UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGY AND MINERAL RESOURCES

OF THE

BUTLER AND ZELIENOPLE QUADRANGLES

PENNSYLVANIA

GEOLOGICAL SURVEY BULLETIN 873

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Bulletin 873

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BY

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CONTENTS

ILLUSTRATIONS

GEOLOGY AND MINERAL RESOURCES OF THE BUTLER AND ZELIENOPLE QUADRANGLES, PENNSYLVANIA

By G. B. Richardson

ABSTRACT

This report is one of a series of publications on the geology and mineral resources of the Appalachian Plateaus. The areas described are the Butler and Zelienople quadrangles, which together include about 450 square miles in Butler, Beaver, and Lawrence Counties, western Pennsylvania.

The exposed rocks consist of 800 feet of strata of middle Carboniferous (Pennsylvanian) age, which, in the northwestern part of the Zelienople quadrangle, are mantled with glacial deposits that mark the southernmost extent in this region of the ice sheet that occupied the northern part of the continent in Pleistocene time. The exposed consolidated beds include the lower half of the Conemaugh formation, the underlying Allegheny, and the upper part of the Pottsville formation. Drilling for oil and gas shows the general character of several thousand feet of beds of Mississippian and Devonian age. The area is situated in the central part of the Pittsburgh-Huntington Basin, a synclinorium that lies between the Cincinnati anticline and the Allegheny Front.

The mineral resources are varied. Limestone, sandstone, and shale are present in practically unlimited quantity. There are extensive deposits of clay, which, however, have not yet been exploited. Before the Lake Superior ore became available iron ore was mined in this area. A satisfactory water supply is available for agricultural and domestic uses, and a small amount of water power can be developed. The chief sources of mineral wealth are coal, oil, and gas.

These quadrangles are underlain by valuable beds of high-volatile bituminous coal. For many years neighborhood mines have supplied local needs, although widespread use of natural gas has restricted the demand for coal. In comparison with thicker beds in nearby areas to the south the coal in these quadrangles in general is thinner and more variable, and mining on a very extensive scale has not been undertaken. The principal coal beds are the Middle Kittanning and Upper Freeport, members of the Allegheny formation, which, though variable and in places absent, over considerable areas range between 30 and 40 inches in thickness and locally are thicker. A bed in the approximate position of the Brush Creek coal, in the lower part of the Conemaugh formation, in places is more than 4 feet thick, and locally the Lower Freeport and Upper and Lower Kittanning coals are well developed.

These quadrangles are situated in the northern Appalachian oil and gas region and were actively drilled during the 30 years following 1872, when the main producing areas were discovered and the maximum output obtained. For many years the yield of oil and gas has been small, the average daily output of oil per well being only a fraction of a barrel. Oil is obtained from lenticular beds of sand which occupy a stratigraphic interval of about 1,800 feet and are mem-

bers of the Pocono, Catskill, and Chemung formations of the Allegheny Front sequence, or their equivalents, of Mississippian and Upper Devonian age. The occurrence of oil and gas is "spotted." Locally gas is found along anticlines, but structure apparently was not of controlling importance in the accumulation of much of the oil. It is not likely that large pools remain to be found in the upper sands, although there may be occasional discoveries of small productive areas. Increased output from these depleted sands may be obtained by improved methods of recovery, but lenticular sands of variable permeability are not as favorable as more homogeneous beds. Deep-lying sands that are productive in other areas are possible sources of future production of oil and gas in these quadrangles.

INTRODUCTION

The Butler and Zelienople quadrangles, which are bounded by parallels 40°45′ and 41° and meridians 79°45′ and 80°15′, include an area of 452 square miles in Butler, Beaver, and Lawrence Counties, western Pennsylvania. (See fig. 1.) The quadrangles are situated in a prosperous farming country in the coal, oil, and gas fields of the northern Appalachian region. Butler, which has a population of about 25,000, is the principal town. Zelienople, Harmony, and Evans City are thriving boroughs, and there are several small settlements, including Wurtemberg, Portersville, Prospect, and Saxonburg. The quadrangles are traversed by several railroads, including the Pittsburgh and Chicago line of the Baltimore & Ohio; the Bessemer & Lake Erie; the Buffalo, Rochester & Pittsburgh; the Butler and Freeport branch of the Pennsylvania; the Foxburg branch of the Baltimore & Ohio; and the Western Allegheny.

Coal has been mined here in country banks for many years, and a few shipping mines have been operated, but in general the coal beds in these quadrangles are not as thick or as valuable as in some other parts of the State. There are, however, local areas of thick coal which will be mined when transportation facilities have been provided. In other parts of the quadrangles the coal constitutes a reserve which will be developed after the deposits in more favored localities have been depleted. In the eighties and nineties of the last century, when the oil fields of Pennsylvania were in their prime, parts of these quadrangles produced large quantities of oil and gas. For many years, however, the output has been small.

These quadrangles comprise part of the area that is described in reports by the Second Geological Survey of Pennsylvania that were issued more than 50 years ago.[1] The present report is one of a series of publications by the United States Geological Survey on quadrangles located in the Appalachian coal, oil, and gas fields for which topographic maps on the scale of 1 inch to the mile, with

[1] White, I. C., Report of progress in the Beaver River district of the bituminous coal fields of western Pennsylvania: 2d Geol. Survey Rept. Q, 1878; The geology of Lawrence County: Pennsylvania 2d Geol. Survey Rept. QQ, 1879. Chance, H. M., The northern townships of Butler County: Pennsylvania 2d Geol. Survey Rept. V, 1879.

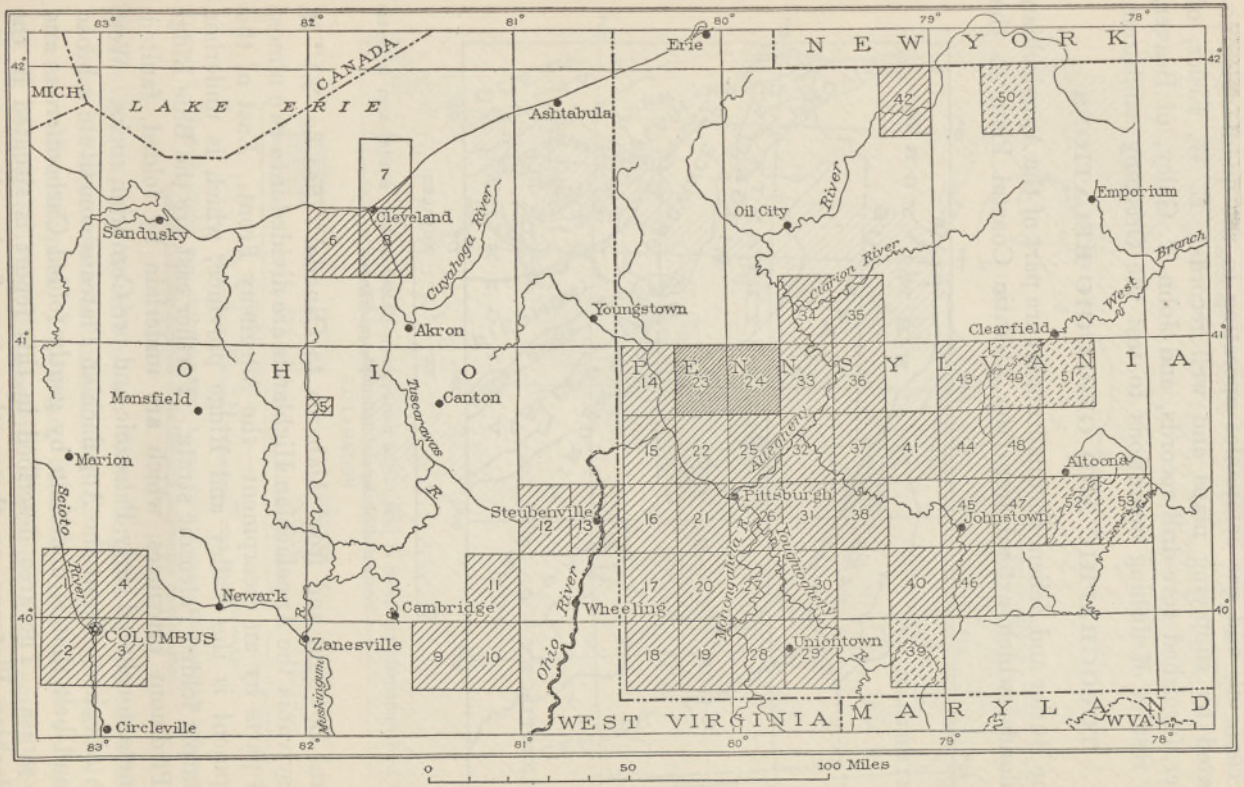


FIGURE 1.—Index map of western Pennsylvania and eastern Ohio, showing the location of the Butler and Zelienople quadrangles and of other quadrangles covered by reports of the U. S. Geological Survey and the Pennsylvania Topographic and Geologic Survey. The reports indicated by dashed ruling are not yet published.

1 Dublin
2 West Columbus
3 East Columbus
4 Westerville
5 Wooster
6 Berea
7 Euclid
8 Cleveland
9 Summerfield
10 Woodsfield
11 Flushing
12 Cadiz
13 Steubenville
14 Newcastle
15 Beaver
16 Burgettstown
17 Claysville
18 Rogersville
19 Waynesburg
20 Amity
21 Carnegie
22 Sewickley
23 Zelienople
24 Butler
25 New Kensington
26 Pittsburgh
27 Brownsville
28 Masontown
29 Uniontown
30 Connellsville
31 Greensburg
32 Freeport
33 Kittanning
34 Foxburg
35 Clarion
36 Rural Valley
37 Elders Ridge
38 Latrobe
39 Meyersdale
40 Somerset
41 Indiana
42 Warren
43 Punxsutawney
44 Barnesboro
45 Johnstown
46 Windber
47 Ebensburg
48 Patton
49 Curwensville
50 Bradford
51 Houtzdale
52 Hollidaysburg
53 Huntingdon.

contour intervals of 20 feet, are available. (See fig. 1.) The field work on which the report is based was done principally in 1915 and 1916, but its preparation was delayed by assignment of the writer to other duties. The area was revisited in 1928 and 1931. R. Van A. Mills assisted in the field and office in 1915, and T. C. Brown in the field in 1916, to both of whom the writer is much indebted. The coal, oil, and gas companies operating in the quadrangles cooperated by supplying maps and well records. E. W. Eisler, of Butler, furnished core-drill records, and John T. Galey, of Beaver, gave results of drilling operations to test the Oriskany sandstone.

TOPOGRAPHIC AND GEOLOGIC RELATIONS

The Butler and Zelienople quadrangles are part of the Appalachian Highlands, which extend from the Atlantic Coastal Plain to the

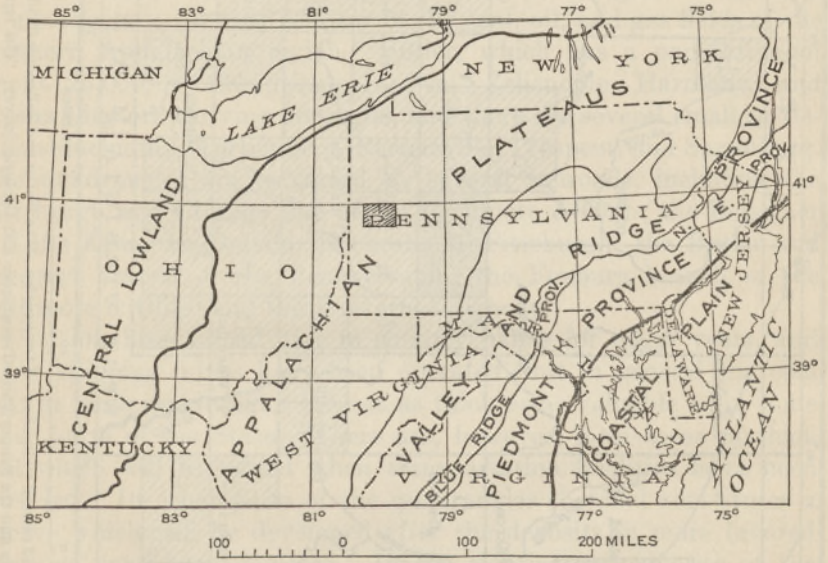


FIGURE 2.—Geomorphic provinces of part of the northeastern United States. Shaded area indicates location of Butler and Zelienople quadrangles.

Central Lowland and from Alabama to Canada. (See fig. 2.) In Pennsylvania the Appalachian Highlands are divided into two almost equal parts by an escarpment—the Allegheny Front. East of this escarpment is the Valley and Ridge province, which is underlain by sharply folded Paleozoic strata. Farther east are the Blue Ridge and Piedmont provinces, which are underlain by folded, faulted, and metamorphosed early Paleozoic and pre-Cambrian rocks. West of the Allegheny Front the Appalachian Plateaus constitute a broad highland belt that is underlain by gently folded Carboniferous and older strata. The area described in this report is situated in the Appalachian Plateaus, on the northwestern flank, adjacent to the

axis, of the Pittsburgh-Huntington Basin, a spoon-shaped synclinorium that lies between the axis of the Cincinnati anticline and the Allegheny Front and extends from New York to Kentucky. The areal distribution of the rocks (see fig. 3) shows the general structure of the basin. Its central part in southeastern Ohio, southwestern

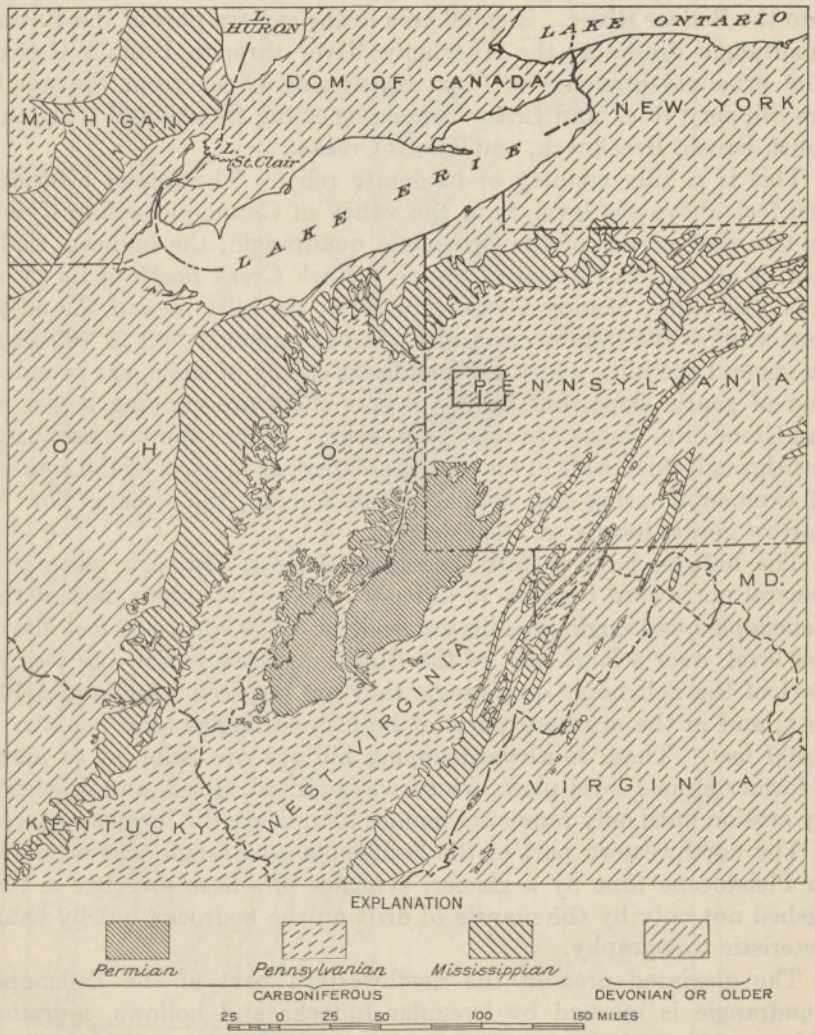


FIGURE 3.—Geologic sketch map of the northern Appalachian Plateaus and adjacent provinces. Rectangles indicate location of Butler and Zelienople quadrangles.

Pennsylvania, and northwestern West Virginia is floored with beds of Permian age, which are surrounded by outcrops of Pennsylvanian strata. Mississippian, Devonian, Silurian, and older rocks crop out in sequence along its western, northern, and eastern margins and underlie the younger strata in the interior of the basin.

The general structure of the rocks at and near the surface in part of the basin is shown by 100-foot contours on plate 5.

DRAINAGE AND RELIEF

The drainage of these quadrangles is tributary to the Ohio River, almost entirely by way of Connoquenessing Creek, which empties into the Beaver River. A small area in the eastern part of the Butler quadrangle drains to the Allegheny River through Buffalo Creek. The principal branches of Connoquenessing Creek from the north are Slippery Rock and Little Connoquenessing Creeks and from the south Brush, Breakneck, and Thorn Creeks.

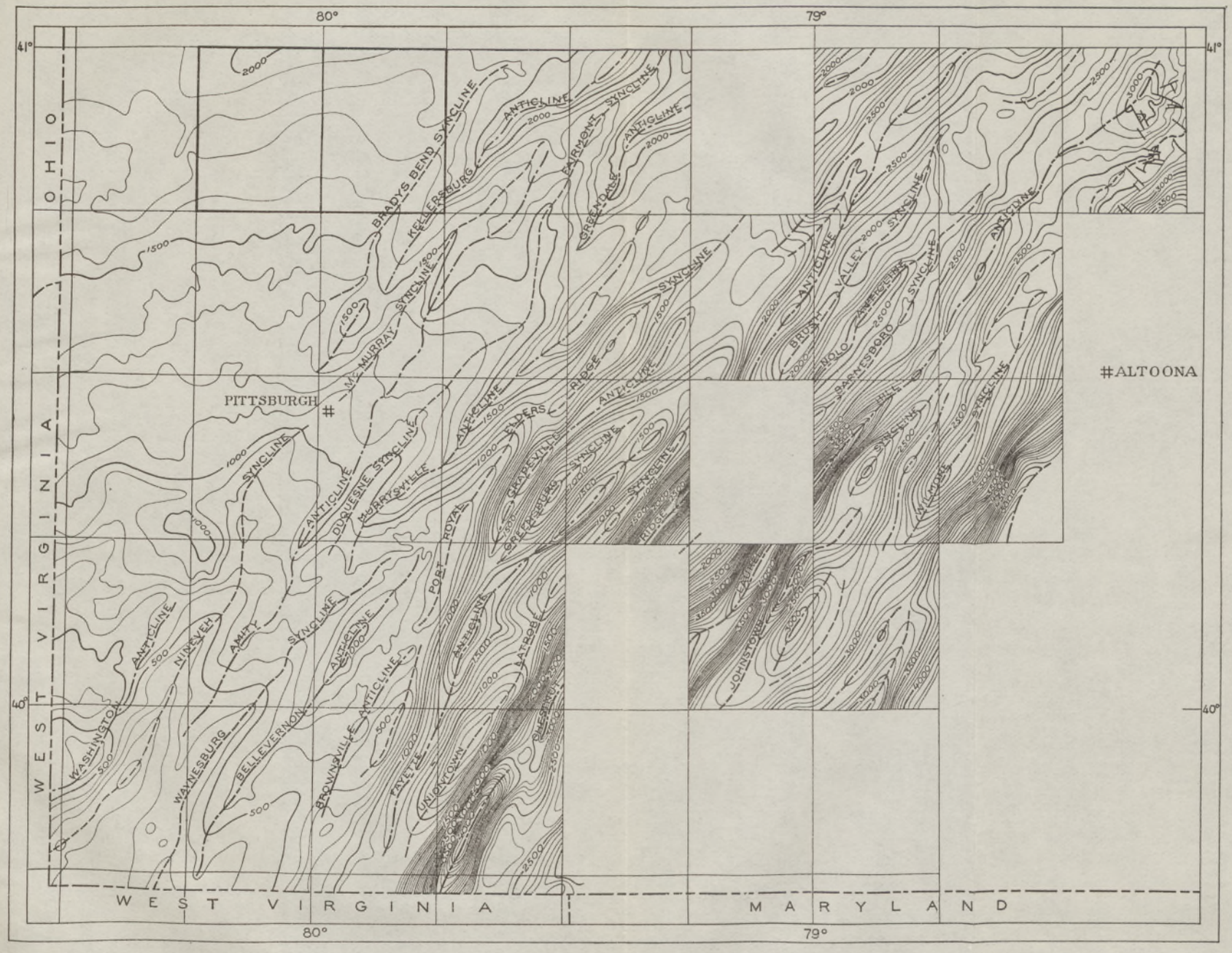
This is a hilly country of moderate relief. The lowest altitude, 860 feet above sea level, is in the valley of Connoquenessing Creek at the west border of the Zelienople quadrangle; the highest, 1,560 feet, is on the divide east of Slippery Rock Creek north of its principal tributary, Muddy Creek. Between the hilltops and the adjacent valleys the difference in altitude is commonly 200 to 300 feet. In general the hills, which are composed chiefly of shale, are rounded and of gentle slope, but locally, where there are capping ledges of sandstone, the slopes are relatively steep. Where the streams have cut through thick beds of massive sandstone, as in parts of the courses of Connoquenessing and Slippery Rock Creeks, the streams flow in narrow gorges locally 400 feet deep.

The hilltops have a fairly accordant height, although there is a general northward increase in altitude. In the southern part of the Zelienople quadrangle the hills are between 1,200 and 1,300 feet above sea level; over a large part of the Butler quadrangle and the central part of the Zelienople quadrangle they are between 1,300 and 1,400 feet; and in the northern parts of both quadrangles they rise above 1,400 feet. These southward-sloping hilltops are believed to mark a former almost level plain, which was uplifted, tilted, and dissected by erosion until only remnants remain to indicate the former surface.[2]

The northwestern part of the Zelienople quadrangle was occupied in Pleistocene time by a glacier, evidence of whose presence is furnished not only by the mantle of drift on the bedrocks but by characteristic topography.

The glaciated area in the northwestern part of the Zelienople quadrangle is marked by irregular hillocks and hollows, morainal ridges, and undrained swampy areas. Other topographic effects of the presence of the ice sheet are the broad flats in the valleys of Muddy and Connoquenessing Creeks. These are underlain by sand and clay that were deposited in ponded parts of the valleys, the drainage of which was blocked by ice.

