately parallel to the Homewood anticline, occur in northeastern Lawrence County in the Plain Grove Township.

COAL RESERVES

As estimated during the course of the present study, the original reserves of coal in Lawrence County before mining began totaled 782 million tons, of which 209 million tons is classified as measured, 308 million tons as indicated, and 265 million tons as inferred. The distribution of these reserves by beds, by thickness of coal, and by thickness of overburden is shown in tables 1–3. The quadrangle areas used for breakdown of reserve data are shown on figure 4. The outcrops, mined areas, and regional variations in thickness of individual beds are shown on plate 5 (A–J).

The reserves are contained in 12 beds, but are largely concentrated in the Lower and Middle Kittanning coal beds and in the Homewood coal bed as shown below:

Coal bed	*Original reserves (millions of short tons)*	*Coal bed*	*Original reserves (millions of short tons)*
Lower Kittanning	205. 26	Upper Freeport	19. 76
Middle Kittanning	201. 75	Quakertown	17. 11
Homewood	155. 26	Clarion	7. 14
Lower Mercer	50. 81	Middle Mercer	6. 54
Brookville(?)	45. 25	Mahoning(?)	. 07
Upper Mercer	39. 42		
Lower Freeport	33. 65	Total	782. 02

Of the original reserves of 782 million tons, a total of about 28 million tons had been mined and lost in mining as of January 1, 1957, that is, 754 million tons remained in the ground as of that date. As shown in the following table, this total includes 67 million tons of

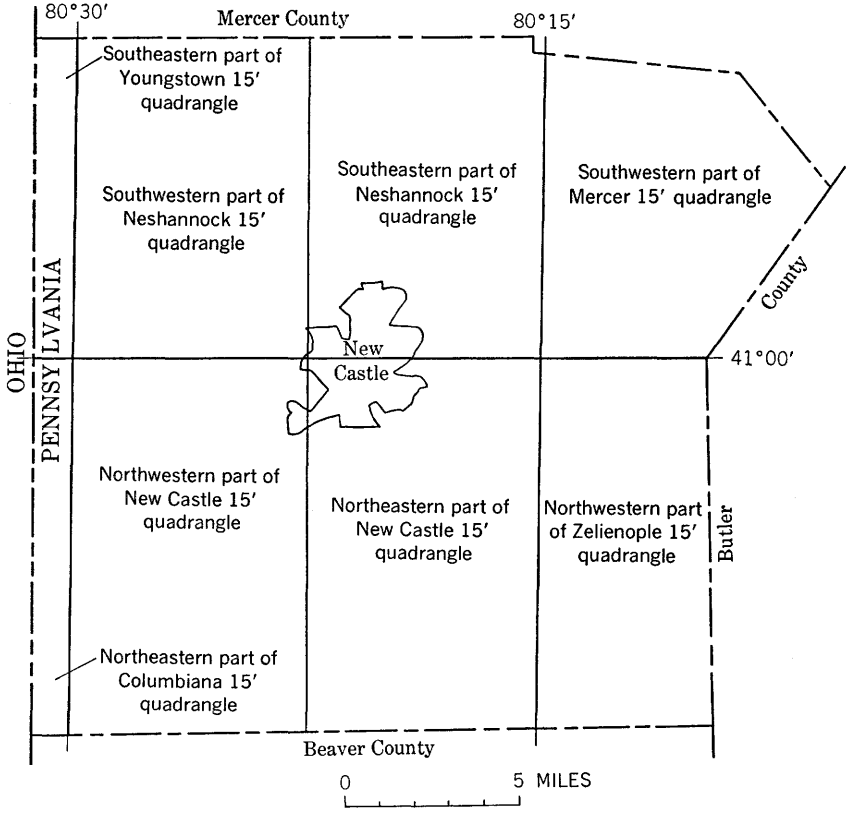

FIGURE 4.—Outline map of Lawrence County, Pa., showing quadrangle areas used for breakdown of reserve shown in tables 1 and 2.

coal less than 60 feet below the surface, which is considered suitable for strip mining, and 687 million tons between 60 and 1,000 feet below the surface, which is considered suitable for underground mining.

Coal reserves of Lawrence County, Pa., as of January 1, 1957

[In millions of short tons]

Overburden	Original reserves	Reserves depleted		Remaining reserves	Recoverable reserves [2]
		Production (1881–1956)[1]	Production plus loss in mining [2]		
0–60 ft	73	[3] 5	6	67	54
60–1,000 ft	709	[4] 11	22	687	344
Total	782	16	28	754	398

[1] From Maize and Struble (1955) and from Pennsylvania Dept. of Mines.
[2] Based on assumption of 80-percent recovery in strip mining and 50-percent recovery in underground mining.
[3] During 1945–56, inclusive, 4,745,255 tons was mined by stripping methods.
[4] During 1881–1956, inclusive, 11,175,378 tons was mined largely by underground methods; total includes small amount of coal mined by stripping methods prior to 1945.