[2] Campbell, M. R., Geographic development of northern Pennsylvania and southern New York: Geol. Soc. America Bull., vol. 14, pp. 227–293, 1903.



STRUCTURE CONTOUR MAP OF SOUTHWESTERN PENNSYLVANIA.

From maps by United States Geological Survey and Pennsylvania Topographic and Geologic Survey. Sketch contours based on Pittsburgh coal; interval 100 feet; datum sea level. See figure 1 for names of quadrangles. Butler and Zelienople quadrangles indicated by heavy outline.

DESCRIPTIVE GEOLOGY

STRATIGRAPHY

GENERAL CHARACTER AND AGE OF THE ROCKS

The rocks of the Butler and Zelienople quadrangles are of sedimentary origin and consist of indurated strata of Paleozoic age and unconsolidated deposits of Pleistocene and Recent age. The Pleistocene deposits are composed of gravel, sand, and clay, chiefly of glacial origin, consisting of a mantle of drift over the bedrocks in the northwestern part of the Zelienople quadrangle and of outwash deposits laid down by streams that flowed from the continental ice sheet. The Paleozoic strata may be separated into those that crop out at the surface and deeper-lying beds that are not exposed in these quadrangles. The outcropping rocks consist of about 800 feet of strata of Carboniferous age, including the lower half of the Conemaugh formation, the underlying Allegheny formation, and the upper part of the Pottsville formation. The unexposed rocks include a great thickness of Carboniferous, Devonian, Silurian, and older strata.

The Paleozoic beds were deposited in the Appalachian geosyncline, the epicontinental marine basin that throughout the greater part of Paleozoic time was an area of subsidence of varying outline, in which a mass of sediments having a maximum thickness of about 40,000 feet accumulated. The subsidence of the geosyncline, which in general kept pace with the deposition of the sediments, was interrupted many times during the Paleozoic era by uplifts, when parts of the basin were raised above sea level and exposed to erosion. These ups and downs and the corresponding retreats and advances of the sea produced hiatuses and overlaps in the sequence of the rocks, and differences in local conditions under which the sediments were deposited caused the beds to vary in composition. While sand was being laid down in one area mud was accumulating in another and calcareous deposits elsewhere. A pronounced stratigraphic feature of this region is the general increase in thickness of the sediments from west to east, toward the deepest part of the geosyncline, and in the direction of the old land mass Appalachia, which was the source of much of the sediments. In the area between the Cleveland district, in northern Ohio, and the Hollidaysburg district, in the vicinity of the Allegheny Front, in central Pennsylvania, for instance, the thickness of the rocks of Upper Devonian age increases from about 1,500 feet in the west to 5,600 feet in the east, and the prevailingly shaly Upper Devonian sediments of the west become sandy toward the east. The eastward thickening of the rocks and the differences in character of the beds of the same series on the western and eastern flanks of the Pittsburgh-Huntington Basin are illustrated in plate 6.

ROCKS NOT EXPOSED

The rocks that are not exposed in these quadrangles are known from the records of churn-drill holes that have been put down in search of oil and gas. These records, however, in general show only the thickness and depth below the surface of the beds of sandstone, though not even all of these are recorded, for the nonproductive strata are of little interest to the driller. Occasionally the presence of red rocks and less frequently beds of shale, limestone, and coal are reported. There has been no core drilling below the lowest beds that crop out in this area, and the information available is not sufficient to subdivide the unexposed rocks into formations.

Selected records of 47 wells, representative of many hundred that have been drilled in the Butler and Zelienople quadrangles, are given on pages 82–88.

Inspection of the records shows three groups of lenticular beds of sands—an upper group, which in many logs is not reported and except in one locality is unproductive of oil or gas; a middle group, which includes the principal producing sands of the area; and lower sands, which are locally productive and to which only a few wells in this area are sunk. The deep-lying Oriskany (?) sandstone has been reached in only two wells.

The upper group, lying between 50 and 500 feet below the Vanport limestone, includes the sandstones of the Pottsville and part of the underlying Pocono formation, which are only occasionally reported by the drillers. These are the Forty-foot, Sixty-foot, and Mountain sands; the first two correspond to the Homewood sandstone member and the upper part of the Connoquenessing sandstone member of the Pottsville formation. Some drillers reverse these names, calling the upper sand the "Sixty-foot" and the underlying sand the "Forty-foot." The name "Mountain sand" is variously used. By some it is applied to the Connoquenessing sandstone, and by others the Mountain sand is made to include the upper sandstone member of the Pocono formation (the Burgoon sandstone), which is more generally known to drillers as the "Big Injun sand." The upper group of sands in the Butler and Zelienople quadrangles is productive at only one horizon and in one locality—the Slippery Rock pool. There the so-called "Slippery Rock sand" occurs between 340 and 400 feet below the Vanport limestone and presumably is in the upper part of the Pocono formation.

The middle group consists of variable lenticular beds of sandstone and intervening shale, which occupy a stratigraphic interval of about 700 feet, lying usually between 700 and 1,400 feet below the Vanport limestone. These sands, which are the principal oil and gas reservoirs of the Butler and Zelienople quadrangles, are the Berea, Butler County gas or Murrysville, Hundred-foot, Thirty-foot, Snee, Boulder,

Third, Fourth, and Fifth sands. They are correlated with the lower part of the Pocono and the upper part of the Catskill formation of the Allegheny Front sequence.

The sands range in thickness from about 100 feet down to a few inches. The Murrysville and Hundred-foot are usually thicker than the underlying sands, which, where well developed, average between 20 and 40 feet in thickness. The sands thicken and thin and locally merge into shale. In places two or more beds of sand combine to form a thick mass of sandstone, and in other places the sands are "broken" into alternating beds of sandstone and shale. In a given interval more beds of sand may be present in one section than in another. Under these conditions it is practically impossible to identify the same beds over wide areas, and the names of oil and gas sands as used in this report imply only relative stratigraphic position and sequence and not identity with the sands at their type localities.

The oil and gas sands in general are thicker and more numerous in the eastern part of the area, and they tend to thin out and disappear toward the west. In the western part of the Zelienople quadrangle drillers report that the sands below the Mountain and Berea sands commonly are thin or "broken" or are absent and are represented by shale.

The sand called by drillers the "Berea" in the Zelienople quadrangle has not been definitely correlated with the typical Berea sandstone of Ohio. In Columbiana County, Ohio, which adjoins Lawrence County, Pa., the top of the Berea sandstone lies between 500 and 600 feet below the Vanport limestone. In the New Castle quadrangle, which adjoins Columbiana County on the east and lies immediately west of the Zelienople quadrangle, a sand that has been correlated with the Berea of Ohio lies about 630 feet beneath the Vanport limestone, and in the Zelienople quadrangle the Berea sand of the drillers lies between 664 and 730 feet below the top of the Vanport limestone. This sand is underlain by the Butler County gas sand (Murrysville).

Red rocks are reported in some of the well records at several horizons between the base of the Murrysville sand and the base of the Fifth sand. They apparently represent the westward thinning of the red beds of the Catskill formation that are conspicuously exposed in the escarpment of the Allegheny Front, where they are about 2,000 feet thick.

Below the Fifth sand, down to the Speechley sand, is an unproductive zone of about 800 feet that consists chiefly of shale in which there are thin lenses of sand. Below this shaly zone are two sands, the Speechley Stray and the Speechley, which lie between 2,100 and 2,200 feet below the Vanport limestone and which are locally productive. The so-called "Bradford sand", lying about 600 feet below

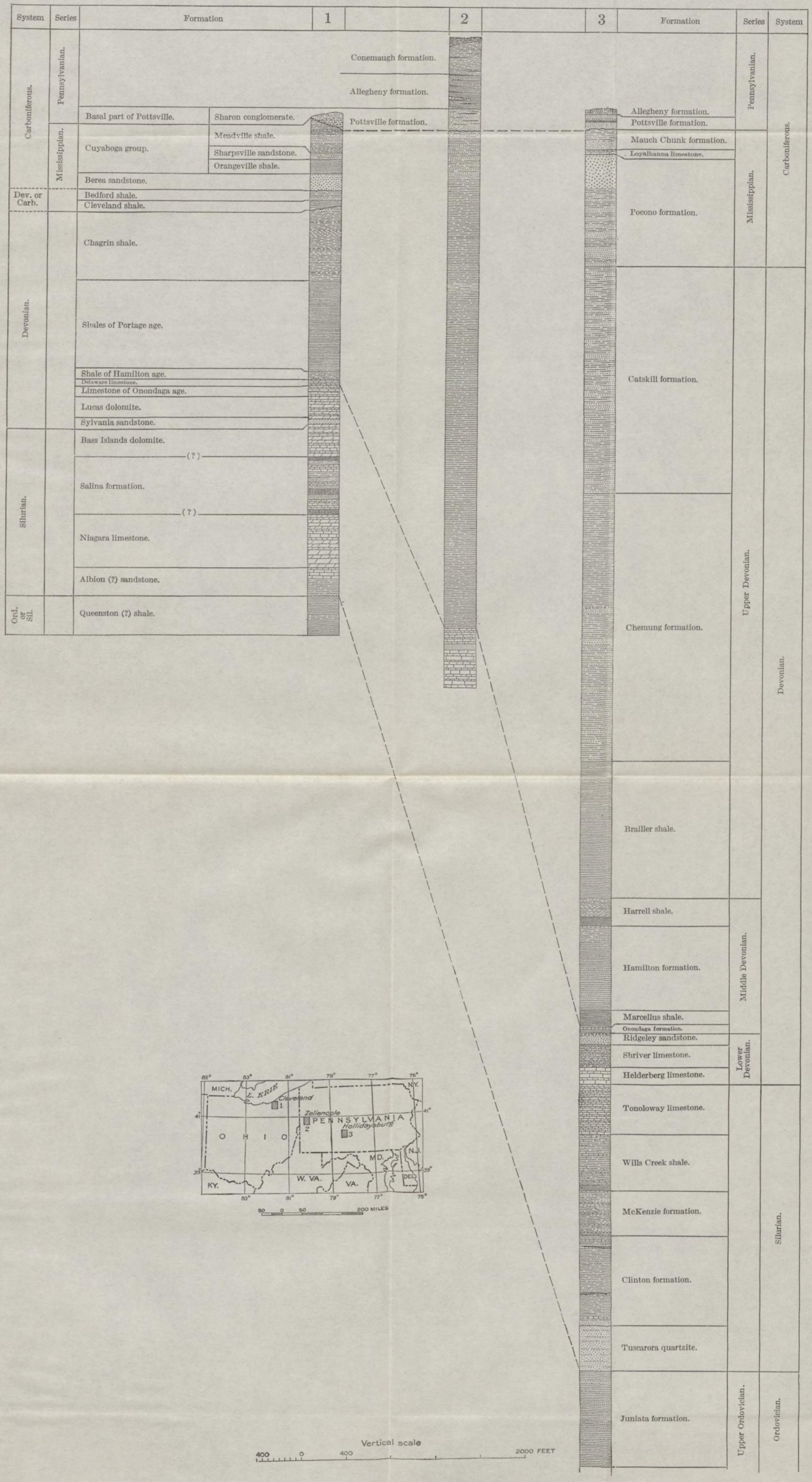
the Speechley, is not known to have yielded oil or gas in these quadrangles. This sand has not been thoroughly tested, and its equivalence with the Bradford sand of McKean County has not been established. These lower sands are believed to be members of the Chemung formation of the Allegheny Front sequence.

Two deep wells were drilled in 1934–35 in the northwestern part of the Zelienople quadrangle, and information concerning them has been courteously furnished by John T. Galey, of Beaver, Pa. One well was put down on the J. Scott Munnell farm, in Slippery Rock Township, Lawrence County, 2½ miles northeast of Princeton (p. 88), and the other on the property of the Lehigh Portland Cement Co. in Muddy Creek Township, Butler County, half a mile southwest of Paynes and 4½ miles southeast of the Munnell well. Both wells were started near the horizon of the Vanport limestone and were abandoned as dry holes at depths of 4,767 and 5,170 feet respectively, after having passed through the Oriskany (?) sandstone. A record of the well on the property of the Lehigh Portland Cement Co. follows:

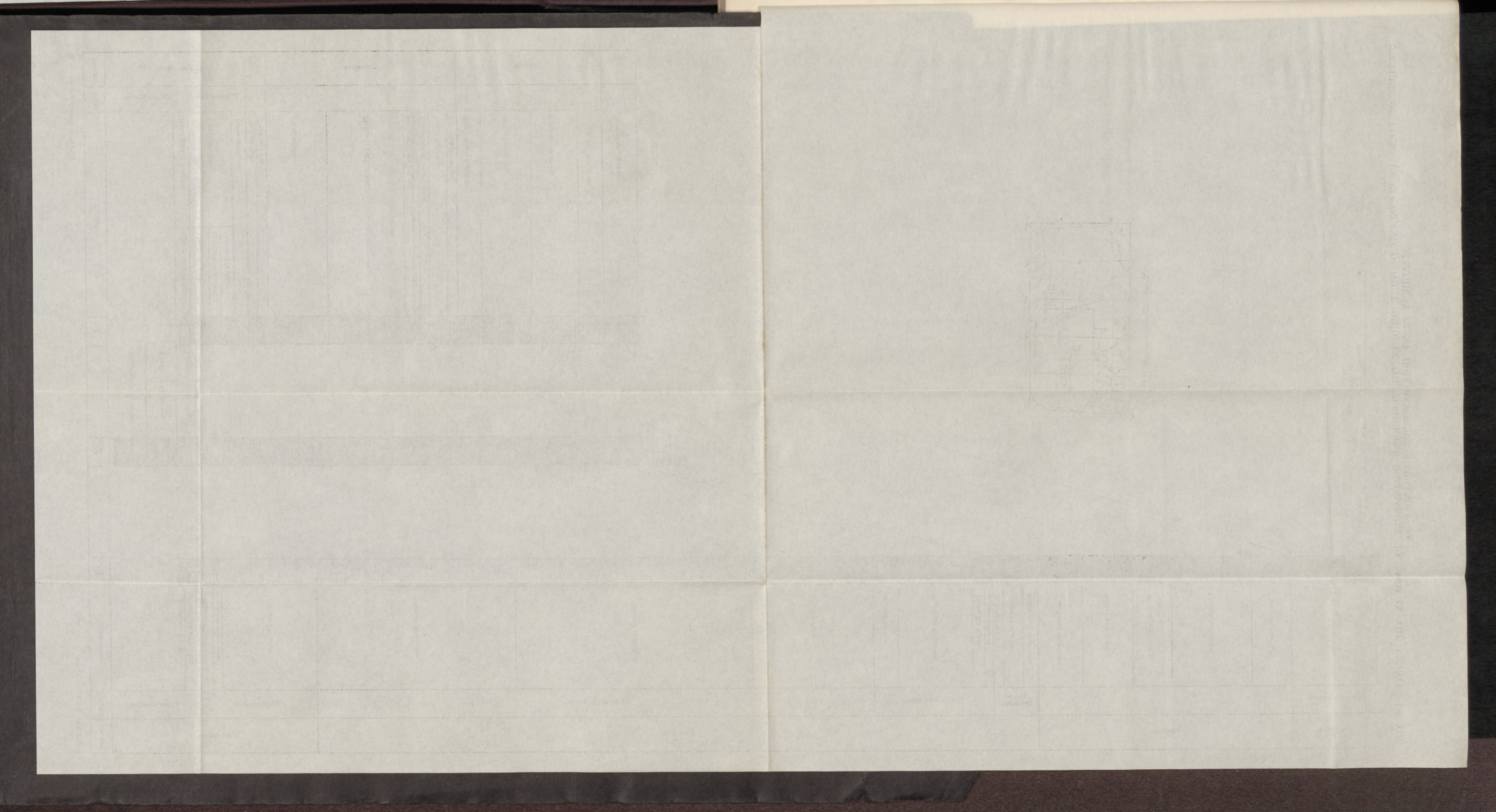
Record of well 1, Lehigh Portland Cement Co., Muddy Creek Township, Butler County, Pa.

[No. 31, fig. 10. Completed Feb. 11, 1935. Well mouth reported 20 feet below Vanport limestone, altitude 1,164 feet.]

	Feet
Sand and gravel	0–33
Pottsville formation; top and base not determined:	
Sandstone, light buff (Homewood sandstone member)	33–95
Shale, dark (Mercer shale member)	95–135
Sandstone and sandy shale, gray	135–180
Sandstone, light gray	180–284
Pocono formation; top and base not determined:	
Sandstone, shaly, and sandy shale, gray; water at 315–335 feet	284–655
Sandstone, shaly, gray; "smell of oil"; hard rock at 682–696 feet (Berea sand of driller)	655–696
Equivalents of Catskill, Chemung, Brailler, Harrell, Hamilton, and Marcellus formations of the Allegheny Front sequence and of the Bedford, Cleveland, Chagrin shales, and shales of Portage and Hamilton age in the Cleveland district, Ohio; undifferentiated (see pl. 6):	
Shale and shaly sandstone, gray	696–728
Shale, gray	728–820
Shale, "pink"	820–848
Shale, gray	848–854
Shale, "pink"	854–870
Shale, gray	870–1, 235
Shale and shaly sandstone, gray, very hard at 1,235–1,242 feet; show of oil at 1,240 feet	1, 235–1, 250
Shale, gray	1, 250–1, 647



SECTIONS OF ROCKS IN CLEVELAND DISTRICT, OHIO, IN THE ZELIENOPLE QUADRANGLE, PA., AND IN THE VICINITY OF THE ALLEGHENY FRONT, HOLLIDAYSBURG QUADRANGLE, PA.



System	Series	Formation	Member	Section	Character of member	General character of formation
Quaternary.	Pleistocene.	Glacial deposits of Wisconsin stage.				Glacial deposits of silt, sand, gravel, and granite boulders, forming ground moraine, terminal moraines, outwash valley trains, and ponded deposits; 0 to 90 feet thick.
Carboniferous.	Pennsylvanian.	Conemaugh.	Ames limestone.		Fossiliferous limestone; averages less than 2 feet thick; important key bed.	
			"Pittsburgh Reds."		Conspicuous zone of red shale; ranges in thickness from a few feet to about 40 feet.	
			Buffalo sandstone.		Thick- to thin-bedded arkosic sandstone and sandy shale.	Only the lower part of the formation, including about 320 feet of strata, is present. Consists of variable beds of shale and sandstone and lenses of limestone and coal.
			Brush Creek coal.		Variable lens of coal, locally minable; 0 to more than 4 feet thick.	
			Mahoning: Red shale and Mahoning limestone.		Sandstone and sandy shale, divisible into lower and upper sandy zones, separated by thin lenses of coal, clay, and limestone. Red shale occurring on an average 30 to 40 feet above Upper Freeport coal. Serves as useful horizon marker.	
			Sandstone.			
		Allegheny.	Upper Freeport coal.		Widely distributed and mined, locally absent; 0 to more than 5 feet thick.	
			Butler sandstone.		Thick- to thin-bedded medium- to fine-grained arkose; 0 to 30+ feet thick.	
			Lower Freeport coal.		Variable, locally absent; less than 2 to more than 5 feet thick.	
			Upper Kittanning coal.		Variable and nonpersistent; in places more than 3 feet thick.	
			Middle Kittanning coal.		Fairly persistent; prospected and mined at many places; averages between 30 and 40 inches thick.	A variable sequence of shale, sandstone, limestone, clay, and valuable beds of coal; average thickness about 300 feet.
			Lower Kittanning coal.		Variable; 0 to 3 feet 4 inches thick.	
			Vanport limestone.		Massive to thin-bedded gray fossiliferous limestone 0 to 20 feet thick; valuable key bed.	
			Scrubgrass coal.		0 to 4 feet 10 inches thick; development known in only one area.	
			Clarion coal.		Not known to be more than 18 inches thick.	
			Brookville coal.		Horizon represented by shale or by coal generally less than 1 foot thick.	
		Pottsville.	Homewood sandstone.		Thick- to thin-bedded fine- to coarse-grained, locally conglomeratic sandstone, in places replaced by sandy shale; average thickness about 50 feet.	
			Mercer shale.		Fissile dark clay shale and thin lenses of limestone and coal; average thickness between 20 and 40 feet.	Chiefly massive grayish-white fine- to coarse-grained sandstone. 90 to 180 feet exposed.
			Connoquenessing sandstone.		Massive to thin-bedded fine- to coarse-grained sandstone; 0 to 100 feet exposed. Locally a dark shale lentil, 0 to 20 feet thick, near middle of member.	

Vertical scale

50 0 50 100 FEET

GENERALIZED COLUMNAR SECTION OF THE EXPOSED ROCKS IN THE BUTLER AND ZELIENOPLE QUADRANGLES.

Record of well 1, Lehigh Portland Cement Co., Muddy Creek Township, Butler County, Pa.—Continued

	Feet
Sandstone, shaly, and sandy shale, gray, hard; small show of gas at 1,660 feet; small show of oil at 1,668 feet	1,647–1,712
Shale, gray	1,712–3,285
Shale, brown; show of gas and oil at 3,321–3,334 feet	3,285–3,334
Shale, gray	3,334–4,377
Shale, black	4,377–4,411
Shale, brown	4,411–4,454
Shale, dark; hard at 4,457 feet; gas pocket at 4,458 feet; some pyrite, calcareous	4,454–4,468
Shale, dark gray, calcareous	4,468–4,564
Shale, brown; gas pockets at 4,622 and 4,627 feet	4,564–4,645
Shale, black	4,645–4,669
Onondaga (?) limestone: Limestone, cherty, dark gray	4,669–4,809
Oriskany (?) sandstone:	
Sandstone, hard, white to gray; show of gas; scum of black oil at 4,811 feet	4,809–4,824
Sandstone, hard, gray; half a bailer of water at 4,830 feet, after interval of 19 days	4,824–4,839
Helderberg limestone and Cayuga group (?): Limestone, hard, gray; 16 bailers of water at 4,850 feet; exhausted	4,839–5,170

The thickness of the stratigraphic section in the Zelienople quadrangle as shown by this record is intermediate between that in the Cleveland area, Ohio, and that in the vicinity of the Allegheny Front in the Hollidaysburg district, Pa. (See pl. 6.) In the Cleveland area the interval between the Pottsville formation and the base of the limestone of Onondaga age (the horizon of the top of the Oriskany sandstone) is about 2,400 feet. In the northwestern part of the Zelienople quadrangle this interval is about 4,500 feet, and in the Allegheny Front section about 7,900 feet.

The record shows the predominance of shale below the Pottsville and Pocono formations and the absence of the beds of sandstone which occur in the section in eastern Butler County and farther east and which are the reservoir rocks of many oil and gas pools. These sandstones lens out westward and merge into shale. The almost complete absence of red rocks in the well, with the exception of "pink shale" reported by the driller at 820–848 and 854–870 feet, testifies to the westward disappearance of the red beds that are so conspicuous in the Allegheny Front sequence. The log shows that the Onondaga (?) limestone and the underlying Oriskany (?) sandstone are well developed in this region. Although the record does not permit the delimitation of the formations above the Onondaga limestone, the presence of

dark shales above it is indicative of the Marcellus and Hamilton, the overlying shales doubtless are correlatives of the Upper Devonian beds that crop out in central Pennsylvania, New York, and Ohio, and the sandstones in the upper part of the section are representatives of the Pocono and Pottsville formations.

ROCKS EXPOSED

The sequence and general character of the rocks that are exposed in these quadrangles are shown in the columnar section (pl. 7).

CARBONIFEROUS SYSTEM

PENNSYLVANIAN SERIES

POTTSVILLE FORMATION

General character.—The Pottsville formation is typically developed at Pottsville, Pa., in the anthracite region, where it is 1,200 feet thick. In western Pennsylvania only the upper part of the formation, between 200 and 300 feet thick, is present. There the Pottsville formation consists of preponderating massive sandstone, in places conglomeratic, subordinate shale, and thin lenses of coal, clay, and limestone. The occurrence of shale in a considerable area makes possible the subdivision of the formation into the Homewood sandstone member at the top, the intermediate Mercer shale member, and the underlying Connoquenessing sandstone member. Locally the Connoquenessing sandstone is underlain by the Sharon shale and the Sharon conglomerate. In this region the formation is variable. Near Homewood, on the Beaver River, southwest of the Zelienople quadrangle, for example, the Mercer shale is apparently absent and the Homewood and Connoquenessing sandstone members seem to unite to form a thick mass of sandstone; and 5 miles northeast of Homewood, at Wurtemberg, the Mercer shale is well developed and the Homewood sandstone is represented chiefly by sandy shale.

Outcrops in valley of Slippery Rock Creek.—The Pottsville formation underlies the entire area of the Butler and Zelienople quadrangles but crops out only in the gorge of Slippery Rock Creek, where between 90 and 180 feet of the formation is exposed in a belt that averages about half a mile in width. The exposed thickness varies with the slope of the bed of the creek and the dip of the rocks, the greatest thickness being found in the vicinity of the mouth of Cheeseman Run, northwest of Portersville. The base of the Pottsville is not exposed and has not been determined by drilling. Along Slippery Rock Creek the three upper members of the formation are locally present and are characteristically variable.

Mercer shale member.—The Mercer shale member is exposed in the lower 30 to 40 feet of the cliffs that rise above Slippery Rock Creek at Wurtemberg and for about 2 miles above the town. Northward it crops out at intervals, higher along the cliff sides. In places a cover

of glacial outwash gravel or a mass of talus conceals the section. Partial sections of the Mercer shale are exposed at the following localities: On the north side of Slippery Rock Creek near the western border of the Zelienople quadrangle, at an altitude between 820 and 850 feet, in the bed of a small gully that crosses the bluff, 20 feet of fissile dark clay shale overlies 8 inches of compact dark limestone, which is underlain by 4 inches of coal. The overlying and underlying beds are concealed. In the bluff at the north end of the lower of the two bridges at Wurtemberg 15 to 20 feet of fissile dark clay shale is overlain by 30 to 40 feet of outwash glacial gravel. In the steep face of the cliff at the east end of the upper bridge at Wurtemberg the following partial section of the Mercer shale member is exposed:

Partial section of Mercer shale member at east end of upper bridge at Wurtemberg

Shale.	Ft.	in.
Shale, fissile, black, with iron carbonate nodules	5	0
Limestone, dark, 1 foot to	1	8
Coal, 4 inches to	1	0
Shale, fissile, black	10	0
Sandstone, whitish, calcareous, 0 to	3	0
Shale, fissile, black	5	0

Half a mile north of the upper bridge at Wurtemberg the following section was measured:

Partial section of Mercer shale member near Wurtemberg

	Ft.	in.
Shale, black	12	0
Limestone, dark	1	0
Shale, black		4
Coal		11
Shale, black	19	0
Coal		3
Sandstone	4	0
Shale to creek level	5	0

The limestone in the Mercer shale member contains numerous fossils of marine origin. Those listed below, identified by G. H. Girty, were collected by the writer east of Wurtemberg.

Fusulina sp.
Fenestelloid Bryozoa.
Rhombopora lepidodendroides Meek?
Prismopora serrata Meek?
Crania modesta White and St. John.
Derbya crassa Meek and Hayden.
Chonetes mesolobus Norwood and Pratten.
Chonetes granulifer Owen?
Productus (Linoproductus) cora D'Orbigny.
Productus semireticulatus Martin.
Productus (Juresania) nebraskensis Owen?
Marginifera splendens Norwood and Pratten var.
Spirifer rockymontanus Marcou.
Punctispirifer kentuckyensis Shumard.
Squamularia perplexa McChesney.
Composita girtyi Raymond?
Allerisma? sp.
Astartella concentrica Conrad?
Griffithides sp.

Homewood and Connoquenessing sandstone members.—The Homewood sandstone member in the vicinity of Wurtemberg is represented almost entirely by sandy shale and includes only a few thin beds of sandstone. North of Wurtemberg the Homewood sandstone becomes more massive, and the northward rise of the strata causes the Connoquenessing sandstone member, which at Wurtemberg is below water level, to crop out. Where the gorge of Slippery Rock Creek is steepest, in the vicinity of McConnell's mill and southward for 3 or 4 miles, the Homewood and Connoquenessing sandstones are especially well developed, and northwest of Portersville they almost if not quite coalesce by the thinning out of the Mercer shale as described by White.[3]

Lithologically the sandstones are indistinguishable. They are massive, grayish, fine- to coarse-grained, locally conglomeratic, and composed of preponderating quartz and subordinate feldspar. The sandstone is exposed in ledges 20 to 40 feet thick, which in the tributaries to Slippery Rock Creek cause picturesque waterfalls. Huge blocks of sandstone are scattered along the valley sides and in the bed of the creek. In the northern part of the quadrangle the sandstones are less massive and the creek has not cut so deeply into the formation.

Complete sections are not exposed because of abundant rock debris, but the following partial sections were measured in the valley of Slippery Rock Creek at the places indicated:

Section 1 mile northeast of Wurtemberg

	Approximate altitude (feet)
Allegheny formation:	
Vanport limestone member	960
Concealed.	
Brookville coal (in run north of road to Mount Pleasant)	900
Pottsville formation:	
Concealed.	
Mercer shale member	830–860

Section along road crossing Slippery Rock Creek 2 miles west of Mountville Church, Perry Township, Lawrence County

	Ft.	in.	Approximate altitude (feet)
Allegheny formation:			
Vanport limestone member			1,050
Pottsville formation:			
Sandstone, thin, and shale, sandy (Homewood sandstone member)			980–1,000
Concealed.			
Shale, black.			
Coal	1	0	
Shale, black	1	0	950
Limestone, dark	1	3	
Shale.			
Concealed.			
Sandstone (Connoquenessing sandstone member)			880–900

[3] White, I. C., The geology of Lawrence County: Pennsylvania 2d Geol. Survey Rept. QQ, pp. 84, 156, 1879.

Section along road crossing Slippery Rock Creek 2 miles northwest of Portersville

	Approximate altitude (feet)
Allegheny formation:	
Vanport limestone member	1, 160
Shale, sandy, dark	1, 110–1, 140
Shale, black (Brookville coal horizon)	1, 090
Pottsville formation:	
Sandstone, massive, gray (Homewood sandstone member)	1, 050–1, 090
Concealed.	
Sandstone, massive, gray (Connoquenessing sandstone member)	980–1, 020
Concealed.	
Shale, buff, only locally exposed (lentil in Connoquenessing sandstone)	950–970

Section on Slippery Rock Creek at McConnell's mill

	Approximate altitude (feet)
Allegheny formation:	
Vanport limestone member	1, 190
Shale (Brookville?)	1, 125
Pottsville formation:	
Sandstone (Homewood sandstone member)	1, 080–1, 125±
Concealed.	
Shale and limestone (Mercer shale member)	1, 060
Concealed.	
Sandstone (Connoquenessing sandstone member)	980–1, 040±

At Rose Point the top of a massive bed of sandstone (Homewood sandstone member) is exposed in the creek below the road crossing, about 70 feet below the top of the Vanport limestone, in the quarry on the hill to the south.

Section at Muddy Creek Falls, near Grant City station, Slippery Rock Township

	Approximate altitude (feet)
Allegheny formation:	
Vanport limestone member	1, 205
Pottsville formation:	
Concealed.	
Sandstone (Homewood sandstone member)	1, 050–1, 110±

Below the falls Muddy Creek flows in a rocky gorge, but just above the mouth of the creek the valley widens, suggesting the presence of the Mercer shale member, though its outcrop was not observed.

Section at Kennedy's mill, Slippery Rock Creek

	Approximate altitude (feet)
Allegheny formation:	
Vanport limestone member	1, 190
Pottsville formation:	
Concealed.	
Sandstone (Homewood sandstone member)	1, 070–1, 120
Shale, locally exposed (Mercer shale member)	1, 050

Down the valley a few hundred feet below Kennedy's mill the following section is exposed:

Section below bridge at Kennedy's mill, on east side of Slippery Rock Creek

	Ft.	in.
Pottsville formation:		
Sandstone, massive, in cliff (Homewood sandstone member)	50±	
Coal, Shale, black } Mercer shale member	1	9
		6
Concealed	25±	
Sandstone in bed of creek (Connoquenessing sandstone member)	5	0

ALLEGHENY FORMATION

Subdivisions and sections.—The Allegheny formation, which conformably overlies the Pottsville, crops out along the outer area of the Pittsburgh-Huntington Basin in Pennsylvania, Maryland, West Virginia, and Ohio but is covered by younger strata in the central part of the basin. The formation consists of about 300 feet of a variable sequence of shale, sandstone, limestone, clay, and valuable beds of coal that lie between the base of the Brookville coal (or its underclay) and the top of the Upper Freeport coal. Where the members at the top and bottom of the formation are poorly developed its delimitation is difficult.

The Allegheny is divisible into a number of members, of which the following, named in descending order, are the principal ones in the Butler and Zelienople quadrangles:

Upper Freeport coal.
Upper Freeport limestone member.
Butler sandstone member.
Lower Freeport coal.
Lower Freeport limestone member.
Upper Kittanning coal.
Middle Kittanning coal.
Lower Kittanning coal.
Lower Kittanning clay.
Vanport limestone member.
Scrubgrass coal.
Clarion coal.
Brookville coal.

The sequence of the beds is shown in the generalized columnar section (pl. 7). The strata are lenticular, and the section does not apply to any one locality. For instance, the beds of coal that occur in the Allegheny formation have not all been found in any one section; in some sections there are more beds of coal than in others, and coal occurs at different horizons in different areas. These variations are illustrated in the sections of core-drill holes on pages 76–80. They render precise correlation of some members of the Allegheny formation over wide areas difficult if not impossible. The names of the members as used in this report imply only approximate position in the general section and not necessarily identitv with the beds at the type localities.

The Allegheny formation underlies all of the Butler and Zelienople quadrangles with the exception of the narrow belt in the gorge of Slippery Rock Creek, where it has been eroded away, exposing the underlying beds of Pottsville age. The formation crops out in the valleys of the principal streams and is covered on the uplands by the Conemaugh formation.

The entire formation is not exposed in any one section in this area, and only one core-drill hole has been put down completely through it. This hole was sunk in 1918 in Connoquenessing Township, Butler County, 7 miles northeast of Zelienople.

Section of Allegheny formation from record of core-drill hole in Connoquenessing Township, Butler County

[No. 8, fig. 9]

	Thickness		Depth	
	Ft.	*in.*	*Ft.*	*in.*
Coal (Upper Freeport)	1	3	1	3
Bone		3	1	6
Clay	2	9	4	3
Shale	22	10	27	1
Shale, black	11	0	38	1
Coal (Lower Freeport)		5	38	6
Shale and coal streaks (Lower Freeport)	6	9	45	3
Coal, bony (Lower Freeport)		1½	45	4½
Shale and coal (Lower Freeport)	1	4	46	8½
Clay	2	0	48	8½
Shale, sandy	10	1½	58	10
Sandstone and shale	8	0	66	10
Shale, dark	41	9	108	7
Coal, bony (Upper Kittanning)		6	109	1
Coal (Upper Kittanning)	1	10	110	11
Sulphur binder (Upper Kittanning)		1	111	0
Coal (Upper Kittanning)		8	111	8
Clay		9	112	5
Shale	5	6	117	11
Shale, variegated	4	0	121	11
Clay	2	0	123	11
Shale	20	3	144	2
Coal		2	144	4
Shale, sandy	10	0	154	4
Shale		6	154	10
Coal, bony		5	155	3
Coal		3	155	6
Coal, bony		3	155	9
Shale, dark	1	6	157	3
Shale, sandy	3	5	160	8
Coal	1	3	161	11
Coal, bony		1	162	0
Clay, shaly	7	0	169	0
Shale, sandy	6	0	175	0
Shale	1	0	176	0
Clay	2	0	178	0
Sandstone	11	0	189	0
Shale, green	11	7	200	7
Shale, sandy	14	0	214	7
Shale, dark	14	4	228	11
Limestone (Vanport limestone member)	10	0	238	11
Shale		1	239	0
Coal, bony (Scrubgrass)		4	239	4
Coal (Scrubgrass)		10	240	2
Clay	4	0	244	2
Sandstone, shale streaks	10	0	254	2
Shale	1	3	255	5
Coal (Clarion)	1	6	256	11
Clay	4	0	260	11
Clay, sandy	10	1	271	0
Sandstone	2	5	273	5
Shale	5	2	278	7
Coal and bone		6	279	1
Sandstone and coal streaks		3	279	4
Shale and clay	5	5	284	9
Shale		7	285	4
Clay	4	0	289	4

The record of another core-drill hole, 9 miles to the southeast, although the drill did not pass entirely through the Allegheny formation, shows the detailed character of the beds in that vicinity from the Upper Freeport coal through the Vanport limestone. This hole was sunk in 1921 on the property of the Valley Coal Co. in Summit Township, Butler County, 2 miles southeast of Butler.

Section of part of Allegheny formation from record of core-drill hole in Summit Township, Butler County

[No. 31, fig. 9]

	Thickness		Depth				Thickness		Depth	
	Ft.	*in.*	*Ft.*	*in.*			*Ft.*	*in.*	*Ft.*	*in.*
Coal (Upper Freeport)	3	1	3	1	Coal, dirty	Lower Kittanning coal zone.		3	209	0
Clay	3	0	6	1	Shale			9½	209	9½
Shale, gray	6	0	12	1	Coal, dirty			3½	210	1
Shale, dark	20	0	32	1	Shale			3	210	4
Sandy shale, gray	28	11	61	0	Coal, dirty			5	210	9
Shale, dark	29	0	90	0	Clay and shale		3	0	213	9
Sandstone	26	0	116	0	Shale			5	214	2
Sandy shale, gray	8	0	124	0	Coal, dirty		1	3	215	5
Sandy shale, dark	14	0	138	0	Clay		2	7	218	2
Sandstone	12	0	150	0	Shale		2	6	220	8
Sandstone with coal streaks	3	5	153	5	Coal		2	0	222	8
Shale		1	153	6	Coal, bony			3	222	11
Coal (Middle Kittanning)	2	0	155	6	Shale, dark		1	0	223	11
Shale		3	155	9	Shale, sandy, gray		15	0	238	11
Clay	3	0	158	9	Shale, dark		11	0	249	11
Shale, gray	7	0	165	6	Limestone (Vanport limestone member)		15	6	265	5
Shale, soft	2	9	168	9	Shale, dark			2	265	7
Shale, gray	12	0	180	6	Coal (Scrubgrass)		1	4	266	11
Shale, dark	27	3	207	9	Clay		2	6	269	5
Sandstone	1	0	208	9	Shale, gray		1	9	271	2

Comparison of the records of these two holes brings out likenesses and differences that are characteristic of sections of the coal measures. The two sections are similar in showing the presence of the Vanport limestone and the Upper Freeport coal and clay, but they differ in several respects, notably in the occurrence of coal beds. In the section in Connoquenessing Township, for instance, there are two thin beds of coal in the general position of the Lower Freeport and Upper Kittanning coals, but the section in Summit Township shows no coal at either of these horizons; and in Summit Township there are several thin beds of coal in an interval of 13 feet at the horizon of the Lower Kittanning coal, but this horizon is not represented by coal in the section in Connoquenessing Township. In the Middle Kittanning coal zone, in the section in Summit Township, a single bed 2 feet thick occurs 95 feet above the Vanport limestone, whereas in the section in Connoquenessing Township there are three thin beds of coal between 67 and 85 feet above the Vanport. Sections of other core-drill holes show similar conditions and emphasize the fact that the members of the Allegheny formation are variable. (See pp. 76-80.)

Brookville, Clarion, and Scrubgrass coals.—The interval of 40 to 60 feet between the Vanport limestone and the base of the Allegheny formation is occupied chiefly by sandy and clay shale and locally by variable beds of coal—the Brookville, Clarion, and Scrubgrass (or Upper Clarion)—and their underclays. In the area of outcrop—the valley of Slippery Rock Creek and that of Connoquenessing Creek near the western edge of the Zelienople quadrangle—these coals are poorly developed and are believed to be of little or no value.

The horizon of the Brookville coal is represented chiefly by shale. Only one prospect on this coal was found, a mile northeast of Wurtemberg. (See p. 14.) Likewise only one prospect on a bed at or near the horizon of the Clarion coal was observed, near water level at the mouth of Brush Creek, where it enters Connoquenessing Creek half a mile below Hazen, in North Sewickley Towhship, Beaver County. There a prospect was opened on a bed of coal about 18 inches thick which is correlated with the Clarion. The Scrubgrass coal also in the area of outcrop is either absent or is represented by coal only a few inches thick. However, the records of core-drill holes in Jackson and Forward Townships, Butler County, show a local thick development of coal at or near the horizon of the Scrubgrass bed. (See pp. 77–78.)

Vanport limestone member.—The Vanport limestone member is the best key stratum in these quadrangles for determining the correlation and structure of the rocks. It crops out in the valleys of Slippery Rock and Muddy Creeks, as shown by the blue line on plate 2, and elsewhere underlies both quadrangles, where its depth beneath the surface is recorded in the logs of many wells that have been sunk in search of oil and gas. This limestone is valuable for making lime and portland cement and for use as a flux and has been extensively quarried near Paynes, in Worth Township, Butler County, and at Rose Point, in Slippery Rock Township, Lawrence County.

The Vanport limestone, although it is not everywhere present in this area, is an unusually persistent bed. It ranges in thickness from a knife-edge to 20 feet and averages possibly 10 feet, but locally it disappears. It is a dense gray fossiliferous limestone that weathers buff. It is usually massive but in places is thin-bedded. Where the limestone thins out it merges into shale. There are differences in composition of the limestone, some parts containing more impurities—silica, alumina, and iron—than others, as shown by the analyses on page 68.

The following fossils collected from the Vanport limestone at the Rose Point quarry were identified by G. H. Girty:

Climacammina sp.
Crinoid fragments.
Echinocrinus sp.
Batostomella? sp.
Cyclotrypa? sp.
Fenestella sp.
Marginifera splendens Norwood and Pratten?
Spirifer rockymontanus Marcou.
Squamularia perplexa McChesney.
Composita girtyi Raymond.
Cleiothyridina orbicularis McChesney.
Nucula? sp.
Schizostoma catilloides Conrad.

Kittanning coal zone.—The rocks in the Allegheny formation that lie between 20 and 150 feet above the Vanport limestone consist of lenticular beds of shale, sandstone, coal, and clay, including the Lower, Middle, and Upper Kittanning coals. In general a coal bed

that occurs between 20 and 50 feet above the limestone is regarded as the Lower Kittanning, a bed between 70 and 100 feet above the limestone as the Middle Kittanning, and a bed between 120 and 150 feet above the Vanport as the Upper Kittanning.

The Lower Kittanning coal, which in many parts of Pennsylvania is very persistent and valuable, locally is absent in these quadrangles and where present is in general not as thick as some of the other beds. In the area of outcrop this coal is poorly developed and has been opened and mined in very few places. (See p. 33.) This coal is underlain by plastic clay (the Lower Kittanning clay), which in many areas is extensively mined but which in these quadrangles has not yet been exploited.

The Middle and Upper Kittanning coals are variable beds, each of which has been referred to as the "Darlington", and to avoid confusion it seems best, as recommended by De Wolf in the report on the New Castle quadrangle,[4] to discontinue the use of that name as applied to these coals. Both of these beds have been mined at several places, the Middle Kittanning being more persistent. (See pp. 33–35)

Freeport coal zone.—The uppermost 30 to 60 feet of the Allegheny formation consists of sandstone, shale, and the Lower and Upper Freeport coals and their associated clays and limestones. Both Freeport coal beds are underlain by clay, and locally the clay is underlain by a thin bed of limestone or by calcareous shale. In many sections, however, one or more of these beds of coal, clay, and limestone are absent; rarely all are present in one section. An excellent exposure of beds in this zone is in the cliff above the plant of the American Rolling Mill Co. 2 miles southwest of Butler, where the following section was measured. The beds are lenticular, and no one section is constant for more than a few feet.

Section of Upper and Lower Freeport coals and associated rocks 2 miles southwest of Butler

	Feet
Shale, sandy.	
Coal (Upper Freeport)	0–3
Shale and clay	2–5
Limestone	0–4
Shale, sandy (including lens of Butler sandstone, in places as much as 15 feet thick)	30–40
Coal (Lower Freeport)	0–1½
Shale and clay	2–5
Limestone	0–5
Shale.	