TABLE 1.—*Estimated original coal reserves of Lawrence County, Pa., less than 60 feet below the surface, by beds and by quadrangles*

[In millions of short tons. Quadrangle areas shown on fig. 4]

Formation and coal bed	Measured reserves				Indicated reserves				Inferred reserves				Total all categories			Grand total
	14–28 inches	28–42 inches	>42 inches	Total	14–28 inches	28–42 inches	>42 inches	Total	14–28 inches	28–42 inches	>42 inches	Total	14–28 inches	28–42 inches	>42 inches	
Southwest part of Neshannock 15-minute quadrangle and southeast part of Youngstown 15-minute quadrangle																
Allegheny:																
Lower Kittanning	0.56			0.56									0.56			0.56
Brookville(?)	.66	3.35		4.01		1.27		1.27	0.47	1.23		1.70	1.13	5.85		6.98
Pottsville:																
Homewood	.02	3.79	0.17	3.98	0.74	2.12		2.86					.76	5.91	0.17	6.84
Upper Mercer		1.49	.24	1.73	.17	.52		.69					.17	2.01	.24	2.42
Lower Mercer		.63		.63		.76		.76	.49	.27		.76	.49	1.66		2.15
Total	1.24	9.26	0.41	10.91	0.91	4.67		5.58	0.96	1.50		2.46	3.11	15.43	0.41	18.95
Southeast part of Neshannock 15-minute quadrangle																
Allegheny:																
Middle Kittanning	0.93			0.93									0.93			0.93
Lower Kittanning	.16	0.08		.24									.16	0.08		.24
Clarion	.07			.07									.07			.07
Brookville(?)	.64			.64	0.42			0.42					1.06			1.06
Pottsville:																
Homewood	.02	.43		.45									.02	.43		.45
Upper Mercer	.27	.29		.56		0.61		.61	0.22	0.10		0.32	.49	1.00		1.49
Lower Mercer	.07			.07					1.36			1.36	1.43			1.43
Total	2.16	0.80		2.96	0.42	0.61		1.03	1.58	0.10		1.68	4.16	1.51		5.67
Southwest part of Mercer 15-minute quadrangle																
Allegheny:																
Middle Kittanning	0.37	2.58		2.95	0.09	0.62		0.71					0.46	3.20		3.66
Lower Kittanning	.27			.27		.25		.25	0.07	2.13		2.20	.34	2.38		2.72
Total	.64	2.58		3.22	0.09	0.87		0.96	0.07	2.13		2.20	0.80	5.58		6.38

Northwest part of New Castle 15-minute quadrangle and northeast part of Columbiana 15-minute quadrangle

Allegheny:																
Upper Freeport	0.03			0.03									0.03			0.03
Lower Freeport	.11	0.67	0.03	.81	0.11	1.09		1.20					.22	1.76	0.03	2.01
Middle Kittanning	1.26	2.88		4.14	2.83	4.32		7.15					4.09	7.20		11.29
Lower Kittanning	2.11	.68		2.79	3.02	1.36		4.38	6.30	0.58		6.88	11.43	2.62		14.05
Pottsville:																
Homewood	.18	.08		.26	.25			.25					.43	.08		.51
Total	3.69	4.31	0.03	8.03	6.21	6.77		12.98	6.30	0.58		6.88	16.20	11.66	0.03	27.89

Northeast part of New Castle 15-minute quadrangle

Allegheny:																
Upper Freeport	0.09		0.46	0.55			0.84	0.84					0.09		1.30	1.39
Lower Freeport	.01			.01									.01			.01
Middle Kittanning	1.89	0.55		2.44	1.46			1.46					3.35	0.55		3.90
Lower Kittanning	.30			.30									.30			.30
Total	2.29	0.55	0.46	3.30	1.46		0.84	2.30					3.75	0.55	1.30	5.60

Northwest part of Zelienople 15-minute quadrangle

Conemaugh:																
Mahoning(?)	0.01			0.01									0.01			0.01
Allegheny:																
Upper Freeport	.06			.06									.06			.06
Lower Freeport	1.41			1.41									1.41			1.41
Middle Kittanning	2.62	2.45		5.07	1.18	1.08		2.26					3.80	3.53		7.33
Lower Kittanning	.05			.05									.05			.05
Total	4.15	2.45		6.60	1.18	1.08		2.26					5.33	3.53		8.86
Grand Total	14.17	19.95	0.90	35.02	10.27	14.00	0.84	25.11	8.91	4.31		13.22	33.35	38.26	1.74	73.35

TABLE 2.—*Estimated original coal reserves of Lawrence County, Pa., 60–1,000 feet below the surface, by beds and by quadrangles*

[In millions of short tons. Quadrangle areas shown on fig. 4]