In the vicinity of Butler a considerable part of the section between the Upper and Lower Freeport coal beds is composed of sandstone,

[4] De Wolf, F. W., Geology and mineral resources of the New Castle quadrangle: Top. and Geol. Atlas of Pennsylvania, no. 5, 1929.

which I. C. White [5] named the Butler sandstone, from this locality. It is a thick-bedded medium- to fine-grained buff arkosic sandstone, which ranges in thickness from more than 30 feet to the vanishing point. The Butler sandstone is variable, and its horizon in many places is represented by sandy shale.

CONEMAUGH FORMATION

Subdivisions.—The Conemaugh formation overlies the Allegheny conformably and has a similar widespread distribution. It consists of a variable sequence of shale, sandstone, and thin beds of limestone and coal lying between the Upper Freeport and Pittsburgh coal beds. The formation increases in thickness from west to east and ranges from about 350 feet in Ohio to slightly more than 900 feet in Maryland. In the New Kensington quadrangle, south of the area here described, it is between 620 and 640 feet thick. Only about the lower half of the Conemaugh is present in the Butler and Zelienople quadrangles, the upper part having been removed by erosion. The greatest thickness in these quadrangles occurs in their southern parts, where the Ames limestone member, which lies near the middle of the formation, crops out on some of the hilltops in the Butler quadrangle. (See pl. 1.) The Conemaugh formation occupies the divides between the creeks that have cut through the formation into the underlying Allegheny beds.

Like the Allegheny, the Conemaugh formation has been divided into several members, of which the following, named in descending order, have been recognized in these quadrangles:

Ames limestone member.
†Pittsburgh Reds.[6]
Buffalo sandstone member.
Brush Creek coal.
Mahoning sandstone member (including red shale and Mahoning limestone).

Neither the Brush Creek nor the Cambridge (†Pine Creek) limestones, the stratigraphic position of which is respectively below and above the Buffalo sandstone, has been recognized in these quadrangles. Apparently they are poorly if at all represented in this area, although their type localities are in the adjacent Sewickley and New Kensington quadrangles, to the south.

[5] White, I. C., Report of progress in the Beaver River district: Pennsylvania 2d Geol. Survey Rept. Q, p. 130, 1878.

[6] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the U. S. Geological Survey. Quotation marks, formerly used to indicate abandoned or rejected names, are now used only in the ordinary sense.

The records of core-drill holes (pp. 76–80) give detailed measurements of the lower part of the Conemaugh formation in this area and show the variability of the beds. The following section is typical:

Partial section of Conemaugh formation in core-drill hole 8, Connoquenessing Township, Butler County

[See fig. 9]

	Thickness		Depth	
	Ft.	*in.*	*Ft.*	*in.*
Surface	15	0	15	0
Shale, soft	9	0	24	0
Shale, black	8	10	32	10
Sandstone (Buffalo sandstone member)	55	0	87	10
Clay	2	4	90	2
Shale	21	10	112	0
Shale	3	6	115	6
Coal (Brush Creek)	1	6	117	0
Clay	3	4	120	4
Shale	14	0	134	4
Shale and sandstone	14	0	148	4
Sandstone (upper part of Mahoning sandstone member)	12	2	160	6
Clay	1	0	161	6
Shale, variegated	2	3	163	9
Limestone, impure	3	8	167	5
Clay	6	3	173	8
Limestone, impure		4	174	0
Shale, with sand streaks	17	5	191	5
Sandstone (lower part of Mahoning sandstone member)	1	6	192	11
Shale, black	3	6	196	5
Coal (Upper Freeport).				

Mahoning sandstone member.—The Mahoning sandstone member, which constitutes the lower part of the Conemaugh formation, consists chiefly of sandstone and sandy shale and in some areas is divisible into a lower and an upper sandy zone separated by thin lenses of coal, limestone, and red shale. Its base is the Upper Freeport coal, and the member extends upward, usually about 70 to 90 feet, to the shale that underlies the Brush Creek coal. In the valley of Little Buffalo Creek below Cabot the Brush Creek coal is absent and the Mahoning and Buffalo members constitute a continuous mass of sandstone more than 100 feet thick. The sandstone is a gray to buff arkose, composed of quartz and feldspar, usually fine-grained but locally conglomeratic, with small rounded pebbles of quartz. The coal and limestone that occur locally in the midst of the Mahoning member are generally only a few inches thick and are of little or no economic importance. The associated red shale that occurs on an average about 30 to 40 feet above the Upper Freeport coal is widespread in this general area and serves as a useful horizon marker.

Brush Creek coal.—A variable bed of coal in the approximate position of the Brush Creek is well developed locally and in Connoquenessing and Oakland Townships, Butler County, attains a thickness between 4 and 5 feet. Core-drill hole 8, put down 7 miles northeast of Zelienople, shows the stratigraphic position of this coal bed in that locality to be 318 feet above the base of the Vanport limestone, 79 feet

above the Upper Freeport coal, and 44 feet above the red shale in the Mahoning sandstone member of the Conemaugh formation. In many places there is no coal at the Brush Creek horizon. The fossiliferous Brush Creek limestone, which overlies the Brush Creek coal at the type locality in the valley of Brush Creek, Cranberry Township, about 7 miles south of Zelienople, may be present but has not been recognized in these quadrangles.

Buffalo sandstone member.—The Buffalo sandstone occurs between 100 and 150 feet above the Upper Freeport coal. Locally the sandstone is thick-bedded and its outcrops form massive cliffs, as in the valley of Connoquenessing Creek below Butler, in the valleys of Thorn Creek and its tributaries, and in the valley of Little Buffalo Creek below Cabot. In other places this sandstone is thin-bedded and merges into sandy shale. The Buffalo is a gray to buff arkosic sandstone, composed of quartz and feldspar. Where it is conglomeratic it contains pebbles of quartz as much as a quarter or half an inch in diameter.

In many places in the plateau region, as in the New Kensington quadrangle south of Butler, the Buffalo sandstone is overlain by a fossiliferous limestone, the Cambridge (†Pine Creek) limestone, which serves as a useful horizon marker. But even where it is well developed the limestone is variable, being replaced by sandstone or shale, and it has not been recognized in the Butler and Zelienople quadrangles.

The interval between the Buffalo sandstone and the Ames limestone in these quadrangles is occupied by thin sandstone and sandy and clay shale. Beds that are conspicuous in other areas are here not present or poorly developed. For instance, the Bakerstown coal, which occurs between 60 and 90 feet below the Ames limestone in the vicinity of Bakerstown, Allegheny County, has not been recognized in this area, and the overlying Saltsburg sandstone is likewise poorly developed.

†*Pittsburgh Reds.*—The Conemaugh formation is characterized by the occurrence of several zones of red beds. The lowest, already mentioned, is in the Mahoning sandstone member; another zone, the †Pittsburgh Reds, occurs near the middle of the formation, below the Ames limestone. Overlying the Ames limestone is the general section is the red shale known as the †"Washington Reds," and there are others still higher which have been eroded from these quadrangles. The †Pittsburgh Reds consist of a variable zone of sandy and clay shale of variegated colors, mainly red but including also yellowish and brownish tints, ranging from a few feet to about 40 feet in thickness. This brightly colored zone is conspicuous along the hillsides beneath the Ames limestone in Penn Township, Butler County.

Ames limestone member.—The Ames limestone member, which occurs near the middle of a complete section of the Conemaugh formation. is the most persistent member of the formation. Economically it is

of little value as a limestone, for it averages less than 2 feet in thickness, is commonly shaly, and in many places is represented by calcareous shale, but because of its widespread distribution it serves as a good key stratum for determining structure and stratigraphy. In this area it lies about 315 feet above the Upper Freeport coal. The Ames limestone occurs so high in the section that it has been eroded from the greater part of both quadrangles and now appears only in remnants in the southern part of the Butler quadrangle. There it crops out near the crests of several isolated hills in Penn and Jefferson Townships, at altitudes between 1,280 and 1,360 feet. Where it is comparatively pure it is a massive fine-grained blue-gray limestone, but commonly it is a greenish-gray shaly rock that breaks with a characteristic granular fracture. It is very fossiliferous and contains abundant specimens of the fossil *Ambocoelia planiconvexa*. The following species from the Ames limestone in the Butler quadrangle were determined by George H. Girty:

Lophophyllum profundum Milne-Edwards and Haime.
Lingula sp.
Derbya aff. D. bennetti Hall and Clarke.
Schizophoria? sp.
Chonetes granulifer Owen.
Productus semireticulatus Martin.
Productus (Linoproductus) cora D'Orbigny.
Productus (Juresania) nebraskensis Owen.
Marginifera splendens Norwood and Pratten.
Spirifer (Neospirifer) cameratus Morton?
Squamularia perplexa McChesney.
Ambocoelia planiconvexa Shumard.
Pinna peracuta Shumard.
Schizodus? sp.

QUATERNARY SYSTEM

PLEISTOCENE AND RECENT SERIES

General features.—The end of the Carboniferous period was also the end of the long era during which deposition of sediments in the downwarping Appalachian geosyncline was the dominant geologic process, and the succeeding era was characterized by an entirely different sequence of events—deformation, uplift, and erosion of the rocks. If any sediments were deposited in western Pennsylvania during Triassic, Jurassic, Cretaceous, or Tertiary time they have been removed by erosion.

During the Tertiary period the northern Appalachian region was eroded to a peneplain, uplifted, and again reduced to a peneplain at least twice. Evidence of the earlier planation, marked by the crests of Allegheny Mountain, Laurel Hill, and Chestnut Ridge in the eastern part of the plateau, is not preserved in this region, but remnants of the later period of erosion are represented in the Butler and Zelienople quadrangles by the hilltops that rise to altitudes between 1,200 and 1,500 feet above sea level. This planation was followed by renewed

uplift and erosion, and by the end of Tertiary time the topography was developed to a stage much like that of the present. Certain changes in the drainage system were, however, caused by the glaciers, which in early Quaternary time occupied the northern part of the continent and extended as far south as the Ohio River and the northwestern part of the Zelienople quadrangle.

There were at least three stages at which ice sheets invaded northwestern Pennsylvania, and these alternated with interglacial stages when the ice melted away. Only a brief outline of the glacial history, which has been studied in detail by Leverett,[7] will be presented here.

Before the first advance of the ice the principal streams in western Pennsylvania and adjacent parts of New York and Ohio probably occupied the courses indicated in figure 4. The Allegheny River north of the Clarion probably flowed into Lake Erie, and the Beaver River and the upper Ohio and its tributaries also flowed northward into Lake Erie. Slippery Rock Creek and Muddy Creek probably flowed westward in the low land now occupied by the valley of Big Run and entered the Beaver River in the vicinity of New Castle. The advance of the ice sheet blocked these streams, filled their old valleys with drift, and initiated the change to their present courses.

Remains of an earlier advance of the ice are preserved in northwestern Pennsylvania by scattered, weathered boulders and pebbles that in places extend southeast of the border of the last (Wisconsin) drift and by the high-lying terrace of gravel deposits in the Beaver, Allegheny, and upper Ohio River Valleys. These materials are believed to be of Illinoian age.[8] In interglacial time, after the old valley of Slippery Rock Creek had been filled with glacial debris and the ice had melted away, the creek established its present course and, after making its way through the softer beds of the Conemaugh and Allegheny formations, cut a gorge in the underlying massive sandstone of the Pottsville formation.

Wisconsin glacial deposits.—The location of the southernmost front in western Pennsylvania of the last or Wisconsin ice sheet, as determined by Leverett, is shown on plate 2 and figure 4. In the Zelienople quadrangle the position of the ice border is indicated locally by the presence of moraines, but in most places the position of the border is indefinite, and the line drawn on the map marks the southern limit of the area in which glacial pebbles and boulders were found. Glacial deposits in this area are grouped as ground moraine or till, terminal moraines, outwash valley trains, and ponded deposits laid down in lakes which occupied valleys that were blocked by the ice.

[7] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio Basins: U. S. Geol. Survey Mon. 41, 1903.

[8] Leverett, Frank, Report of Committee on Sedimentation, National Research Council, p. 46, 1927; Glacial deposits outside the Wisconsin terminal moraine in Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. G 7, pp. 91–118, 1934.

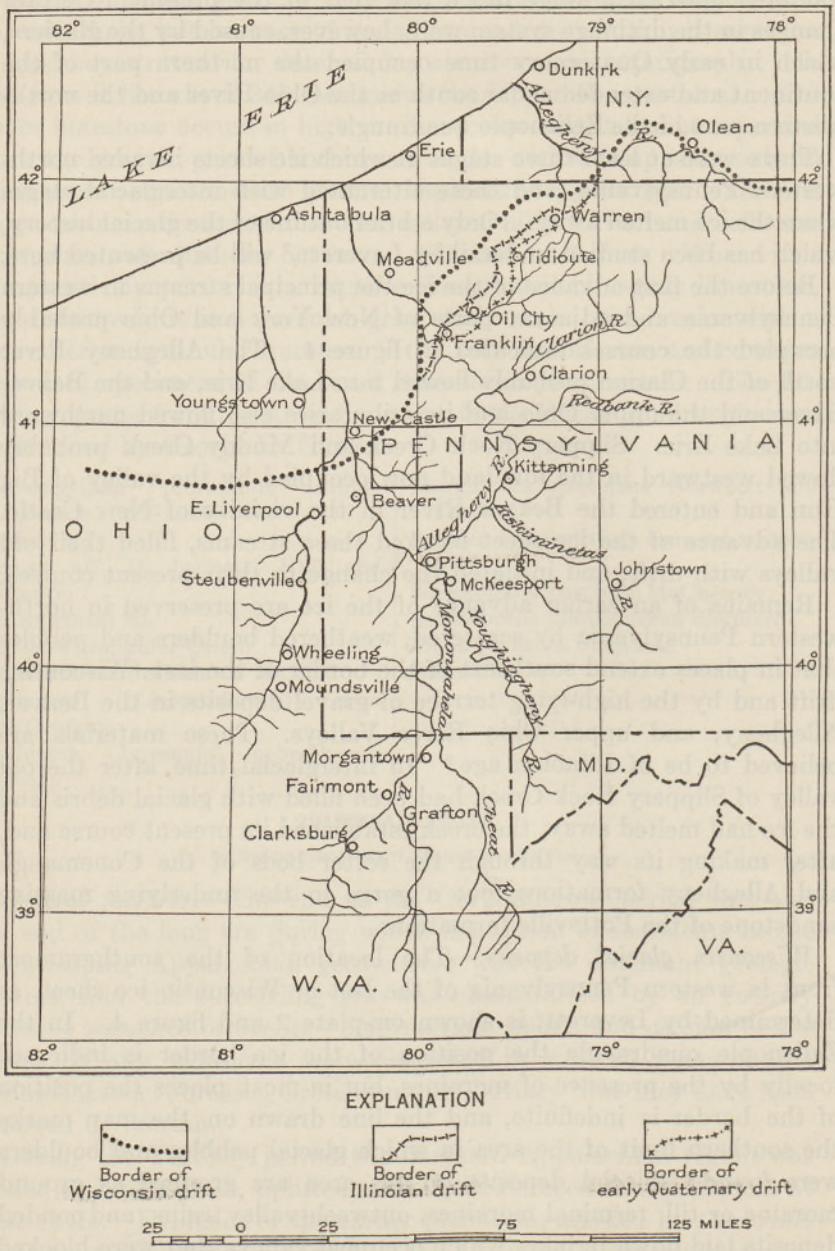


FIGURE 4.—Map showing probable preglacial drainage of western Pennsylvania and adjacent areas and the location of the Wisconsin ice front. (After Leverett.) Rectangles indicate location of Butler and Zelienople quadrangles.

The part of the quadrangle that lay north of the ice border was occupied by the Wisconsin glacier and possibly also in part by earlier ice sheets, the southern limits of which, however, in this region are not known, their position being concealed by the later deposits. This area is covered by ground moraine, or till, consisting of unconsolidated, heterogeneously arranged material—silt, sand, gravel, and boulders—composed in part of foreign materials that were plucked by the ice from the rocks farther north and transported to their present positions, where they were dropped when the ice melted. This material ranges from a thin veneer to deposits 90 feet or more thick, as shown by well records. The greatest thickness reported in this area is in a well at Gibsondale, in the valley of Big Run, in the northwest corner of the Zelienople quadrangle, where a depth of 90 feet of sand and gravel was encountered without striking bedrock. This material was laid down apparently in the old valley of Slippery Rock Creek in the course occupied by the stream when it flowed into Beaver River. On the upland the thickness of the till commonly averages between 20 and 40 feet. Wells in the vicinity of Princeton, for instance, were put down through 35 feet of sand and gravel before reaching bedrock. The most characteristic components of the till are boulders of granite, ranging commonly from a few inches to 5 feet in diameter, which occur irregularly distributed on upland and lowland throughout the drift-covered area. As granite does not crop out within a few hundred miles north of this area, it is evident that the boulders were transported from distant sources.

Although most of the glacial material in the area occupied by the ground moraine is heterogeneously arranged, some is stratified, being water-laid by streams coming from the ice. For instance, where Big Run turns northward east of Gibsondale, just south of the road, there is exposed 15 feet of stratified sand and gravel containing rounded pebbles of granite as much as 3 inches in diameter, and in a cut on the Pittsburgh and Mercer road in Slippery Rock Township, just south of the Western Allegheny Railroad, a section shows about 20 feet of stratified sand and gravel containing boulders of granite and gneiss as much as 12 inches in diameter.

Moraines are developed at several places along the border of the Wisconsin drift. They are marked by steep-sided, irregular-shaped ridges and knobs and more or less undrained hollows composed usually of unsorted glacial drift, boulders, sand, and gravel. In places these deposits are stratified. The moraines are conspicuous a quarter of a mile south of Breakneck Bridge, northwest of the road along Cheeseman Run 1½ miles northwest of Portersville, and immediately northwest of Portersville station on the Western Allegheny Railroad.

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The drift border north of Hogue Run, between 3 and 4 miles northeast of Portersville station, is marked by typical marginal glacial deposits—a moraine in Brady Township and an outwash slope of sand and silt in Worth Township—and by a small eskerlike ridge near the border of Worth and Brady Townships.

The ice front during the Wisconsin stage crossed the newly cut gorge of Slippery Rock Creek 3½ miles above Wurtemberg, and glacial debris was carried down the creek and deposited, where topographic conditions made it possible, at several localities. Remnants of this "valley train" are preserved in the vicinity of Wurtemberg, where there are terrace deposits 40 feet or less in thickness, consisting of sand and gravel and a few granite boulders.

The Wisconsin ice sheet blocked Connoquenessing Creek at Elwood City, about 2½ miles west of the Zelienople quadrangle, and also Muddy Creek at Portersville station. These streams were ponded, and long, narrow lakes were formed in their valleys above the ice border—along Muddy Creek to an altitude of about 1,210 feet above sea level and along Connoquenessing Creek to about 940 feet. Sand and silt were deposited in these bodies of water and later covered in part by Recent alluvium.

STRUCTURE

SURFACE AND NEAR-SURFACE ROCKS

GENERAL FEATURES

The rocks of the north-central part of the Appalachian Plateaus are folded into a broad, spoon-shaped synclinorium, the Pittsburgh-Huntington Basin, that lies between the axis of the Cincinnati anticline and the Allegheny Front and extends from New York to Kentucky. The axis through the lowest part of the basin, as indicated by the attitude of the surface and near-surface rocks, extends southwestward through Pittsburgh to a point about 10 miles south of Huntington. In West Virginia this axis is interrupted by the Burning Springs anticline, which trends north. Southwest of the Burning Springs anticline the axis of the basin is marked by the Parkersburg syncline, and northeast of that anticline by the Middlebourne-Nineveh syncline. The southeast flank of the basin is characterized by secondary folds, which are more numerous and more pronounced in Pennsylvania, Maryland, and northern West Virginia than farther south, and the folds are generally more pronounced southeastward toward the Allegheny Front. The northwest flank of the basin is characterized by a monoclinal rise, toward the axis of the Cincinnati anticline, modified by minor undulations.[9]

BUTLER AND ZELIENOPLE QUADRANGLES

The Butler and Zelienople quadrangles are situated in the north-central part of the Pittsburgh-Huntington Basin a few miles west of

[9] Richardson, G. B., Structure contour maps of the Pittsburgh-Huntington Basin: Geol. Soc. America Bull., vol. 39, pp. 543–554, 1928.

its axis. (See pl. 5.) The westernmost of the pronounced northeastward-trending folds of the synclinorium in this latitude, the Kellersburg anticline, extends across the southeast corner of the Butler quadrangle. This fold is succeeded on the northwest by two less pronounced folds—the Bradys Bend syncline and the Millerstown anticline. In the northwestern part of the Zelienople quadrangle lies the Homewood anticline. In the area between the Millerstown and Homewood anticlines, constituting the greater part of both quadrangles, the rocks are gently warped, although the structure contours trend in general eastward and the prevailing dip of the strata is southward, averaging less than 30 feet per mile.

The approximate structure of the surface and near-surface rocks of the Butler and Zelienople quadrangles is shown on plates 3 and 4 by means of contours drawn at intervals of 50 feet, based on the top of the Vanport limestone. The position of the limestone was determined from its outcrop in the valleys of Muddy and Slippery Rock Creeks and from the records of a few core-drill holes and of numerous wells put down in search of oil and gas. In addition to these direct measurements the position of the limestone has been estimated in those areas where coal beds whose relation to the Vanport limestone is approximately known are exposed. There are, however, extensive areas in which the position of the limestone is not known, and in these areas the contours necessarily are generalized.

Kellersburg anticline.—The Kellersburg anticline has been traced for a distance of about 50 miles across the Clarion, Rural Valley, Kittanning, Butler, and New Kensington quadrangles. (See pl. 5.) It trends in general northeast, but, as is characteristic of the folds in the Appalachian Plateau province, the axis curves, and in places in the Kittanning quadrangle it trends almost east. The axis also undulates vertically, causing locally knobs and depressions, but in general the fold plunges southwestward, resulting in a descent of more than 1,000 feet in the strata on the crest of the fold from the eastern edge of the Clarion quadrangle to the southwest corner of the New Kensington quadrangle, a distance of about 60 miles.

In the Butler quadrangle the axis of the Kellersburg anticline (see pl. 3) crosses Little Buffalo Creek a quarter of a mile below Cabot and extends northeastward across the southeast corner of the quadrangle, a distance of 2 miles. In this distance the southwestern pitch of the axis causes the rocks to descend about 100 feet. The dip is steeper on the southeast flank of the anticline, where it is more than 100 feet to the mile, but on the northwest flank the dip is considerably less. Along the axis of this fold the Upper Freeport coal is estimated to lie only about 20 feet beneath the bed of Little Buffalo Creek. Large quantities of natural gas have accumulated along the Kellersburg anticline.

Bradys Bend syncline.—The Bradys Bend syncline, named from Bradys Bend on the Allegheny River in the Kittanning quadrangle (see pl. 5), lies west of the Kellersburg anticline and in general parallel to it. It extends from the Clarion quadrangle across the Kittanning, Butler, and New Kensington quadrangles. In the Butler quadrangle the Bradys Bend syncline is a shallow trough, in which the beds descend along the axis in Clearfield, Summit, and Jefferson Townships, at a rate between 10 and 15 feet to the mile.

Millerstown anticline.—The Millerstown fold was named by Chance [10] from Millerstown (Chicora), in the Kittanning quadrangle, 10 miles northeast of Butler. It is a distinct though not strongly developed anticline that lies northwest of the Bradys Bend syncline and has been traced across the Kittanning, Butler, and New Kensington quadrangles and part of the Sewickley quadrangle. The axis lies about 2 miles southeast of Chicora, 3 miles southeast of Butler, and 1 mile northwest of Mars. Like the adjacent folds, the Millerstown anticline plunges southwestward, and in the Butler quadrangle, along the axis of the fold, the Vanport limestone descends from an altitude of above 1,000 feet to one of less than 750 feet in a distance of 12 miles.

Homewood anticline.—The Homewood anticline extends across the east-central part of the New Castle quadrangle and the northwestern part of the Zelienople quadrangle. Its axis, plunging southwestward, lies southeast of Rose Point, leaves the Zelienople quadrangle about 3 miles southwest of Princeton, and passes through Elwood City and the vicinity of Homewood on the Beaver River.

Area between the Millerstown and Homewood anticlines.—Between the Millerstown and Homewood anticlines the general structure is synclinal, although the beds are irregularly warped. In this region there are areas of considerable size, as between Prospect and Connoquenessing and between Utley and North Butler, where the dip averages less than 10 feet to the mile. Although locally the dip is as much as 100 feet to the mile, in general the average inclination of the beds is between 30 and 50 feet.

DEEP-LYING ROCKS

Sketch contours based on the productive oil and gas sands indicate that their structure is in general accord with that of the outcropping beds. The structure of the deep-lying rocks, however, owing to the convergence of the beds, may be quite different from that of the surface or near-surface rocks. In the northwestern part of the Zelienople quadrangle the records of the two deep wells that were sunk to the Oriskany sandstone (?) suggest that the Homewood anticline, which involves rocks in the upper part of the section, may be poorly developed in the deep-lying strata.

[10] Chance, H. M., The northern townships of Butler County: Pennsylvania 2d Geol. Survey Rept. V, p. 10, 1879.

A pronounced example of the effect of convergence on structure occurs in the area between Pittsburgh and Ligonier, Pa. Between the Geary well (Peoples Gas Co. well 770), 15 miles west of Pittsburgh, and the Booth & Flinn well (Peoples Gas Co. well 1588), 4 miles northwest of Ligonier, a distance of about 50 miles, a bed of sandstone that lies approximately at the Oriskany horizon descends eastward about 800 feet, whereas the Pittsburgh coal rises eastward about 1,500 feet.

MINERAL RESOURCES

The mineral resources of these quadrangles include coal, oil, gas, limestone, clay, shale, sandstone, sand and gravel, iron ore, and water.

COAL

OCCURRENCE

The Butler and Zelienople quadrangles, which are in the north-central part of the Appalachian bituminous-coal region (see fig. 5), are underlain by coal beds in the Pottsville, Allegheny, and Conemaugh formations. For many years neighborhood mines have supplied local needs, although widespread use of natural gas has restricted the demand for coal; a few mines, mostly small, have been opened along the railroads.

The principal coal beds are the Middle Kittanning and Upper Freeport, of the Allegheny formation, which over considerable areas range from 30 to 40 inches in thickness and in places are thicker. Locally a bed in the approximate position of the Brush Creek, in the Conemaugh formation, is more than 4 feet thick, and in places the Lower Freeport and Upper and Lower Kittanning coals are well developed. These coal beds are variable in occurrence and thickness and in places are absent. In comparison with the thick Upper Freeport and Pittsburgh beds in nearby areas to the south, the coal in these quadrangles in general is thinner. But very little core drilling has been done, and therefore much remains to be determined concerning the occurrence, thickness, and correlation of the coal beds in this area.

COAL IN THE POTTSVILLE FORMATION

The lowest horizon at which coal occurs in this area is in the Mercer shale member of the Pottsville formation, in which there are two variable beds of coal, the Upper and Lower Mercer, separated by 30 to 40 feet of shale. The Mercer coal in this area, so far as known, is less than 14 inches thick and is of little present value.

COAL IN THE ALLEGHENY FORMATION

Coal in the Allegheny formation includes the Brookville; Clarion; Scrubgrass; Lower, Middle, and Upper Kittanning; and Lower and

Upper Freeport beds. Of these only the Kittanning and Freeport have been mined in these quadrangles, and the most persistent are the Middle Kittanning and Upper Freeport.

BROOKVILLE, CLARION, AND SCRUBGRASS COALS

Beds at the horizons of the Brookville, Clarion, and Scrubgrass coals in the lower part of the Allegheny formation, between 0 and 60 feet below the Vanport limestone, crop out in the valleys of Slippery Rock and Connoquenessing Creeks near the western border of the Zelienople quadrangle. In the area of outcrop, so far as known, these

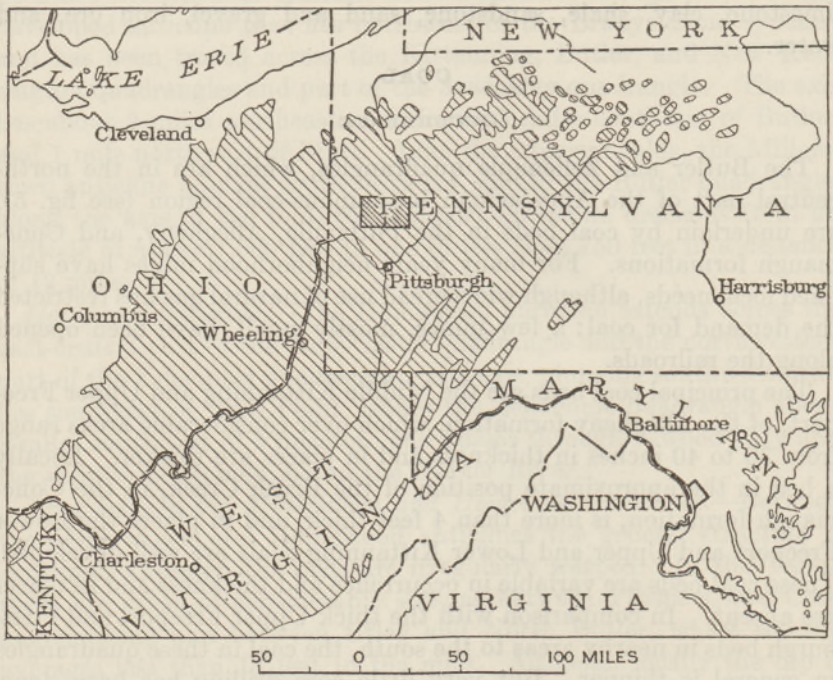


FIGURE 5.—Map of the northern Appalachian bituminous-coal region. Closely shaded area indicates location of Butler and Zelienople quadrangles.

coals are not present or are poorly represented. However, core drilling in Forward Township shows an unusually thick local devlopment of the Scrubgrass (Upper Clarion) coal, which lies directly beneath the Vanport limestone or is separtted from it by only a few inches of shale. The records of four core-drilled holes between 2 and 3 miles north and northeast of Evans City show the presence of a coal bed at the Scrubgrass horizon between 4 feet and 4 feet 10 inches thick. (See records 11, 12, 13, and 14, pp. 77–78.) In the drill holes the coal lies between 200 and 350 feet beneath the surface, but the extent of this thick bed has not been determined.

KITTANNING COALS

The core-drill records (pp. 76–80) show the variable thickness and stratigraphic occurrence of the Lower, Middle, and Upper Kittanning coal beds.

Lower Kittanning coal.—Little is known of the Lower Kittanning coal in these quadrangles. Beds at its horizon crop out in the valley of Muddy Creek below Barber, in the valley of Slippery Rock Creek, and in the valley of Connoquenessing Creek below Camp Run, but the coal bed has been opened at only a few places. In abandoned banks in the valley of Connoquenessing Creek, near the mouth of Camp Run, coal between 18 and 24 inches thick is reported. At the mine of Thorman Bros., 1½ miles north of Princeton, the following section was measured. The bed is reported to decrease in thickness to 6 inches on the opposite side of the hill on which the mine is located.

Section of Lower Kittanning coal at Thorman Bros.' mine

	Ft.	in.
Shale, black.		
Coal		10
Shale		¼
Coal	2	6
Clay.		

In the area in which the Lower Kittanning coal is covered by younger rocks, including all of the Butler quadrangle and the greater part of the Zelienople quadrangle, little is known of this bed. Its presence is shown in the record of only one core-drill hole (no. 31) in Summit Township, Butler County. (See p. 80.) In drill holes 8, 11, 13, and 14 (pp. 77–78) no coal at the Lower Kittanning horizon was reported. East of Butler, in the Kittanning quadrangle (see fig. 1), the Lower Kittanning coal is well developed, and over a considerable area it averages between 3 and 4 feet in thickness. Evidently the bed thins to the west, but where the thinning takes place and the extent and thickness of the bed in the area where it is covered remain to be determined by core drilling.

Middle Kittanning coal.—Coal in the Middle Kittanning zone crops out in the valleys of Muddy, Slippery Rock, and Connoquenessing Creeks and their tributaries, where there are several country banks and a few shipping mines.

In the valley of Muddy Creek several small mines have been opened along the Western Allegheny Railroad. Most of them have had a precarious existence in striving to meet the economic conditions that have depressed the coal industry since the World War. Sections 1 to 10, plate 8, show the thickness of the coal where measured in Worth and Brady Townships, Butler County. Sections 11 to 19 show the thickness in the valley of Slippery Rock Creek, and sections 20 to 26 in the valley of lower Connoquenessing Creek and Camp Run.

The Middle Kittanning coal crops out a few feet above water level in Connoquenessing Creek in the vicinity of Zelienople, and I. C. White in 1878 reported that the bed was opened below the Lutheran Church and mined under the town. These workings have long been abandoned. White states that the coal was extensively mined just below the mouth of Little Connoquenessing Creek, where the following section is shown:

Section in Jackson Township, Butler County, below mouth of Little Connoquenessing Creek

	Ft.	in.
Coal	1	4
Shale		1
Coal	1	2
Concealed to creek	10	0

At Harmony Junction the coal was formerly mined in a shaft 35 feet deep, where section 27 was measured. At Evans City the coal was also formerly mined in a shaft 112 feet deep, where the bed is reported to be about 3 feet thick.

In the valley of Yellow Creek the Middle Kittanning coal crops out near water level for a distance of several miles, and a number of country coal banks have been opened and abandoned. Sections 28 to 31, plate 8, were measured at the places indicated.

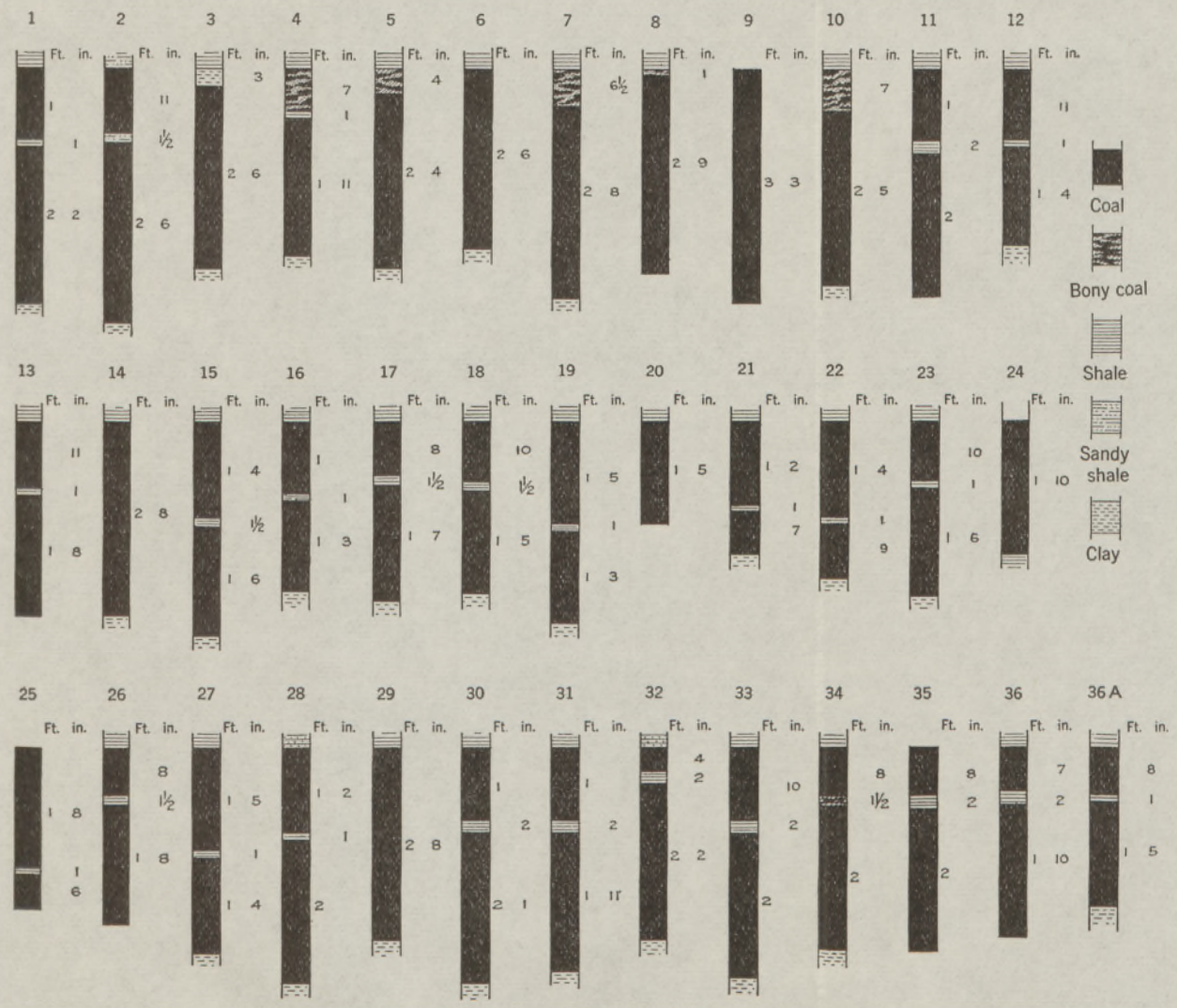
The Middle Kittanning coal is under the cover of overlying rocks in the valley of Connoquenessing Creek for several miles between the vicinity of Harmony Junction and North Butler, but the coal again crops out near water level between North Butler and the vicinity of Oneida. There the bed has been opened at several localities and mined at the Brier Hill, Zenith, Cosco, and other mines. Sections 32 to 36A, plate 8, indicate the thickness of the bed in this area.

Records of core-drill holes show that the Middle Kittanning coal ranges in thickness northeast of Evans City from 1 foot 7 inches to 2 feet 11 inches, and in the area north of Butler and west of Connoquenessing Creek from 2 feet 5 inches to 3 feet 1 inch.

Upper Kittanning coal.—The Upper Kittanning coal is nonpersistent and variable and has been opened at only a few places. Records of the few core-drill holes that have been put down indicate that in some areas the Upper Kittanning coal is absent; in others it is represented by only a few inches of coal; and in one record (CD 24) a thickness of 4 feet is shown. (See fig. 6.)

In Center Township, in the vicinity of Center School, section 37, figure 6, was measured in an old bank.

Coal in the Upper Kittanning zone has been opened at several places along Muddy, Little Connoquenessing, and Connoquenessing Creeks. Near the mouth of Crab Creek the following section (see fig. 6) was measured:



SECTIONS OF MIDDLE KITTANNING COAL.

Numbers refer to locations on plates 3 and 4.

Section in Lancaster Township, Butler County, half a mile southeast of Bloomfield School (no. 38)

	Ft.	in.
Shale.		
Coal, bony		8
Coal	2	0
Clay.		

FREEPORT COALS

The Freeport coal zone is exposed over a large area in both quadrangles, in the valleys of Connoquenessing, Slippery Rock, and Muddy Creeks and their principal tributaries. Although variable, the coal beds in this zone are in general thicker in the eastern part of the area than in the western part. The Lower Freeport coal, except

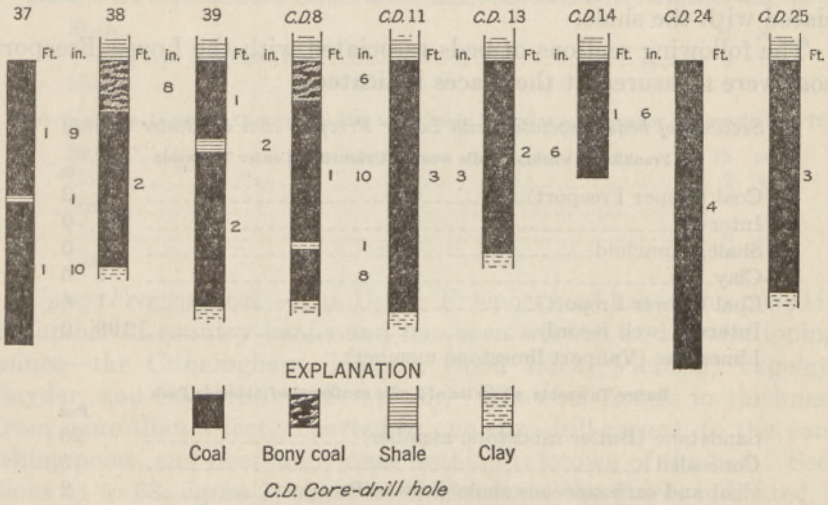


FIGURE 6.—Sections of Upper Kittanning coal. (Numbers refer to locations on pl. 4 and fig. 9.)

locally, does not attain workable thickness; the Upper Freeport, however, has a widespread distribution, has been opened in a number of country banks, and in the Butler quadrangle is worked at a few shipping mines.

Lower Freeport coal.—The Lower Freeport coal is known at only a few localities in these quadrangles.

At Fenelton, in Clearfield Township, about a mile east of the Butler quadrangle, the Lower Freeport coal is 3 feet thick and has been mined. However, the bed thins to the west, and in core-drill holes in Oakland and Summit Townships it is only 2 feet thick. In some core-drill holes the Lower Freeport coal is absent, and in others it is represented by a bed generally less than 2 feet thick. A record

of a hole in Worth Township shows the following unusual development of coal in or near the Lower Freeport zone:

Section in Worth Township, Butler County, 1½ miles north of Nealeys

	Ft.	in.
Shale.		
Coal, cannel	2	0
Coal, bituminous	3	7
Clay		4
Coal, bituminous	1	0
Clay.		

In the valleys of Swamp Run and Muddy Creek a variable bed of black shale occurs in the zone of the Lower Freeport coal. The shale is locally canneloid, and in places a thin bed of cannel coal is associated with the shale.

The following sections of beds associated with the Lower Freeport coal were measured at the places indicated:

Sections of beds associated with Lower Freeport coal in Butler County

Franklin Township 1 mile west of Unionville, Center Township

	Ft.	in.
Coal (Upper Freeport)	1	2
Interval	38	0
Shale, canneloid	8	0
Clay	1	6
Coal (Lower Freport)	1	6
Interval (well record)	198	0
Limestone (Vanport limestone member).		

Butler Township a quarter of a mile southeast of Alameda Park

	Feet
Sandstone (Butler sandstone member)	20
Concealed	5
Coal and carbonaceous shale (Lower Freeport)	2
Clay and shale	3
Limestone	1

Forward Township railroad cut at Wahlville

	Feet
Shale	15
Coal (Lower Freeport)	2
Clay and shale	5
Limestone	2
Interval	50±
Coal (Upper Kittanning), mined at Wahlville.	

Forward Township, Breakneck Creek, southeastern part of Evans City

	Inches
Shale.	
Coal (Lower Freeport)	13
Clay.	

In the vicinity of Portersville a bed of coal, locally known as the "5-foot bed," is tentatively considered to be at or near the horizon of the Lower Freeport, although the stratigraphic position of the coal in relation to the Vanport limestone remains to be determined by core drilling. This bed has been opened at several country banks; at the Scheidemantle, Bauder, Garner, and Kelly mines, in Muddy

Creek Township, Butler County; and at the Young and Workley (lower) mines, in Perry Township, Lawrence County. The limits of this thick bed, however, have not been determined. The following measurements have been made on this bed:

Sections of coal bed locally known as the "5-foot bed"

Muddy Creek Township, Butler County, Scheidemantle mine, three-quarters of a mile south of Portersville (no. 77)

	Ft.	in.
Shale.		
Coal	2	2
Shale		2
Coal	2	2
Clay.		

Muddy Creek Township, Butler County, Bauder bank, 1 mile southeast of Portersville (no. 78)

	Ft.	in.
Shale.		
Coal 3 feet 4 inches to	4	6
Shale.		

Perry Township, Lawrence County, Workley lower bank, 2¼ miles southwest of Portersville (no. 79)

	Ft.	in.
Shale.		
Coal	2	0
Shale		½
Coal	2	0
Clay.		

Upper Freeport coal.—The Upper Freeport coal has been opened in a number of country banks and has been worked at a few shipping mines—the Cunningham, Holben, Good Luck, Victoria, Vogeley, Snyder, and Coal Run. (See pl. 3.) The coal ranges in thickness from more than 5 feet, reported in one core-drill record, to the vanishing point, and over large areas nothing is known of the bed. Sections 41 to 68, figure 7, show its thickness at the places indicated.