Formation and bed	Measured reserves				Indicated reserves				Inferred reserves				Total all categories			Grand total
	14–28 inches	28–42 inches	>42 inches	Total	14–28 inches	28–42 inches	>42 inches	Total	14–28 inches	28–42 inches	>42 inches	Total	14–28 inches	28–42 inches	>42 inches	
Southwest part of Neshannock 15-minute quadrangle and southeast part of Youngstown 15-minute quadrangle																
Allegheny:																
Lower Kittanning	0.05			0.05									0.05			0.05
Brookville(?)	1.01	0.25		1.26	0.64			0.64	1.02			1.02	2.67	0.25		2.92
Pottsville:																
Homewood	2.84	8.86	0.15	11.85	4.98	1.54		6.52	3.49			3.49	11.31	10.40	0.15	21.86
Upper Mercer	.74	3.68	.57	4.99	1.54			1.54					2.28	3.68	.57	6.53
Lower Mercer	.75	.62	.19	1.56	2.26	6.95		9.21	.45	4.70		5.15	3.46	12.27	.19	15.92
Quakertown	.66	.42		1.08	.74	1.29		2.03	6.18	7.82		14.00	7.58	9.53		17.11
Total	6.05	13.83	0.91	20.79	10.16	9.78		19.94	11.14	12.52		23.66	27.35	36.13	0.91	64.39
Southeast part of Neshannock 15-minute quadrangle																
Allegheny:																
Middle Kittanning	1.31			1.31	0.50			0.50					1.81			1.81
Lower Kittanning		0.66		.66	1.29			1.29	10.63			10.63	11.92	0.66		12.58
Clarion	1.25			1.25	.98	0.80		1.78	3.83	0.21		4.04	6.06	1.01		7.07
Brookville(?)	1.54			1.54	4.36			4.36	7.60	3.15		10.75	13.50	3.15		16.65
Pottsville:																
Homewood	6.20	10.84	1.46	18.50	20.13	21.55		41.68	1.71			1.71	28.04	32.39	1.46	61.89
Upper Mercer	.64	.04		.68	4.35	.91		5.26	22.87	.17		23.04	27.86	1.12		28.98
Lower Mercer	1.36			1.36	8.23			8.23	21.03			21.03	30.62			30.62
Total	12.30	11.54	1.46	25.30	39.84	23.26		63.10	67.67	3.53		71.20	119.81	38.33	1.46	159.60
Southwest part of Mercer 15-minute quadrangle																
Allegheny:																
Middle Kittanning	0.38	8.27		8.65	3.09	4.17		7.26	1.54			1.54	5.01	12.44		17.45
Lower Kittanning	.74	.42		1.16	.89	3.14		4.03	9.24	27.38		36.62	10.87	30.94		41.81
Brookville(?)	.26	5.43		5.69	.89	5.03		5.92	4.63	.64	0.76	6.03	5.78	11.10	0.76	17.64

Pottsville:																
Homewood	4.28	2.24		6.52	20.00	2.76		22.76	5.63			5.63	29.91	5.00		34.91
Lower Mercer						.69		.69						.69		.69
Total	5.66	16.36		22.02	24.87	15.79		40.66	21.04	28.02	0.76	49.82	51.57	60.17	0.76	112.50
Northwest part of New Castle 15-minute quadrangle and northeast part of Columbiana 15-minute quadrangle																
Allegheny:																
Upper Freeport	0.29	0.23	0.02	0.54	1.55	2.82		4.37		0.59		0.59	1.84	3.64	0.02	5.50
Lower Freeport	.22	1.74	1.22	3.18	1.56	8.41	0.26	10.23	0.55	5.78		6.33	2.33	15.93	1.48	19.74
Middle Kittanning	6.20	14.82		21.02	12.11	25.16		37.27	4.62			4.62	22.93	39.98		62.91
Lower Kittanning	5.90	1.98		7.88	18.50	7.19		25.69	37.71	16.75		54.46	62.11	25.92		88.03
Pottsville:																
Homewood	2.74	.11		2.85	5.37			5.37	1.01			1.01	9.12	.11		9.23
Total	15.35	18.88	1.24	35.47	39.09	43.58	0.26	82.93	43.89	23.12		67.01	98.33	85.58	1.50	185.41
Northeast part of New Castle 15-minute quadrangle																
Allegheny:																
Upper Freeport	0.18		4.57	4.75	0.27	0.14	0.08	0.49	1.06	0.15		1.21	1.51	0.29	4.65	6.45
Lower Freeport	.12			.12	1.80			1.80					1.92			1.92
Middle Kittanning	15.54	4.00		19.54	19.05	.57		19.62	2.48			2.48	37.07	4.57		41.64
Lower Kittanning	1.49			1.49	6.62			6.62	30.75			30.75	38.86			38.86
Pottsville:																
Middle Mercer					.36			.36					.36			.36
Total	17.33	4.00	4.57	25.90	28.10	0.71	0.08	28.89	34.29	0.15		34.44	79.72	4.86	4.65	89.23
Northwest part of Zelienople 15-minute quadrangle																
Conemaugh:																
Mahoning(?)	0.06			0.06									0.06			0.06
Allegheny:																
Upper Freeport	1.14			1.14	4.94			4.94	0.25			0.25	6.33			6.33
Lower Freeport	2.54	0.43		2.97	4.35	0.88		5.23	.36			.36	7.25	1.31		8.56
Middle Kittanning	19.83	12.45		32.28	11.51	7.04		18.55					31.34	19.49		50.83
Lower Kittanning	.27			.27	1.22			1.22	4.52			4.52	6.01			6.01
Pottsville:																
Homewood	4.85	1.08		5.93	13.44			13.44	.20			.20	18.49	1.08		19.57
Middle Mercer	1.61			1.61	4.57			4.57					6.18			6.18
Total	30.30	13.96		44.26	40.03	7.92		47.95	5.33			5.33	75.66	21.88		97.54
Grand total	86.99	78.57	8.18	173.74	182.09	101.04	0.34	283.47	183.36	67.34	0.76	251.46	452.44	246.95	9.28	708.67