COAL IN THE CONEMAUGH FORMATION

Coal in minable thickness occurs locally in the Conemaugh formation in these quadrangles, at the approximate horizon of the Brush Creek bed, about 80 feet above the Upper Freeport coal, in Connoquenessing, Lancaster, and Oakland Townships, Butler County, and in Perry Township, Lawrence County.

In Connoquenessing Township and adjacent parts of Lancaster Township, in the valleys of Semiconon, Mulligan, and Crab Runs, a few country banks have been opened on the outcrop of this coal, and core drilling has shown the occurrence of the bed beneath the divides. Measurements of the Brush Creek coal are shown in sections 70 to 76, figure 8.

CHEMICAL CHARACTER OF THE COAL

Analyses of mine samples of coal from the Butler and Zelienople quadrangles (see pp. 40–41) show its chemical character. The samples were collected in the mines by representatives of the United States Geological Survey or the United States Bureau of Mines, in accordance with the standard method of sampling, by making a cut from the roof

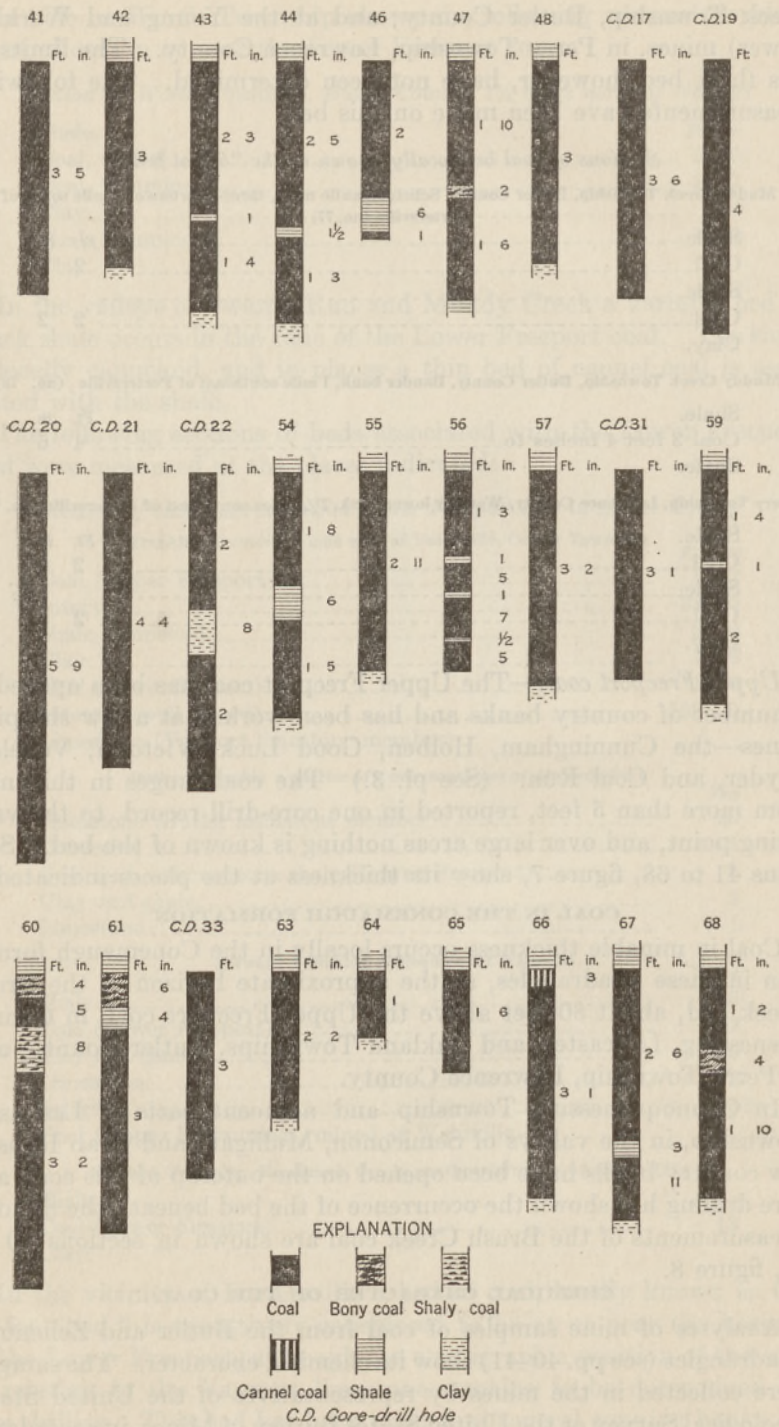


FIGURE 7.—Sections of Upper Freeport coal. (Numbers refer to locations on pls. 3 and 4 and fig. 9.)

to the floor across a fresh face of the bed and rejecting the partings that are discarded in mining. After each sample was pulverized and quartered down in the mine, it was sealed in a galvanized can and sent to the laboratory of the Bureau of Mines, where it was analyzed.

A proximate analysis, showing the percentages of moisture, volatile matter, fixed carbon, and ash, was made of each sample, and an ultimate analysis, showing the percentages of carbon, oxygen, hydrogen, nitrogen, and sulphur, was made of selected samples. The results of the analyses are given in four forms. Form A shows the composition of the sample on an air-dried basis, form B shows the composition of the sample as received at the laboratory and represents the condition of the coal in the mine, form C shows the composi-

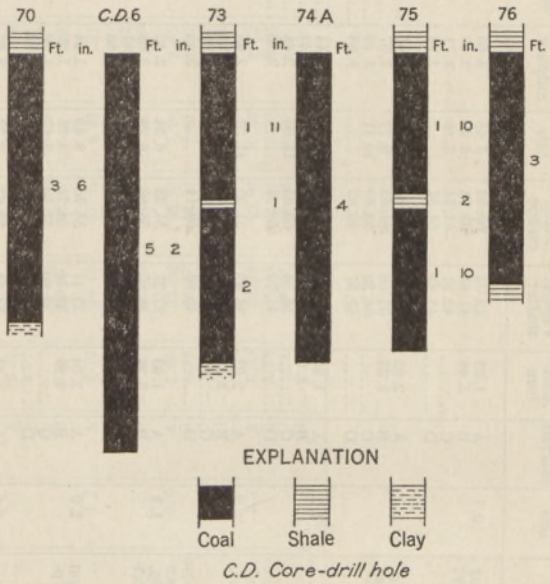


FIGURE 8.—Sections of Brush Creek coal. (Numbers refer to locations on pls. 3 and 4.)

tion of the coal dried at a temperature of 105° C., and form D computed as theoretically free from moisture and ash.

The coal is a high-volatile bituminous variety. It has a fuel ratio (fixed carbon divided by volatile matter) of about 1.5 and a fixed carbon content, on a moisture- and ash-free basis, of about 59 percent. The coal is low in moisture, moderately low in sulphur, and not high in ash. A typical sample "as received" has the following composition:

Moisture	3
Volatile matter	36
Fixed carbon	53
Ash	8
	100

Analyses of samples of coal from mines in the Butler and Zelienople quadrangles, Pa.

[Made by U. S. Bureau of Mines]

Laboratory No.	Mine	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value (British thermal units)
				Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	
25823	Young mine, Connoquenessing Township, Butler County; Brush Creek coal (?).	2.1	A	1.38	42.32	50.82	5.48	3.66	5.26	76.45	1.19	7.96	13,948
			B	3.46	41.43	49.75	5.36	3.58	5.38	74.84	1.16	9.68	13,653
			C		42.91	51.54	5.55	3.71	5.18	77.52	1.20	6.84	14,143
			D		45.43	54.57		3.93	5.48	82.08	1.27	7.24	14,974
23129	Victoria mine, Center Township, Butler County; Upper Freeport coal.	1.3	A	2.05	35.55	52.50	9.90	3.41					13,136
			B	3.33	35.08	51.82	9.77	3.37					12,964
			C		36.29	53.60	10.11	3.49					13,410
			D		40.37	59.63		3.88					14,918
23130	do	1.2	A	1.95	36.65	49.65	12.75	2.43					12,722
			B	3.08	35.24	49.08	12.60	2.40					12,577
			C		36.36	50.64	13.00	2.48					12,976
			D		41.79	58.21		2.85					14,915
23131	Composite of 23129 and 23130	1.2	A	2.03	35.42	51.25	11.30	2.95	5.06	71.52	1.47	7.70	12,910
			B	3.24	34.98	50.62	11.16	2.91	5.14	70.64	1.45	8.70	12,751
			C		36.15	52.32	11.53	3.01	4.94	73.01	1.50	6.01	13,178
			D		40.86	59.14		3.40	5.58	82.52	1.70	6.80	14,895
23125	Eagle mine, Center Township, Butler County; Upper Freeport coal.	1.3	A	1.93	37.37	54.32	6.38	2.62	5.32	75.85	1.58	8.25	13,747
			B	3.24	36.87	53.60	6.29	2.58	5.40	74.83	1.56	9.34	13,563
			C		38.11	55.39	6.50	2.67	5.21	77.34	1.61	6.67	14,017
			D		40.76	59.24		2.86	5.57	82.72	1.72	7.13	14,990
23066	Cunningham mine, Donegal Township, Butler County; Upper Freeport coal.	2.9	A	2.04	33.11	56.36	8.49	1.24	5.07	75.57	1.33	8.30	13,410
			B	4.91	32.14	54.71	8.24	1.20	5.25	72.36	1.29	10.66	13,018
			C		33.80	57.53	8.67	1.26	4.94	77.15	1.36	6.62	13,689
			D		37.01	62.99		1.38	5.41	84.47	1.49	7.25	14,989
23065–F	Vogeley mine, Summit Township, Butler County; Upper Freeport coal.	2.1	A	1.75	34.85	53.67	9.73	3.67	4.95	73.19	1.30	7.16	13,291
			B	3.78	34.13	52.56	9.53	3.59	5.08	71.67	1.27	8.86	13,016
			C		35.47	54.63	9.90	3.73	4.84	74.49	1.32	5.72	13,527
			D		39.37	60.63		4.14	5.37	82.68	1.47	6.34	15,014
23128	Muntz mine, Butler Township, Butler County; Upper Freeport coal.	1.0	A	1.93	37.15	53.32	7.60	3.01	5.33	75.46	1.44	7.16	13,568
			B	2.95	36.76	52.77	7.52	2.98	5.39	74.68	1.43	8.00	13,516
			C		37.88	54.37	7.75	3.07	5.21	76.95	1.47	5.55	13,927
			D		41.06	58.94		3.33	5.65	83.41	1.59	6.02	15,097

23127	Reamer mine, Jefferson Township, Butler County; Upper Freeport coal.	2.4	A	2.20	33.78	55.79	8.23	1.29	5.25	75.69	1.43	8.11	13,529
			B	4.57	32.96	54.44	8.03	1.26	5.39	73.86	1.40	10.06	13,201
			C		34.54	57.05	8.41	1.32	5.11	77.40	1.47	6.29	13,833
			D		37.71	62.29		1.44	5.58	84.51	1.60	6.87	15,012
23132	Zenith No. 1 mine, Center Township, Butler County; Middle Kittanning coal.	1.7	A	2.10	36.40	57.02	4.48	.85					14,119
			B	3.72	35.80	56.07	4.41	.84					3,887
			C		37.18	58.24	4.58	.87					14,423
			D		38.96	61.04		.91					15,116
23133	do	1.7	A	2.35	36.90	56.37	4.38	.89					14,117
			B	3.97	36.29	55.43	4.31	.88					13,883
			C		37.79	57.72	4.49	.92					14,458
			D		39.57	60.43		.96					15,138
23134	Composite of 23132 and 23133	1.7	A	2.10	36.45	57.02	4.43	.91	5.39	78.62	1.56	9.09	14,092
			B	3.73	35.84	56.07	4.36	.89	5.48	77.31	1.53	10.43	13,858
			C		37.23	58.24	4.53	.92	5.27	80.30	1.59	7.39	14,395
			D		38.99	61.01		.96	5.52	84.11	1.67	7.74	15,077
23064–F	Thompson's mine, Summit Township, Butler County; Middle Kittanning coal.	2.6	A	1.80	35.30	55.70	7.20	2.05	5.09	76.48	1.46	7.72	13,738
			B	4.38	34.37	54.24	7.01	2.00	5.25	74.47	1.42	9.85	13,376
			C		35.94	56.73	7.33	2.09	4.98	77.88	1.49	6.23	13,988
			D		38.78	61.22		2.26	5.37	84.04	1.61	6.72	15,095
25822	Nealey mine, Worth Township, Butler County; Middle Kittanning coal (?).	3.7	A	1.65	37.95	49.80	10.60	3.85	5.13	72.13	1.23	7.06	13,070
			B	5.32	36.53	47.95	10.20	3.70	5.35	69.44	1.18	10.13	12,582
			C		38.58	50.65	10.77	3.91	5.03	73.34	1.25	5.70	13,289
			D		43.24	56.76		4.38	5.64	82.19	1.40	6.39	14,893

PRODUCTION

The table below shows the production of coal mines in the Butler and Zelienople quadrangles in 1928, as reported by the Department of Mines of Pennsylvania.

Coal produced in 1928 at mines in the Butler and Zelienople quadrangles

[From Department of Mines of Pennsylvania]

Mine	Operator	Opening	Production (net tons)
Brannon (formerly Fox)	Brannon Mining Co	Drift	5,753
Brier Hill	Brier Hill Coal Co	do	31,793
Butler No. 2	Butler Coal Mining Co	Slope	41,020
Cosco No. 1	Cosco Gas Coal Co	Drift	90,460
Cosco No. 2	do	Slope	57,937
Holben	DeWolf Holben Coal Co	do	43,245
Kildoo No. 2	F. P. Filer & Co	Drift	Idle
Flint (formerly Jewel)	W. H. Flint	do	Idle
Haney	Haney Coal Co	do	4,915
Hilliard	J. M. Hilliard	Slope	3,622
Good Luck	Roy S. Imbrie Coal Co	Drift	16,984
Black Block	F. L. Jackson	do	2,025
Keystone	Keystone Mechanical Collieries	do	29,457
Snyder	McCormick Coal Co	do	25,490
Nealey	Nealey Mining Co	do	3,000
Harmony Junction	North Pittsburgh Realty Co	Shaft	Idle
Oneida	Oneida Coal Co	Drift	21,368
Vogeley No. 1	Vogeley Coal Co	do	97,811
Vogeley No. 2	do	do	37,671
Susanna	Wilson & Gloninger	Shaft	17,875
Coal Run	James Zellreno	Drift	9,000
Zenith No. 1	Zenith Coal Co	Slope	46,152
Zenith No. 2	do	do	10,806
			596,384

OIL AND GAS

REVIEW OF NORTHERN APPALACHIAN REGION

The Butler and Zelienople quadrangles are situated in the northern Appalachian oil and gas region, which occupies an area of elliptical outline in the central part of the Pittsburgh-Huntington synclinorium. The region includes many fields in Ontario, New York, Pennsylvania, Ohio, West Virginia, and eastern Kentucky.

The northern Appalachian oil and gas region is underlain by beds of sandstone, shale, and limestone, ranging in age from Cambrian to Carboniferous, and the productive strata have a correspondingly wide range. From the Potsdam sandstone, of Upper Cambrian age, small quantities of natural gas have been obtained in central New York. The Trenton limestone, of Middle Ordovician age, has produced small quantities of gas in New York, and a limestone of Trenton or Black River age is the principal source of oil and gas in the Lima-Indiana field of northwestern Ohio and northeastern Indiana. The Albion sandstone, of early Silurian age, is the source of much natural gas in western New York, and the so-called "Clinton sand", at approximately this horizon, has yielded large quantities of oil and gas in central Ohio. The eastward and southward con-

tinuation of this sand has been the objective of deep drilling, but on account of the eastward thickening of the section this horizon has not yet been reached by wells in southwestern Pennsylvania and northern West Virginia, although in northwestern Pennsylvania, in Erie, Crawford, and Warren Counties, small quantities of natural gas have been found in the Albion sandstone.

In a well near Ligonier, Westmoreland County, gas has been obtained from beds at two horizons—one, which may be in the Cayuga group, at a depth of 7,440 feet, and the other, which may be the horizon of the Oriskany sandstone or possibly the Onondaga limestone, at a depth of 6,827 feet. A limestone at or near the horizon of the Onondaga (†Corniferous) limestone, of Middle Devonian age, is the principal productive bed in Kentucky, and some gas has been obtained from a bed at this horizon in New York. In Tioga and Potter Counties, Pa., and in south-central New York, gas is obtained in wells of large capacity in the Oriskany sandstone.

The most productive oil and gas sands of Pennsylvania, West Virginia, and southeastern Ohio are of Upper Devonian and Mississippian age. Locally a small output is obtained from beds of Pennsylvanian age. Some of the oil sands, such as the Berea sandstone (Mississippian), are persistent over wide areas, but in general the beds are characteristically lenticular. The productive sands of Upper Devonian age, which are well developed in southwestern Pennsylvania and northern West Virginia, thin out and disappear to the west, and in northwestern Pennsylvania, southwestern West Virginia, and eastern Ohio their horizons are represented by shale.

The Appalachian oil and gas fields are characteristically elongated and occur in alinement with the major structural trends. The productive sands are commonly lenticular beds, in which there are streaks of coarser sand and gravel, that presumably were laid down parallel to the old shore lines of the sea in which the beds accumulated. Although some of the oil and gas sands maintain relative homogeneity over considerable areas, most of the sands are variable and within short distances thicken or thin and merge into beds of different composition and texture. The sands show pronounced variations in porosity and permeability and differ in degree of cementation. Oil and gas occur in the more porous "open" parts of the beds, in places regardless of structure, and are absent from the less porous "tight" parts.

Although lithologic conditions play so important a part in the occurrence of petroleum in this region, there is in many of the Appalachian fields, as in other areas, a distinct relation between the occurrence of oil and gas and the structure of the rocks. Gas is generally trapped in the tops of domes, the crests of anticlines, or the structurally high parts of lenticular sands. Water, on the other hand,

tends to migrate down the dip into structurally lower parts of the beds. Oil, containing gas in solution, occupies an intermediate position between the gas and the water if all three are present. Where water is absent oil may be found on the lower flanks of folds and in synclines. Where water is present but gas does not occur in abundance, oil may accumulate on the crests of anticlines. Where gas is plentiful it may occur not only along the crests of anticlines but on their flanks and, in the absence of oil and water, along synclines. In the Butler and Zelienople quadrangles gas occurs locally along anticlines, but in general there seems to be little relation between the occurrence of oil and the geologic structure.

Many questions concerning the origin of petroleum are unanswered, but it is believed to be derived chiefly from certain aquatic plants and animals of low orders that accumulated in sediments in the basins in which the oil sands were deposited, and the petroleum was probably generated by bacterial, chemical, and dynamic processes acting in the course of geologic time on the organic matter in the sediments. Oil may be driven from the source deposits and concentrated in the pore spaces of the reservoir rocks by the compaction of the source beds, capillarity, the expansive force of gas dissolved in the oil, diastrophism, the pressure of water, and gravitation. The occurrence of a relatively impervious cap or barrier, such as shale, compact limestone, or indurated sandstone, tends to prevent the escape of the hydrocarbons from the reservoir sands.

Little is known of the source beds from which the oil and gas of the Appalachian region were derived, but probably they are chiefly the shales that are associated with the producing sands. Under favorable conditions locally abundant source material was laid down with the sediments that are interstratified with the reservoir rocks. In some fields there may have been comparatively little migration of the hydrocarbons. The varying productivity of certain areas seems to have been controlled by the porosity, size, and structure of the reservoir sands and by the varying content of source material in adjacent beds.

OIL AND GAS IN THE BUTLER AND ZELIENOPLE QUADRANGLES

GENERAL FEATURES

Shortly after the discovery of oil in the Drake well in the valley of Oil Creek, in Venango County, in 1859, and the development of the Smiths Ferry field, in Beaver County, in 1861, a small quantity of oil was found in the Butler-Zelienople area in shallow wells in the valley of Slippery Rock Creek, Lawrence County. The beginning of the major development in this area, however, dates from 1872, when oil was found in Concord Township, Butler County, in the southern extension of the productive belt of Clarion and Armstrong Counties.

The development of the belt was extended southward until 1876, when operations reached the vicinity of Saxonburg, at the southern boundary of the Butler quadrangle. About this time the Bradford field, in McKean County, attracted so many workers from the "lower fields" that for several years operations in Butler County were neglected.

Bringing in of gushers south of Butler in 1882–83 caused renewed interest in this region. Shortly thereafter several productive areas were discovered, including the Thorn Creek, Glade Run, "Little Creek", and Muddy Creek fields, and by 1902 the main areas in these quadrangles had been discovered and the maximum yield obtained. From time to time, however, small productive areas have been found, tending to stimulate the drilling of new wells. For many years production in these quadrangles has been decreasing, and the average daily output of oil per well is now only a fraction of a barrel.

Plates 3 and 4 show the location of oil and gas wells concerning which information was obtained, but not of many hundred abandoned wells, all trace of which has disappeared. Notwithstanding the large number of wells that have been drilled in the Butler and Zelienople quadrangles, there is very little information concerning the mode of occurrence of oil and gas in this area. The available information is summarized below.

OIL AND GAS SANDS

Oil and gas in these quadrangles have been obtained from several sands that lie between 340 and 2,200 feet beneath the Vanport limestone and are members of the Pocono, Catskill, and Chemung formations of the Allegheny Front sequence, or their equivalents, of Mississippian and Upper Devonian age. In the nomenclature of the drillers the sands are known as the "Slippery Rock, Berea, Butler County gas or Murrysville, Hundred-foot, Thirty-foot, Snee, Boulder, Third, Fourth, Fifth, and Speechley." Most of the oil and gas has come from the sands lying between the Murrysville and Fourth, inclusive, which occupy an interval of about 500 feet, and the most productive sands have been the Third, Fourth, and Hundred-foot. (See pp. 8–10.)

Core samples of the oil and gas sands in these quadrangles have not been taken, and the sands are known only from bailings obtained in churn drilling and from specimens brought to the surface in shooting the wells. The sands range in thickness from less than 5 feet to more than 100 feet; those below the Hundred-foot are rarely more than 30 feet thick. The pay streaks average between 2 and 10 feet. In texture they are fine- to coarse-grained, and commonly there are streaks of pebbles. The sands are chiefly quartzose but contain also feldspars, flakes of mica, and a few ferromagnesian minerals embedded in a clayey matrix, cemented chiefly by silica and subordinate calcite.

The sandstones vary in degree of cementation; in general they are thoroughly indurated, but locally they are somewhat soft. The pay streaks, the pore spaces of which are occupied by oil and gas, are comparatively uncemented and, as reported by the drillers, are soft and "open", in contrast with the barren parts of the sand, which are hard and "tight."

The beds of sand that are encountered in drilling for oil and gas in these quadrangles are indicated in the records of selected wells that are representative of many hundred that have been drilled (pp. 81–88). All the wells start in rocks that lie above the base of the Pottsville formation and therefore span the unconformity between rocks of Pennsylvanian and Mississippian age. The records show, however, only slight variations in the intervals between the Vanport limestone and the oil and gas sands.

PRINCIPAL PRODUCING AREAS

SLIPPERY ROCK FIELD

The first petroleum found in the Butler-Zelienople area came from shallow wells in the gorge of Slippery Rock Creek a few miles above Wurtemberg. Lesley examined the field in 1864,[11] and it was described by White in his report on Lawrence County, published in 1879.[12] This was a small pool of little economic importance. It is of interest, however, because of its early discovery and of the shallow occurrence of the oil in a sand stratigraphically higher than the other oil sands of this region.

This area was drilled originally, it is reported, because of a small seepage of oil from the Connoquenessing sandstone in the bed of the creek about 3 miles above Wurtemberg. Most of the wells were located between 10 and 20 feet above water level, and oil was obtained in sandstone at a depth of about 200 feet. The wells were small, having in general an initial production of less than 10 barrels. White reports that the well of greatest capacity had an initial output of 50 barrels a day and to 1877 had yielded a total of about 40,000 barrels of oil. The oil is reported to have been "heavy", having a gravity between 32° and 36°. It was hauled by wagon to New Castle, a distance of about 10 miles.

When the area was visited by the writer in 1916 all the old wells in the gorge of the creek had long been abandoned, but there were two wells on a small tributary run about half a mile northwest of the creek and 2½ miles due west of the Mountville Church. These were being pumped and produced less than a barrel of oil a day and con-

[11] Lesley, J. P., Report on petroleum in Pennsylvania: Pennsylvania 2d Geol. Survey Rept. J, pp. 90 104, 1875.

[12] White, I. C., The geology of Lawrence County: Pennsylvania 2d Geol. Survey Rept. Q³, pp. 88–90,–1879.

siderable water. The log of one of these wells, furnished by T. A. Book, driller, follows:

Log of oil well 2½ miles west of Mountville Church, Slippery Rock Township, Lawrence County

	Thickness (feet)	Depth (feet)
Shale	34	34
Limestone (Vanport limestone member)	14	48
Shale	85	133
Sandstone	55	188
Shale	90	278
Sandstone	60	338
Shale	50	388
Sand (Slippery Rock oil sand; oil at 415 to 425 feet)	60	448

According to this record, the Slippery Rock sand lies 340 feet below the Vanport limestone. Here the sand is 60 feet thick, the oil stood 27 feet below its top, and the pay streak was 10 feet thick. This record in connection with others given by I. C. White shows that the sand is a lens that ranges in thickness from a featheredge to 60 feet. In some drill holes the sand was not found. Small quantities of oil in this area have also been found in the so-called "Amber sand" at a depth of about 670 feet below the Vanport limestone.

A test well sunk in the valley of Slippery Rock Creek many years ago showed the absence in this area of the sands between the Hundred-foot and the Fifth which are abundant producers farther east. This is the Shaffer or "Cove Hollow" well, 4 miles northeast of Wurtemberg and 3½ miles southwest of Rose Point, which was started about 15 feet below the Lower Mercer limestone and sunk to a depth of 1,436 feet. (See record 29, p. 88.)

THIRD AND FOURTH SAND FIELDS

The most productive areas in these quadrangles have yielded oil from the Third and Fourth sands in the belt that lies across the eastern part of the Butler quadrangle and the westward extension of that belt.

Third and Fourth sand belt.—This belt, which extends from the vicinity of Saxonburg and Jefferson Center northeastward through Great Belt, Herman, Carbon Center, and St. Joe to Greece and Troutman, is part of the Third and Fourth sand belt of Clarion, Armstrong, and Butler Counties. Northeast of the Butler quadrangle the belt extends through Kerns City, Fairview, Petrolia, Parkers Landing, St. Petersburg, and Edenburg to Elk City, and southwestward the belt continues to the vicinity of Bakerstown, in the New Kensington quadrangle. (See fig. 1.) A westward extension of the belt includes the Thorn Creek and Glade Run fields. During the height of the development, between 1870 and 1890, the localities mentioned were

the centers of much activity, and some of the wells of largest initial capacity and longest life in Pennsylvania are situated in this area.

In 1868, 9 years after oil was discovered in the famous Drake well, in Venango County, oil was found in the vicinity of Parkers Landing, on the Allegheny River about 7 miles northeast of the Butler quadrangle. Development rapidly extended northeastward to St. Petersburg, Edenburg, and Elk City and southwestward to Bruin, Petrolia, and Millerstown (Chicora). Oil was at first found in the Third sand, lying between 1,150 and 1,200 feet below the Vanport limestone. In 1870 production was obtained in a well on Armstrong Run, about 7 miles east of the northeast corner of the Butler quadrangle, from beds which later proved to be the Fourth sand and which is 50 to 70 feet below the Third sand. This discovery opened up the Butler County "cross belt", which extended diagonally across the previously found producing area westward from the mouth of Armstrong Run at the Allegheny River for about 5 miles to Petrolia and thence southwestward 7 miles to Greece.

The first oil production in the Butler quadrangle apparently was made on the Jamison farm, in Concord Township, where on August 22, 1872, the Morrison well came in flowing at a rate between 300 and 700 barrels a day. This was a "wildcat" well several miles southwest of the nearest producing well. Rapid development of the surrounding area followed, and the oil-boom towns of Greece and Modoc (at the crossroads half a mile northwest of Byers Corner) sprang up. By January 1873, 30 wells were being drilled in the vicinity of Greece, and in March a well flowing several hundred barrels came in on the Troutman farm, about 2½ miles northeast of Greece, which opened new territory. In a short time the area in the vicinity of Byers Corner, Troutman, and Haysville was dotted with wells. Development of the main belt continued southward during the succeeding few years. By 1874 activities had reached Donegal Township, where the oil town of St. Joe had sprung up, and by 1876 operations had extended as far as Herman, in Summit Township.

An indication of the activity in these oil fields is afforded by the following statements: [13] On January 3, 1874, 5,590 barrels of oil was produced from 86 wells on 24 farms in the "cross belt." In the Butler County district in July 1874, there were 667 producing wells, 112 wells were being drilled, and shipments of oil for the month amounted to 656,861 barrels. On February 20, 1875, 721 wells produced 14,085 barrels of oil.

Maps showing the location of these old wells are not available. Many wells had an initial daily production of several hundred barrels, some came in at the rate of 1,000 barrels a day, and possibly a few were somewhat larger. Some wells were short-lived, but others

[13] The Derrick's Handbook of petroleum, pp. 220, 241, Oil City, Pa., 1898.

have produced for many years. The Divener well, for instance, is one of the longest-lived wells in Pennsylvania. This well, situated on the Divener farm, in the valley of Buffalo Run in Donegal Township, half a mile northeast of North Oakland, was brought in on February 28, 1874, flowing at the rate of 1,000 barrels a day. On March 7, 1874, the well together with a lease of 107 acres was purchased for $92,500. The following data relating to the production of the Divener well are recorded in The Derrick's Handbook of petroleum: On March 13, 1874, the daily output of the well was 600 barrels; on May 29 it was 500 barrels; on July 7, 400 barrels; and on November 19, 250 barrels. No record is available for 1875, but on October 10, 1876, the daily output of the well had fallen to 18 barrels. There is a long gap in the record, but it is reported that in 1892 the well produced about 4 barrels a day. In 1905 the well was cleaned and driven about 12 feet deeper through the Third sand, which there is 23 feet thick, 16 feet of which carries oil. After cleaning, the production rose to about 17 barrels a day, but a few years later it had dropped to 8 barrels. When visited by the writer in 1914 it was reported that the Divener well had been in continuous operation since it was drilled 40 years previously, but the output was only a fraction of a barrel a day. In 1931 the well was reported to be still producing.

Although a number of the old wells in this belt have survived and have been operated more or less continuously, most of the original wells have been abandoned. From time to time new wells have been sunk, and the entire belt has been thoroughly drilled over. The occurrence of oil was "spotty", highly productive spots being separated by relatively unproductive or dry areas. In a few places oil and gas have been obtained from other beds, but production in this belt came chiefly from the Third and Fourth sands, one or both, and from those parts of the beds that are physically well adapted to serve as reservoirs. The pay streaks were coarse-grained and pebbly and delimited by "tight", fine-grained sands. The productive sands are reported to have contained no water.

An instance of the "spotty" occurrence of oil in the Third sand is furnished by a small productive area between 2½ and 3 miles southwest of Butler, on the Waldron farm. There in 1905 the McBride well came in with an initial production between 1,200 and 1,500 barrels. The output soon diminished, and the well was shot 11 times in the succeeding 10 years in efforts to increase the yield. In 1915 the well produced 1½ barrels a day. In this well the Hundred-foot sand was found between 1,385 and 1,500 feet, some gas being encountered at 1,404 feet, and the Third sand was found between 1,690 and 1,707 feet, the pay stratum being a coarse pebbly streak between 1,697 and 1,702 feet. A few nearby wells yielded some oil, but much less than the McBride well. The productive area is surrounded by dry holes in which the Third sand was reported "close and tight."

Thorn Creek field.—In 1882 and 1883 a number of wells having initial production between 100 and 200 barrels were brought in on the Weber, Renfrew, and McCalmont farms, in the Baldridge district, about 5 miles southwest of Butler. In June 1884 the Armstrong well 1, on the Marshall tract, came in flowing and started the boom on Thorn Creek. The oil came from the Third and Fourth sands at a depth of about 1,500 feet. In August 1884 Phillips Bros. completed a well on the Bartley farm, north of the Armstrong well, on the hillside north of Thorn Creek, about three-quarters of a mile below McBride. On September 6, 1884, this well produced 1,500 barrels, in some hours flowing 80 barrels; on September 25 it flowed 147 barrels in an hour. This gusher caused much excitement, and many wells were drilled nearby. The Christie well, 400 feet from the Phillips, produced 1,442 barrels the first day, October 12, 1884, and 2 days later for 6 consecutive hours it flowed more than 200 barrels an hour. On October 27, 1884, the Armstrong well 2, on the Marshall tract 500 feet southeast of the Phillips well, came in. This well is reported to have had the greatest initial production of the wells drilled in Pennsylvania up to that time. Its output, however, was exceeded in 1891 by a well on the Mathews farm, in the McDonald pool, southwest of Pittsburgh, which is credited with a maximum flow of 730 barrels an hour.

The bringing in of the Armstrong well is graphically described in the following extract:

> After the torpedo was exploded a column of water rose 8 or 10 feet and then fell back again, and some minutes elapsed before the force of the explosion emptied the hole; * * * then with a mighty roar the gas burst forth. The noise was deafening. * * * For a moment the cloud of gas hid the derrick from sight, and then as it cleared away a solid golden column half a foot in diameter shot from the derrick floor 80 feet through the air till it broke in fragments on the crown pulley and fell in a shower of yellow rain for rods around. * * * In a few moments the ground around the derrick was covered inches deep with petroleum; the branches of the oak trees were like huge yellow plumes, and a stream as large as a man's body ran down the hill to the road. * * * In two hours these flats were covered with a flood of oil; the hillside was as if a yellow freshet had passed over it; heavy clouds of gas, almost obscuring the derrick, hung low in the woods and still that mighty rush of oil continued. * * * It was literally a flood of oil. There is no one now who saw it but that estimates the well made over 500 barrels an hour from 2 o'clock till 4, and that it made over 8,000, some say 10,000 barrels the first 24 hours after being shot.[14]

John F. Carll, of the Second Geological Survey of Pennsylvania, accepts as reliable the estimated flow of 10,000 barrels during the 24 hours after the well was torpedoed and reports the following measurements after the oil from this well was turned into the tanks: October 28, 400 barrels an hour; October 29, 260 barrels; October 30, 230 barrels; and October 31, 210 barrels. The field was soon developed

[14] The Derrick's Handbook of petroleum, pp. 376-377, Oil City, Pa., 1898.

and rapidly declined. Carll reports that at the end of the first year the field had become almost deserted as far as new drilling was concerned and that the gross daily production from 170 wells did not equal the first 4 hours' flow of the Armstrong well 2.

The production of the Baldridge district, including Thorn Creek, from September 1884 to October 1885 was reported by Carll as follows:[15]

Average daily pipe-line runs by months from the Baldridge district, including Thorn Creek, from September 1884 to October 1885

	Barrels		Barrels
1884:		1885—Continued.	
September	2, 644	April	9, 333
October	6, 034	May	7, 488
November	9, 493	June	5, 904
December	8, 730	July	3, 856
1885:		August	2, 268
January	6, 199	September	2, 021
February	7, 349	October	1, 898
March	7, 239		

The above record of the output of the Thorn Creek area illustrates the results of the rapid development of a small tract in which flowing wells of large initial output soon became relatively small pumping wells. Nevertheless some of the wells in the Thorn Creek field produced for many years.

Within a few years after the discovery of the Thorn Creek pool, wildcatting in all directions from it resulted in opening up a number of other highly productive areas in the Third and Fourth sand belt. In the upper valley of Thorn Creek in Jefferson Township, about a mile west of Saxonburg, several gushers were brought in during the autumn of 1887. Some of the best wells in this area were the Bolard & Greenlee, on the Lonitz farm, which on October 24 flowed 120 barrels an hour and on October 30 had decreased to 50 barrels an hour; a well on the Seibert farm, which had an initial flow of 175 barrels an hour; a well on the Bander Felder farm, which flowed 75 barrels an hour; and a well on the Adler farm, which produced 300 barrels in 48 hours. On November 10, 1887, the wells in the vicinity of Saxonburg produced 2,596 barrels.[16]

In 1889 several wells were brought in on the Montag and Grenert farms, north of Jefferson Center, some of them producing as much as 200 barrels an hour, and in 1892 a well was brought in on the Wolfe farm, near Herman, in Summit Township, that flowed 117 barrels an hour, but the productive areas throughout the belt are "spotted", and numerous dry holes were sunk in close proximity to good wells.

In 1892 a well was completed on the Campbell farm, near Brownsdale, Penn Township, which had an initial output of 125 barrels the

[15] Carll, J. F., Pennsylvania Geol. Survey Ann. Rept. for 1885, p. 24, 1886.
[16] The Derrick's Handbook of petroleum, p. 469, Oil City, Pa., 1898.

first day and which was the forerunner of considerable drilling in that vicinity. Sixteen years later, in 1908, a well was drilled on the Dodds farm, about 2 miles east of Brownsdale, which had an initial production of 250 barrels a day and which started another period of intensive development.

Glade Run field.—Another productive area in the Third sand was the Glade Run field, in Forward Township, near the junction of Glade Run and Connoquenessing Creek. This field was discovered in 1886 and attained its maximum development in 1887. The most productive part of the field occupied a belt extending northeast and southwest for somewhat more than a mile between Connoquenessing Creek and the Baltimore & Ohio Railroad. The principal production came from the Behm, Gailbaugh, Markel, and Heid farms. Some of the best wells were Behm No. 6, which was reported to have had an initial production of 250 barrels an hour; Heid No. 3, which flowed initially 1,500 barrels; and Markel No. 3, which flowed 1,020 barrels the first day. On March 1, 1887, the pool's output was estimated as 8,000 barrels from about 30 wells. On May 13, 1887, the field gages recorded 6,071 barrels from 60 wells, and on September 6, an output of 6,294 barrels from 83 wells was recorded. This field is reported to have been drowned by water entering the Third sand from some of the upper sands through improperly plugged abandoned wells.

Evans City field.—The Evans City field, on Breakneck Creek in Jackson and Forward Townships, Butler County, was the site of a "town-lot" development in 1915 that attracted considerable attention. As the field was situated in the midst of an area of old wells of small yield in the Hundred-foot sand and was almost surrounded by dry holes driven below the horizon of the Third sand, the discovery of virgin territory in the famous Third sand of Butler County resulted in a boom. This boom, however, met the usual fate of town-lot oil developments, which are characterized by the sinking of many more wells than are warranted by the quantity of recoverable oil, so that more money is put into the ground than is taken out. Such a discovery nevertheless stimulates the drilling that goes on year after year in the Appalachian region, with the occasional result of finding a pool that was missed by earlier drilling.

Oil was discovered in the Third sand March 26, 1915, on the J. W. Kreitzburg farm, on the hillside west of Breakneck Creek, within the borough of Evans City. This well is reported to have had an initial production at the rate of 30 barrels a day, but the yield soon diminished to about 5 barrels. The location proved to be near the western border of the pool. On May 13 a well that was put down on the German Lutheran parsonage lot, near the center of the town, came in as a gusher, flowing about 100 barrels a day. This well was the immediate forerunner of the boom. Options on town lots were

eagerly sought, and bonuses ranging from $100 to $200 are reported to have been paid for the privilege of drilling on lots, some of which were hardly large enough for a standard rig. A well on the Mickley lot, which came in about June 17 with an initial production of 400 barrels the first 24 hours, added considerably to the excitement. Several other good wells were brought in shortly thereafter. One on the B. F. White property, west of Breakneck Creek in the southern part of the borough, is credited with an initial production of 700 barrels. This well proved to be the largest total producer of the field. Development was at its height in July, when a number of gushers were brought in on the Sutton heirs' property immediately east of Breakneck Creek, at the southeast corner of the borough. One of these wells, which is credited with the largest initial production in the field, flowed 1,250 barrels, by pipe-line gage, during the first 24 hours. The next day, however, the output was reduced by half, and 6 months later the well produced only 2 barrels a day. Drilling was conducted so recklessly during the height of the excitement that five dry holes were put down on one block along the so-called "Crazy Alley" between Jefferson and Van Buren Streets. The following list of wells was prepared by R. U. Criswell for the Oil City Derrick:

Production of certain wells in the Evans City field

Date brought in	Operator	Property	Initial daily production (barrels)	Daily production January 1916 (barrels)
1915				
Mar. 26	Plaisted & Heinle	J. W. Kreitzberg	30, 5(?)	----------
May 13	Webber & McClay Bros	Lutheran Church parsonage	100+	1
June 12	Meyer & Co	Fred Rahaiser	50	1
16	Plaisted & Heinle	J. W. Kreitzberg	700(?)	2
17	Goe	Catherine Mickley	500	----------
22	J. T. Ryan & Co	J. T. Ryan	500	5
22	Fowler	Rev. Mr. Marshall	100	1
25	South Penn	B. F. White	700	10
July 8	McSwaney	W. H. Pierce	680	5
14	Snee & Co	R. Irwin	150	½
20	Sauer & Harris	North Pittsburgh Realty Co	250	2
27	Root, Hupp & Duff	Sutton heirs	600	2
27	Fowler	------do	480	3

In the Evans City field the top of the Third sand lies about 300 feet below the top of the Hundred-foot sand. The Third sand is lenticular and ranges from less than 1 foot to 51 feet in thickness. An instance of this difference in thickness is shown in wells on the B. F. White property. In one well the sand is reported to be 42 feet thick, and in another well less than 200 feet distant only 11 feet thick. On the adjacent Young property the Third sand is reported to be absent, its place being taken by shale. At Evans City the Third sand, as shown by churn-drill cuttings, no core drilling having been done, in general is a fine-grained gray sandstone composed of rounded and

semirounded grains of quartz and feldspar and flakes of sericite in a clayey matrix. Some samples of the sand are medium- to coarse-grained, composed of larger grains and small pebbles of quartz as much as 0.2 inch in diameter.

The pay streak commonly was between 2 and 10 feet thick, though locally oil occurred through a thickness of 34 feet. In a number of wells there were two pay streaks and in some three, separated by breaks of shale. The pay was described by the drillers as "soft, open, sugary" sand with locally some pebbles. The oil-bearing sand is a narrow lens, and the limit of the pool appears to be marked by the fringing out of the sand and its replacement by shale or by the absence of more porous parts of the sand. In such places the entire bed is indurated. The oil was accompanied by some gas, and the early wells were gushers, but gas did not occur abundantly, and the flows soon ceased.

Most of the oil in the Evans City field came from the Third sand, although in some wells relatively small quantities of oil were found in the Hundred-foot sand, in which locally, as on the Methodist parsonage lot, there were two pay streaks. In a well on that lot the Hundred-foot sand extended from 1,130 to 1,211 feet beneath the surface, and oil was found at two horizons—from 1,151 to 1,156 feet and from 1,196 to 1,203 feet. In one well a show of oil was reported in the Snee sand, 100 feet above the Third sand.

Two deep holes were sunk during the Evans City boom to test the Speechley sand—one on the Miller lot, adjacent to the Miller Hotel, within the town site, and the other on the Christine Marburger farm, half a mile southwest of the borough. The Marburger well, which started about 100 feet above the Upper Freeport coal and was sunk to a depth of 2,819 feet, was a dry hole, and no sand was reported at or near the horizon of the Speechley. Neither was the Speechley sand encountered in the Miller well.

In 1925 a deep test hole was drilled near the bend in Connoquenessing Creek about 2 miles northeast of Evans City. The well, which was put down to a depth of 5,180 feet, was a dry hole bottomed in black shale not far above the horizon of the Oriskany sandstone. No sands were reported below the Speechley (?), the bottom of which was 2,400 feet beneath the surface. (See p. 87.)

In the Evans City district water occurs in all the sands above the Hundred-foot and is of variable occurrence in that sand, but the sands below the Hundred-foot are said by the drillers to be dry. Analyses of water in this area have not been made, but it is reported that the water in the sands above the Butler County gas sand (Murrysville) is fresh and that the water in the Butler gas sand and Hundred-foot sand is salty. The Third sand is reported to be free from water, and the operators say that when the oil was removed its place was not taken by water.