TABLE 3.—*Estimated original coal reserves of Lawrence County, Pa., by beds and by thickness of overburden*

[In millions of short tons]

Formation and coal bed	Measured reserves				Indicated reserves				Inferred reserves				Total all categories			Grand total
	14–28 inches	28–42 inches	>42 inches	Total	14–28 inches	28–42 inches	>42 inches	Total	14–28 inches	28–42 inches	>42 inches	Total	14–28 inches	28–42 inches	>42 inches	
Overburden 0–60 feet																
Conemaugh:																
Mahoning(?)	0.01			0.01									0.01			0.01
Allegheny:																
Upper Freeport	.18		0.46	.64			0.84	0.84					.18		1.30	1.48
Lower Freeport	1.53	0.67	.03	2.23	0.11	1.09		1.20					1.64	1.76	.03	3.43
Middle Kittanning	7.07	8.46		15.53	5.56	6.02		11.58					12.63	14.48		27.11
Lower Kittanning	3.45	.76		4.21	3.02	1.61		4.63	6.37	2.71		9.08	12.84	5.08		17.92
Clarion	.07			.07									.07			.07
Brookville(?)	1.30	3.35		4.65	.42	1.27		1.69	.47	1.23		1.70	2.19	5.85		8.04
Pottsville:																
Homewood	.22	4.30	.17	4.69	.99	2.12		3.11					1.21	6.42	.17	7.80
Upper Mercer	.27	1.78	.24	2.29	.17	1.13		1.30	.22	.10		.32	.66	3.01	.24	3.91
Middle Mercer																
Lower Mercer	.07	.63		.70		.76		.76	1.85	.27		2.12	1.92	1.66		3.58
Quakertown																
Total	14.17	19.95	0.90	35.02	10.27	14.00	0.84	25.11	8.91	4.31		13.22	33.35	38.26	1.74	73.35
Overburden 60–1000 feet																
Conemaugh:																
Mahoning(?)	0.06			0.06									0.06			0.06
Allegheny:																
Upper Freeport	1.61	0.23	4.59	6.43	6.76	2.96	0.08	9.80	1.31	0.74		2.05	9.68	3.93	4.67	18.28
Lower Freeport	2.88	2.17	1.22	6.27	7.71	9.29	.26	17.26	.91	5.78		6.69	11.50	17.24	1.48	30.22
Middle Kittanning	43.26	39.54		82.80	46.26	36.94		83.20	8.64			8.64	98.16	76.48		174.64
Lower Kittanning	8.45	3.06		11.51	28.52	10.33		38.85	92.85	44.13		136.98	129.82	57.52		187.34
Clarion	1.25			1.25	.98	.80		1.78	3.83	.21		4.04	6.06	1.01		7.07
Brookville(?)	2.81	5.68		8.49	5.89	5.03		10.92	13.25	3.79	0.76	17.80	21.95	14.50	.76	37.21
Pottsville:																
Homewood	20.91	23.13	1.61	45.65	63.92	25.85		89.77	12.04			12.04	96.87	48.98	1.61	147.46
Upper Mercer	1.38	3.72	.57	5.67	5.89	.91		6.80	22.87	.17		23.04	30.14	4.80	.57	35.51
Middle Mercer	1.61			1.61	4.93			4.93					6.54			6.54
Lower Mercer	2.11	.62	.19	2.92	10.49	7.64		18.13	21.48	4.70		26.18	34.08	12.96	.19	47.23
Quakertown	.66	.42		1.08	.74	1.29		2.03	6.18	7.82		14.00	7.58	9.53		17.11
Total	86.99	78.57	8.18	173.74	182.09	101.04	0.34	283.47	183.36	67.34	0.76	251.46	452.44	246.95	9.28	708.67
Grand total	101.16	98.52	9.08	208.76	192.36	115.04	1.18	308.58	192.27	71.65	0.76	264.68	485.79	285.21	11.02	782.02

METHODS OF PREPARING ESTIMATES

The size of an estimate of coal reserves is determined primarily by the assumption made as to the minimum thickness of coal and maximum thickness of overburden considered. Other factors such as methods of determining continuity or correlation of beds and the weight of coal influence the size of the estimate to a lesser degree but are important in understanding the significance of the estimate. To be of greatest usefulness, estimates must also be classified according to the rank of coal and according to the relative abundance and reliability of data used in preparing the estimate. Following are the assumptions and procedures used in calculating and classifying the coal reserves of Lawrence County.

CLASSIFICATION ACCORDING TO CHARACTERISTICS OF THE COAL

Rank of coal.—Most of the coal in Lawrence County is of high-volatile *A* bituminous rank as determined by the standard classification of the American Society for Testing Materials (1954). (See table 4.)

TABLE 4.—*Classification of coals by rank*

[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. FC, fixed carbon; VM, volatile matter; Btu, British thermal units. From American Society for Testing Materials (1954, p. 80)]

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 than 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 of coal.—For uniformity in making calculations, all the coal in Lawrence County was assumed to weigh 1,800 tons per acre-foot.

Thickness of beds.—In tables 1–3 the reserves are divided into three categories according to the thickness of beds as follows: 14–28 inches, 28–42 inches, and more than 42 inches. The 14- to 28-inch category represents coal that must be mined either by stripping methods or underground by hand. Such coal is of little economic interest at the present time. The 28- to 42-inch category represents coal that can be mined underground by machine but must be loaded by hand. Coal more than 42 inches thick can be mined by completely mechanized methods. In Lawrence County, 62 percent of the estimated reserves is in the 14- to 28-inch category, 36.5 percent is in the 28- to 42-inch category, and only 1.5 percent is more than 42 inches thick.

Thickness of overburden.—All the minable coal in Lawrence County is less than 1,000 feet below the surface. Because most of the mining in the county is by stripping methods, the reserves in tables 1–3 are divided into two categories of overburden: 0 to 60 feet, and 60 to 1,000 feet. Reserves in the 0- to 60-foot category include only coal in which the ratio of thickness of overburden to thickness of coal does not exceed 20:1 and in which the belts of coal are at least 200 feet wide. As shown in the tables, about 9 percent of the estimated reserves in Lawrence County is in the 0- to 60-foot category and 91 percent is in the 60- to 1,000-foot category.

CLASSIFICATION ACCORDING TO RELATIVE ABUNDANCE OF INFORMATION

The estimates of coal reserves in Lawrence County are also divided into three categories according to the relative abundance of reliable information. These categories, termed "measured," "indicated," and "inferred," are defined below:

Measured reserves are those for which tonnage is computed from the thicknesses of the coal beds revealed in outcrops, prospect openings, mine workings, and drill holes. The points of observation are so closely spaced and the thickness and extent of the coal so well defined that computed tonnage is considered to be within 20 percent of the true tonnage. Although the spacing of points of observation necessary to demonstrate continuity of coal varies in different regions according to the character of the coal beds and the geologic structure, points of observation are generally about half a mile apart.

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, the points of coal measurement are about 1 mile apart, but they may be as much as 1½ miles apart in beds of known geologic continuity.

Inferred reserves are those for which quantitative estimates are based on a broad knowledge of the bed or region and for which there are few, if any, measurements of the coal. The estimates are based on an assumed continuity for which there is good geologic evidence. In general, inferred reserves lie more than 2 miles from points of observed thickness.

DISTINCTION BETWEEN ORIGINAL, REMAINING, AND RECOVERABLE RESERVES

As used in this report, original reserves are the total reserves in the ground before mining began. The tonnages cited in tables 1–3 are for original reserves.

Remaining reserves as of January 1, 1957, are the unmined reserves remaining in the ground on that date. The figures for remaining reserves are obtained by subtracting from original reserves the cumulative production through 1956 plus an allowance for coal lost in past mining.

Recoverable reserves as of January 1, 1957, are the reserves considered to be recoverable in the future. The figures are obtained by subtracting from remaining reserves the estimated future losses in mining.

The remaining and recoverable reserves in Lawrence County were calculated on the assumption that in strip mining, both past and future, 80 percent of the coal in the ground is recovered and 20 percent is lost, and in underground mining 50 percent of the coal in the ground is recovered and 50 percent is lost. As shown in the table on page 17, the remaining reserves of Lawrence County, as of January 1, 1957, totaled 754 million tons and the recoverable reserves as of the same date totaled 398 million tons.

METHOD OF RECORDING DATA AND MAKING CALCULATIONS

The locations of the observed outcrops of coal beds in Lawrence County were plotted on topographic base maps, and the lateral extent of the coal was determined from outcrop, drill-hole, and mine data. Measurements of coal thickness from these sources were plotted on the maps, and thickness lines were drawn so as to divide the coal into the three thickness categories—14 to 28 inches, 28 to 42 inches, and more than 42 inches. Other lines were drawn to divide the bed into the measured, indicated, and inferred categories as defined above.

Within each of the areas thus defined, the average thickness of the coal was determined from the existing measurements. The figures used excluded all partings more than three-eighths of an inch thick and all parts of beds or beds where the thickness of partings exceeded the thickness of coal.

The acreage in each category of reserves was determined by use of a planimeter, and the tonnage of coal was calculated by multiplying the number of acres by the average thickness of the coal, measured in feet and tenths, by 1,800, the assumed weight of coal in tons per acre-foot. The results of the calculations are presented in tables 1–3.

PREVIOUS ESTIMATES OF RESERVES IN LAWRENCE COUNTY

A previous detailed estimate of reserves in Lawrence County was prepared by Reese and Sisler (1928, p. 115–119) as part of a general study of the bituminous coal resources of Pennsylvania. The methods used by Reese and Sisler were similar to those employed in the present study, but their assumptions as to the minimum thickness of coal included, the number of beds included, and the assumed weight of coal were slightly more conservative than those used in the present estimate, as shown in the following table.

Comparison of past and present estimates of coal reserves in Lawrence County, Pa.

Source of estimate	Estimated original reserves (millions of short tons)	Assumptions used in preparing estimates		
		Minimum coal thickness (inches)	Beds included	Assumed weight of coal (tons per acre-foot)
This report	782	14	12	1,800
Reese and Sisler (1928)	1,008	18	6	1,688
Ashley (1944)	[1] 1,110			

[1] Reese and Sisler estimate increased 10 percent on basis of findings in nearby areas.

In spite of the several more conservative assumptions, the Reese and Sisler estimate of 1,008 million tons for the original reserves of Lawrence County is 22 percent larger than the present estimate of 782 million tons. This difference is explained primarily by the fact that Reese and Sisler assumed greater continuity and thickness for the Brookville(?) coal and obtained the relatively large figure of 315 million tons as the original reserves in this bed, whereas in the present study the much smaller figure of 45 million tons was obtained. Other differences between the two estimates are of smaller magnitude and tend to be self compensating.

In a general report on the mineral resources of Pennsylvania, Ashley (1944, p. 83) proposed the larger figure of 1,110 million tons as the original reserves in Lawrence County. This figure is a 10-percent increase in the Reese and Sisler estimate and was made by Ashley because detailed work in other parts of Pennsylvania after the Reese and Sisler estimate was prepared yielded larger estimates of reserves.

The present estimate of 782 million tons for the original reserves of the county is believed more accurate than the estimates of Reese and Sisler and of Ashley because it is based on modern data and because it is classified according to thickness of beds, thickness of overburden, and relative abundance of information.

QUALITY OF COAL

Most of the coal in Lawrence County is of high-volatile *A* bituminous rank and is relatively high in heat value. Analyses published by the U.S. Bureau of Mines (1939) and by Aresco, Haller, and Abernethy (1955, 1956) show moisture contents ranging from 3 to 10 percent; ash contents, calculated on the as-received basis, ranging from 1.4 to 18.2 percent; and sulfur contents, calculated on the as-received basis, ranging from 0.9 to 5.4 percent. These and other analyses are presented in table 5.

PRODUCTION OF COAL

As recorded by the Pennsylvania Department of Mines, coal production in Lawrence County during the period 1881 to 1956, inclusive, totaled 15,920,613 tons (Maize and Struble, 1955). About 70 percent of the total has been mined by underground methods, and about 30 percent has been mined by strip-mining methods. In the early days of mining all production was by underground methods. The transition to strip-mining methods began in the late 1930's and early 1940's, and since 1945 virtually the entire production has been by stripping methods. The annual production of coal in Lawrence County is shown on figure 5; the annual production expressed as percent of total production of bituminous coal in Pennsylvania is shown on figure 6.

TABLE 5.—*Analyses of coal in Lawrence County, Pa.*

[Kind of sample: U, underground mine; S, strip mine; P, prospect pit; T, tipple. Form of analysis: 1, as received; 2, moisture free; 3, moisture and ash free; 4, as received, but some moisture probably lost between time of sampling and analysis]

Coal bed and location	Size of sample (inches)	U.S. Bureau of Mines sample no. or published source	Kind of sample	Form of analysis	Proximate				Ultimate					Heat value (Btu)	Softening temperature of ash (°F)
					Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen		
Upper Freeport: Big Beaver Tp.; 2 mi. south of Wampum		34736	U	1	3.8	38.2	51.9	6.1	2.6					13,470	2,130
		34737	U	1	3.8	38.6	52.5	5.1	2.4					13,530	2,190
		[1] 34738	U	1	3.8	38.4	52.2	5.6	2.6	5.5	75.0	1.5	9.8	13,540	
				2		40.0	54.2	5.8	2.7	5.3	78.0	1.6	6.6	14,080	
				3		42.4	57.6		2.8	5.6	82.8	1.7	7.1	14,950	
Lower Freeport: Big Beaver Tp.; near Wampum		86807	P	1	10.0	30.5	51.7	7.8	.9					11,020	
				2		33.9	57.4	8.7	1.0					12,240	
				3		37.1	62.9		1.1					13,410	
Perry Tp.		F-57435	S	1	3.3	37.2	52.6	6.9	2.2	5.5	75.1	1.5	8.8	13,490	2,240
				2		38.4	54.5	7.1	2.3	5.3	77.7	1.5	6.1	13,940	
				3		41.4	58.6		2.4	5.7	83.7	1.7	6.5	15,010	
Perry Tp.		F-57436	S	1	3.3	36.2	50.0	10.5	2.6	5.3	71.6	1.4	8.6	12,890	2,330
				2		37.4	51.8	10.8	2.7	5.1	74.0	1.5	5.9	13,320	
				3		42.0	58.0		3.0	5.7	83.0	1.7	6.6	14,940	
Middle Kittanning: Mahoning Tp.; near Edinburg	4	[2]	T	1	3.7	41.0	49.3	9.7	3.0					12,590	2,340
	4×4½	[2]	T	1	4.7	39.2	51.4	9.4	2.7					12,570	2,070
	1¼×1½	[2]	T	1	6.1	37.3	50.2	12.5	2.8					11,910	2,020
	½×0	[2]	T	1	8.4	34.0	47.8	18.2	4.1					10,820	2,020
Big Beaver Tp.; 2 mi. west of Wampum		34739	U	1	7.8	34.3	48.5	9.4	5.4					12,390	2,410
		34740	U	1	6.9	32.4	49.8	10.9	1.9					12,200	2,450
		34741	U	1	5.7	33.4	54.3	6.6	1.9					13,040	2,410
		[3] 34742	U	1	6.9	33.5	50.7	8.9	3.0	5.4	69.6	1.3	11.8	12,550	
				2		36.0	54.4	9.6	3.2	5.0	74.8	1.4	6.0	13,470	
				3		39.8	60.2		3.6	5.5	82.7	1.5	6.7	14,890	
Little Beaver Tp., Enon Valley	Run of mine	[4]	T	1	9.3	36.3	53.3	10.4	1.2					11,740	2,120

Lower Kittanning:														
Mahoning Tp.; near Hillsville		57431	S	1	4.9	38.7	53.1	3.3	1.9	5.6	76.1	1.6	11.5	13,660	2,150
				2		40.7	55.9	3.4	2.0	5.4	80.1	1.7	7.4	14,370	
				3		42.2	57.8		2.1	5.6	82.9	1.7	7.7	14,880	
		57432	S	1	5.4	38.0	53.1	3.5	2.4	5.7	75.2	1.6	11.6	13,520	2,220
				2		40.2	56.1	3.7	2.5	5.4	79.6	1.7	7.1	14,300	
				3		41.7	58.3		2.6	5.6	82.6	1.7	7.5	14,850	
Washington Tp.; near Harlansburg	4	(2)	T	1	4.0	40.5	51.8	7.7	1.1					13,790	2,550
	4×2	(2)	T	1	4.5	38.9	51.5	9.6	1.6					12,770	2,450
	2×1¼	(2)	T	1	5.4	37.3	50.7	12.0	1.9					12,310	2,440
	1¼×¾	(2)	T	1	7.0	35.8	51.1	13.1	2.2					11,920	2,380
	¾×0	(2)	T	1	6.9	33.8	50.7	15.5	2.2					11,460	2,220
Homewood:														
Mahoning Tp.; northeast of Robinson		F-57433	S	1	4.1	39.3	47.3	9.3	3.2	5.4	70.8	1.4	9.9	12,880	2,060
				2		40.9	49.4	9.7	3.4	5.2	73.9	1.5	6.3	13,430	
				3		45.3	54.7		3.7	5.8	81.8	1.6	7.1	14,870	
		F-57434	S	1	4.4	38.9	47.6	9.1	4.1	5.5	70.5	1.4	9.4	12,830	2,020
				2		40.7	49.8	9.5	4.2	5.2	73.7	1.5	5.9	13,420	
				3		45.0	55.0		4.7	5.8	81.5	1.6	6.4	14,830	
Quakertown:														
Mahoning Tp.; north of Robinson		(5)		4	2.03	42.1	44.2	7.1	4.1						
Mahoning(?):														
Perry Tp.; 5 mi. north of Wurtemburg:														
Upper bench		(5)		4	1.9	39.2	55.8	2.2	.7						
Lower bench		(5)		4	1.9	40.1	55.6	1.4	.8						
Upper Mercer:														
Taylor(?) Tp.; near Mahoningtown		(5)		4	1.1	48.1	44.0	4.6	1.9						

[1] U.S. Bureau of Mines (1939). Composite of samples 34736 and 34737.
[2] Aresco, Haller, and Abernethy (1956, p. 40).
[3] U.S. Bureau of Mines (1939). Composite of samples 34739 to 34741.
[4] Aresco, Haller, and Abernethy (1955, p. 35).
[5] White (1878, p. 25, 56, and 65).

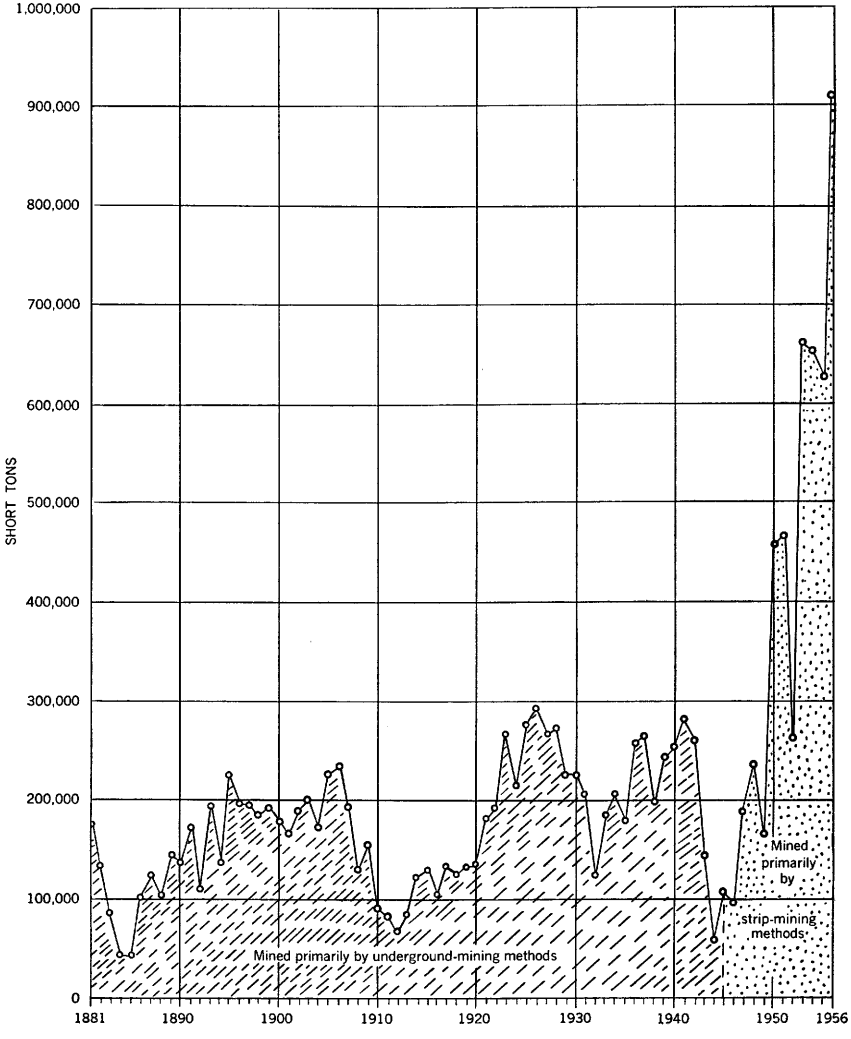

FIGURE 5.—Production of coal in Lawrence County, Pa., 1881–1956.

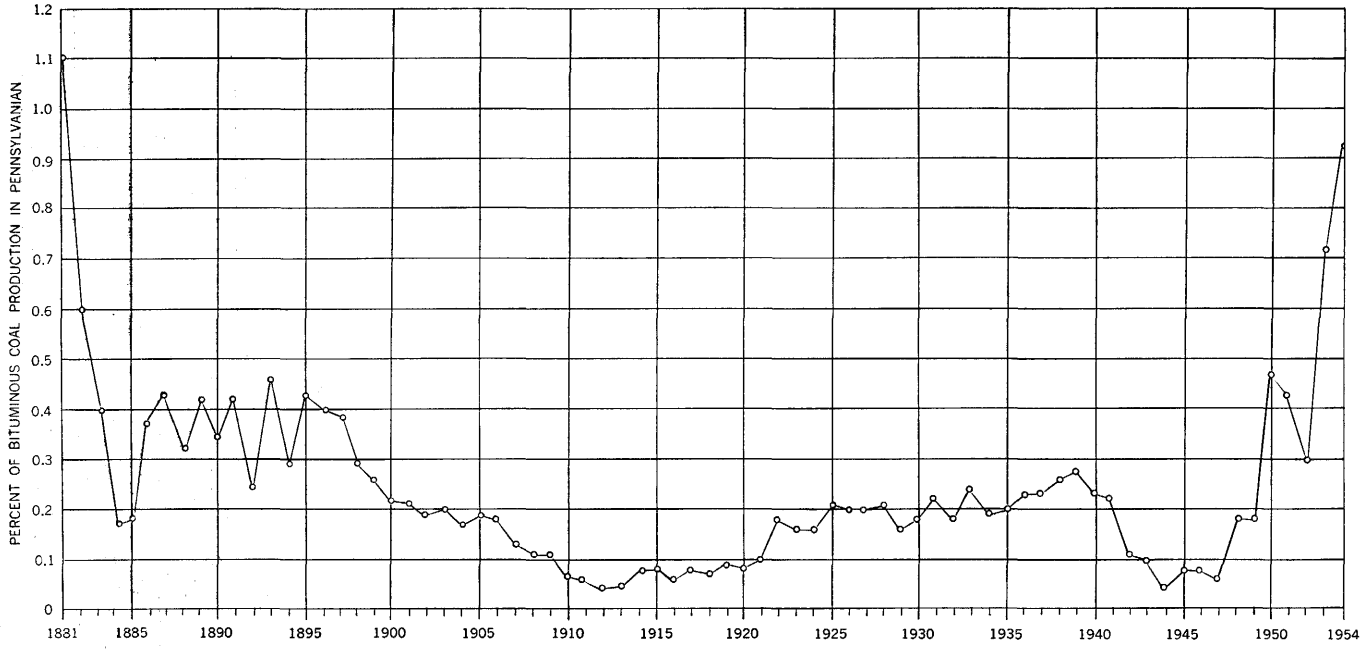

FIGURE 6.—Production of coal in Lawrence County, Pa., expressed as percent of total production of bituminous coal in Pennsylvania.

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