The regional dip of the strata in the vicinity of the Evans City field is low to the southeast. Logs of wells in the field show a maximum variation in the altitude of the top of the Third sand of only 20 feet. Evidently structure did not greatly affect the accumulation of petroleum in this field.

The following log of the well on the Ida Graham lot is representative of the field:

Log of well on Ida Graham lot, Evans City

	Feet
Not recorded	0–225
Limestone, hard, white (Vanport limestone member)	225–235
Not recorded	235–380
Sand, soft, white (Homewood sandstone member)	380–460
Not recorded	460–465
Sand, hard, "blue" (Connoquenessing sandstone member)	465–550
Not recorded	550–675
Sand, hard, white (Big Injun)	675–780
Not recorded	780–980
Sand, soft, white (Gas or Murrysville); salt water	980–1,070
Not recorded	1,070–1,120
Sand, hard, gray (Hundred-foot)	1,120–1,210
Not recorded	1,210–1,325
Sand, soft, white (Snee)	1,325–1,335
Not recorded	1,335–1,423
Sand, soft, white (Third); oil and gas at 1,430–1,438 feet	1,423–1,453

Skeleton logs of six wells in Evans City field

Well	Gas sand	Hundred-foot sand	Snee sand	Third sand
	Feet	Feet	Feet	Feet
Mary Nicklas	970–1,065	1,120–1,214	1,335–1,345	Oil 1,426–1,452. 1,431–1,438. 1,440–1,448.
Methodist parsonage	990–1,085	Oil 1,130–1,211 1,151–1,156. 1,196–1,203	1,330–1,341	1,430–1,482.
Kreiss	995–1,085	1,140–1,225	1,335–1,347	Oil 1,433–1,471. 1,454–1,464. 1,468–1,471.
Zeigler & Fox	990–1,090	1,130–1,215	1,324–1,334	1,427–1,440.
B. F. White no. 5	Not recorded	1,141–1,226 (Show of oil, 1,201–1,215.	1,345–1,355	1,442–1,484. Oil, 1,450–1,484.
Sutton heirs	992–1,072	1,114–1,206 Oil 1,162, 1,195	1,326–1,334	1,420–(?). Oil and gas, 1,430, 1,438, 1,448.

Relation to structure.—Between the vicinity of Elk City, Clarion County, and Bakerstown, Allegheny County, a distance of about 50 miles, the oil-bearing rocks have a regional southward dip and descend about 800 feet. In the southern part of the area the oil belt lies in the southwestward-plunging Bradys Bend syncline, but the belt crosses the Millerstown anticline and extends northward across gently folded rocks regardless of their attitude. Structure apparently was not of controlling importance in the accumulation of the oil. The

shape and extent of the Third and Fourth sand belt suggest that an important factor in the location of the oil was abundant accumulation of source material, in a zone possibly parallel to the old shore line, in beds contiguous to the lenticular reservoirs. There may have been comparatively little migration of the oil. It is desirable that core samples be taken of the reservoir and associated beds, examination of which would not only throw light on the origin of the oil in this once highly productive belt but would be helpful in planning methods of recovering the remaining oil that cannot be obtained by present methods.

SPEECHLEY FIELD

Oil was discovered in the Speechley sand in Concord Township, Butler County, in 1901, 29 years after the beginning of the intensive development of the Third and Fourth sand belt in the vicinity of Troutman, only about a mile to the east. The delayed exploitation of this area is due to the fact that for several miles west of Troutman the Third and Fourth sands are either absent or nonproductive, and the test wells did not go deep enough to encounter the Speechley sand. When oil was found in this sand, however, the field was rapidly developed, and the productive area was soon outlined. It extends northeast beyond the Butler quadrangle and toward the southwest tapers off to a point. This area seems to be delimited by unfavorable sand conditions, either by the disappearance of the sand or by its decrease in porosity.

The Speechley sand here lies about 2,100 feet below the Vanport limestone, 1,200 feet below the top of the Hundred-foot sand, and 900 feet below the Fourth sand. Very little or no sand is recorded between the Fourth and the Speechley sands, and the intervening rocks are reported to consist almost entirely of shale. The Speechley sand in this field averages between 15 and 20 feet in thickness. It is fine-grained and chocolate-brown, and drillers report it to be free from pebbly streaks, which are present in the overlying oil sands, such as the Hundred-foot, Third, and Fourth. A. F. Melcher determined the porosity of samples of the Speechley sand shot from the Fort Kelly well No. 22, about 5 miles northeast of the Butler quadrangle, to range from 4.3 to 15.4 percent.[17] The sand is reported to be uniform in thickness and texture and to be practically free from water. None of the wells in this field have been large producers from the Speechley sand, but they have yielded consistently and have been long-lived. The initial daily production rarely exceeded 50 barrels to the well. In 1915 the Speechley sand wells averaged about half a barrel a day. Throughout this field within

[17] Melcher, A. F., Texture of oil sands with relation to the production of oil: Am. Assoc. Petroleum Geologists Bull., vol. 8, p. 741, 1924.

the Butler quadrangle oil is obtained in no other sand than the Speechley except in a small streak in the Fourth sand southeast of Hooker.

In 1902, a year after production was obtained in the Speechley sand in this area, a highly productive streak in the Fourth sand was found in the midst of the Speechley field about 1½ miles west of the western limit of the main Third and Fourth sand belt at Troutman and surrounded by an area in which the Fourth sand is dry. This productive streak in the Fourth sand is half a mile southeast of Hooker. It is less than a mile long and about a tenth of a mile wide and trends N. 60° E. The largest well in the field, A. W. Starr No. 5, is reported to have yielded 2,500 barrels in the first 24 hours. There were several other gushers, but the large wells are reported to have soon "blown themselves out." A. W. Starr No. 7, which had an initial production of 700 barrels, yielded 5 barrels a day in 1915. The Fourth sand in this productive streak is reported to be about 18 feet thick and to consist of coarse pebbly sand. In surrounding nonproductive areas the Fourth sand is said to be very hard and "tight." This small productive streak in the Fourth sand is an instance of the lithologic control of the location of a pool of oil.

HUNDRED-FOOT SAND FIELDS

The Hundred-foot sand has yielded considerable oil in this region. The most productive areas are in the southern part of the Zelienople quadrangle.

"Little Creek" field.—The largest and most productive of the Hundred-foot sand fields is in the valley of Little Connoquenessing Creek north and west of the town of Connoquenessing. Oil was discovered there in 1889. Several good wells were obtained, and the field was rapidly developed. The most productive area was a belt extending for about 3 miles northeastward from the big bend in Connoquenessing Creek, north of Wahlville, and some of the richest tracts were the Anderson, Rader, Fehl, Brandon, Graham, and Humphrey farms. Many wells had initial yields of several hundred barrels a day, and a well on the Humphrey farm is reported to have come in flowing 300 barrels an hour. Three years later this well was flowing 100 barrels a day. In general, however, the production of the field fell off rapidly. About 1900 the effect of water entering the oil sand from upper sands in abandoned, poorly plugged wells increased the output of the field for a few years by flooding, after which the production declined rapidly.

In 1906 the field was revived by the discovery of oil in the Snee sand, which lies about 120 feet below the base of the Hundred-foot. Many of the old wells were deepened to the Snee sand, and new ones were sunk. The initial production of these wells was not as great

as that of the wells in the Hundred-foot, yet the output of the wells in the more uniformly fine grained Snee sand held up better.

The following record shows the Vanport limestone and the Butler gas, Hundred-foot, and Snee sands:

Record of well on A. D. Nicklas farm, near Petersville, Connoquenessing Township

	Feet
Limestone (Vanport limestone member)	465–480
Sand (Butler gas); water at 1,298 feet	1,295–1,345
Sand (Hundred-foot); oil at 1,455 to 1,473 feet	1,390–1,486
Sand (Snee); oil at 1,610 to 1,620 feet	1,605–1,625

In this area the top of the Hundred-foot sand lies between 1,100 and 1,400 feet beneath the surface. The texture of the sand is variable, and the thickness differs from place to place, though it averages about 100 feet. The sand usually contains one or more bands of shale. One of these shale partings, which is rather persistent over a considerable area, is 3 feet thick and occurs about 17 feet below the top of the sand. Beneath Petersville the shale streak is not well developed and what is believed to be the Hundred-foot zone consists almost entirely of sand. In this area the upper 20 feet or so of the Hundred-foot sand is reported to be black sand and to be underlain by white sand. Where oil is present it occurs in a lenticular streak, commonly a coarse-grained pebbly bed, which is described in the well logs as "open" and "soft." The pay streaks, which average about 8 or 10 feet in thickness, occur irregularly throughout the bed. In some wells there is only one pay streak in the Hundred-foot sand, and in others there are three, but commonly two are present. The pay streaks in the Hundred-foot sand, in contrast to those of the lower sands, generally contain salt water, and the oil and water are recovered together throughout the life of the well. In the "tight" portions of the sand neither water nor oil occurs.

The following are partial sections of the Hundred-foot sand in several wells in the "Little Creek" field:

Depth beneath surface of beds in Hundred-foot sand in wells in "Little Creek" field

Peter Rader No. 1

	Feet
Top of Hundred-foot	1,333
Top of white sand	1,353
Pay sand	1,373–1,385

Peter Rader No. 17

Top of white sand	1,304
First pay streak	1,314–1,326
Second pay streak	1,334

C. G. Shannor No. 5

Top of Hundred-foot	1,275
First oil	1,332
Second oil	1,344

The Snee sand in the Petersville district is a fine-grained white sandstone 18 to 20 feet thick, which is separated from the overlying Hundred-foot sand by about 120 feet of shale. The pay streak consists of 8 to 10 feet of soft fine-grained sand near the middle of the bed. The sand above and below the pay is said by the drillers to be tight and hard. The Snee sand forms a lens, which is reported only locally in drill records.

Harmony and Zelienople fields.—About the time that the field along Little Connoquenessing Creek was being developed, oil was found in the Hundred-foot sand at Harmony and north of Zelienople. A town-lot boom occurred in the borough of Harmony, but no detailed information was obtained concerning it. The boom suffered the fate of similar attempts to sink many wells in a small area, more money being put into the venture than was recovered.

No trace now remains of the former drilling activity in the old Zelienople pool. The area that once contained many derricks is now devoted entirely to farming. Development was active in a belt about a quarter of a mile wide, extending from the valley of Scholars Run southwest of Middle Lancaster southward to the vicinity of Zelienople. The Cunningham well, on the John Shriver farm, which is reported to have had an initial production of 1,000 barrels a day, was the best well in the field, but information concerning the development of the area is not available. The field is reported to have been watered out and abandoned about 1902. After the flooding of the Hundred-foot sand in this area some of the wells were deepened, and small yields of oil and gas were obtained locally in the Boulder sand about 150 feet lower. The lower sands are reported missing or unproductive.

Watters field.—Another area of Hundred-foot sand wells is in the vicinity of Watters, in Forward Township, near the southeast corner of the Zelienople quadrangle. In this area there are locally two pay streaks. The best pay occurs in the lower part of the sand, and in some wells this pay streak is reported to be between 40 and 50 feet thick. The following record of a well on the Kriss farm, half a mile east of Watters, shows a section of the sand there:

Section of Hundred-foot sand in well on Kriss farm

	Feet
Top of Hundred-foot sand	1, 381
First pay	1, 431–1, 437
Second pay	1, 452–1, 497

On the neighboring Martin farm the following section of the sand is reported:

Section of Hundred-foot sand in John Martin well 8

	Feet
Hundred-foot sand	1, 351–1, 475
Pay	1, 400–1, 442

The pay sand in this well is described as "loose and full of pebbles."

The following partial sections of the Hundred-foot sand from records of wells in the general vicinity of Watters, southeast of Evans City, show conditions in this sand:

Depth beneath surface of beds in Hundred-foot sand in wells near Watters, Pa.

	Feet
Pfeiffer No. 2	
Top of Hundred-foot sand	1, 295
First pay	1, 340–1, 370
Second pay	1, 380
Irwin No. 15	
Top of Hundred-foot sand	1, 323
First pay	1, 346–1, 356
Second pay	1, 363–1, 422
Irwin No. 11	
Top of Hundred-foot sand	1, 300
First pay	1, 330–1, 341
Second pay	1, 345–1, 383
Third pay	1, 392–1, 398

Salt water occurs with the oil in the Hundred-foot sand in all these wells. The Watters field was finally practically abandoned because the Hundred-foot sand became flooded with fresh water derived from upper sands that were not cased off or properly plugged. The progress of flooding is shown by the following statement: In 1907 the monthly production of four wells in the Watters field ranged between 200 and 350 barrels. The flood reached these wells in May 1908, and from then until July their output increased to more than 700 barrels, after which the yield decreased rapidly and by January 1909 reached the stage of production that existed before the flood. In 1910 the wells were abandoned.

Scattered areas.—Oil has been found in the Hundred-foot sand in several other localities but in much smaller quantity than in the areas that have been mentioned.

Southwest of Whitestown, in Connoquenessing Township, oil has been obtained from the Hundred-foot sand in several wells, but they were abandoned after a few years because of the large quantity of water from the Hundred-foot sand that accompanied the oil. Another small development of the Hundred-foot sand was on Scotts Ridge, in Lancaster Township, 1½ miles northwest of Middle Lancaster. A small yield of oil is also obtained from scattering Hundred-foot wells south of Evans City, in Jackson and Forward Townships.

Relation to structure.—In all these Hundred-foot sand fields the rocks dip at a low angle to the southeast, and the geologic structure has had little apparent effect on the localization of the oil.

MUDDY CREEK FIELD

The Muddy Creek field is situated in Muddy Creek, Franklin, and Brady Townships, Butler County, the northern part of the field being crossed by Muddy Creek. Its development followed the finding of oil on the Shanor farm, northwest of Prospect, in 1891. None of the wells in this field have been large producers, one of the best having had an initial production of 60 barrels a day. Most of the wells are long-lived, however, and the output has been well maintained. Some wells, after having produced for more than 20 years, yield between 2 and 3 barrels a day. It is reported that access of water from upper sands through abandoned, unplugged wells has increased production. The sand is fine-grained and relatively uniform and is well adapted to flooding. It averages between 10 and 20 feet in thickness.

The top of the producing sand, the Berea (?), lies between 720 and 740 feet below the Vanport limestone. A skeleton record of a well on the W. H. Yerkey farm, in Brady Township, which is typical for the field, is given on page 85.

Several holes have been sunk in this general area in search of deeper producing sands but without success. One well on the S. F. McClung farm, in Franklin Township, was drilled to a depth of 2,450 feet. A sand called by the drillers the "Hundred-foot" and ranging from 20 to 60 feet in thickness occurs about 200 feet below the top of the Berea (?). Apparently the lower sands that are reservoirs of oil farther east in Butler County are poorly represented in this area.

Structurally the oil in the Muddy Creek field occurs along the southeast flank of the Homewood anticline, the beds dipping southeastward about 60 feet to the mile. Structure contours based on the oil sand are essentially parallel to the contours on the Vanport limestone shown on plate 4.

NATURAL GAS

Natural gas occurs dissolved in petroleum and is obtained in greater or less quantity in all the oil fields. Where the gas is under considerable pressure gushers result when wells are put down to oil-bearing sands, and throughout the life of a field gas is the principal motive power in the recovery of oil. Gas also occurs without oil ("dry" gas) and where water is present tends to be trapped in the tops of domes, the crests of anticlines, or the structurally high parts of lenticular beds.

In the Butler and Zelienople quadrangles "dry" gas has been obtained in several areas. The fields have long been greatly depleted, however, and little information is available concerning the capacity of the wells or the occurrence of the gas. "Dry" gas has been obtained from all the sands that produce oil, but chiefly from the Butler County (Murrysville), the Hundred-foot, the Fourth, and the Fifth. The largest gas field in these quadrangles is in Winfield

and Jefferson Townships, in the southeast corner of the Butler quadrangle, along the crest and upper flanks of the Kellersburg anticline. The field is part of a gas-producing area that extends northeastward and southwestward along the Kellersburg anticline for many miles. In 1874 gas was discovered in a well at Saxon City, now Cabot, at a depth of 1,150 feet, in the Butler County gas sand. This well was mentioned by I. C. White as "one of the great wells of the Butler County field", but measurements of pressure, capacity, and production are not available. It is reported that many wells were put down and much gas obtained from this field in the eighties and nineties of the last century, and for a time carbon black was made. When the output of the shallower sands declined, wells were drilled deeper, and gas was obtained from the Fourth, Fifth, and Speechley sands, but in no one well in this area has gas been reported from all these sands. The Speechley sand has not been exploited as intensively as the upper sands, and the beds that lie below it have been tested in only a few holes. The occurrence of gas is spotty, as if its presence were in part controlled by favorable conditions in the sand, the lenticularity of the beds and the varying degree of cementation preventing free movement of the gas. Wells of large capacity, yielding gas under high pressure, have been brought in adjacent to old wells that have been exhausted.

The following skeleton log of a well in Winfield Township shows the depth beneath the surface of the sands from the Murrysville to the Speechley in that locality:

Log of well on Peter Kennedy farm, Winfield Township

[From Godfrey Cabot]

	Depth (feet)
Top of Vanport limestone (member)	405
Sand	1,045–1,065
Sand (Murrysville)	1,290–1,315
Sand (Hundred-foot)	1,430–1,540
Sand (Thirty-foot)	1,575–1,620
Sand (Third)	1,725–1,750
Sand (Fourth)	(?)–1,780
Sand (Fifth)	1,825–1,860
Sand (Speechley)	2,645–2,680

When the Third and Fourth sand belt was first developed, several gas wells of large capacity were obtained in the Butler quadrangle. Noteworthy among them were the Burns well, on the Duffy farm, near St. Joe, in Donegal Township, and a well on the Thompson farm, a few miles to the southwest, in Clearfield Township. The main supply of gas in this area came from the Fourth sand. The Burns well, in which the Fourth sand was reached at a depth of about 1,600 feet, is said to have had an initial capacity of 12,000,000

cubic feet, and the gas was delivered through a 2-inch pipe to Freeport, a distance of about 17 miles. These wells were short-lived, and the gas-producing areas proved to be small. Structurally the gas occurred along the Millerstown anticline.

Westward and southwestward from St. Joe, along this anticline, gas has been obtained in a number of wells in Donegal, Oakland, and Summit Townships. These occurrences of gas also are spotty. In several areas of only a few acres good wells have been found adjacent to dry holes, and from time to time new productive tracts are discovered in which gas under considerable pressure is found not far from old productive wells in the same sand in which the pressure has been greatly reduced. Evidently in such places there is absence of free communication in the sand.

Some comparatively recent gas developments in this area further show the spotty character of the occurrence. In 1907 a well was drilled on the Ritzert farm, near St. Joe, in which gas was obtained that had a reservoir pressure between 700 and 800 pounds. This well continued to produce gas for about 7 years, when the pressure had become reduced to 35 pounds. The well was only 200 feet from an old large producer that had been abandoned. Another nearby well was a dry hole. In 1911 the Portman well, in Summit Township, 2 miles southeast of Butler, came in with an estimated initial capacity of 30,000,000 cubic feet of gas in the Fifth sand, and in 1917 the Heeter well was drilled on the Gordon farm, in Oakland Township, 1¼ miles west of Woodbine, and had a measured open flow of 17,000,000 cubic feet. These wells, which were practically surrounded by old or abandoned wells, opened small pockets that had been missed in previous drilling.

In the vicinity of Brinker, in Summit Township, there are a few wells from which small quantities of gas were obtained, chiefly from the Hundred-foot and Fourth sands. These wells are located along the upper flanks of the low southwestward-pitching Millerstown anticline.

In the northwestern part of the Zelienople quadrangle, in an area in which practically no oil has been found, natural gas has been obtained from shallow sands along the upper flanks of the Homewood anticline. The wells were of small capacity, and the field, which was in its prime between 1890 and 1910, has been practically abandoned. Near Princeton, Slippery Rock Township, Lawrence County, a few abandoned gas wells mark the northeastern extension of the old Big Meadows gas field, and a few miles to the east, in Worth and Brady Townships, Butler County, there were also small gas wells. Gas was found at depths usually between 700 and 800 feet below the Vanport limestone in sands in the approximate position of the Amber and Berea. Showings of gas have been obtained from possible repre-

sentatives of the Hundred-foot and Thirty-foot sands, but the lower sands down to the Speechley, so far as known, are poorly represented in this general region, and the outlook for large production in that zone is not good. The deep-lying Oriskany sandstone has been reached in this area by two wells. (See p. 10.)

In addition to wells in the gas-producing areas on anticlines there were a number of gas wells not located along such features. In these localities the gas may have been trapped in lenticular beds. In the vicinity of Middle Lancaster, Lancaster Township, for instance, a number of gas wells apparently obtained their supply from a lens in the Butler gas sand. The Seig well, a quarter of a mile northeast of Middle Lancaster, which was drilled about 1891, was one of the good gas wells of this region. The gas was piped to Rochester, in Beaver Valley, and the well is reported to have yielded a large but unmeasured supply for about 8 years, when it was drowned.

OUTLOOK FOR OIL AND GAS

Drilling in the Butler and Zelienople quadrangles over a period of more than 60 years has rather thoroughly tested the rocks for oil and gas down to the Fifth sand, and it is not likely that any large pools remain to be found in the upper sands. In the future as in the past, however, because of the "spotted" occurrence of oil and gas in lenticular sands of variable permeability, there may be occasional discoveries of small productive areas. Under present conditions of operation presumably the slow decline in yield that has been in progress for many years will continue.

Increased production from the depleted sands may be attained by improved methods of recovery in the attempt to obtain some of the 70 percent, more or less, of the original oil content that is believed to be left in the sand by present methods. Under favorable conditions more oil can be recovered by increasing the pressure on the sands by flooding with water or by introducing into the sands compressed gas or air. Increased production may also be obtained by decreasing the surface tension and the adhesion of the oil to rock particles by the use of certain solutions, such as soda ash. Before attempting new methods of recovery, however, it is desirable to have detailed knowledge of subsurface conditions, such as is afforded by core samples of the sands and analyses of water, to avoid bypassing and to prevent the clogging of the sands by chemical precipitates. Lenticular beds of variable porosity and permeability are not as favorable for the application of repressuring as more persistent and homogeneous sands.

The sands below the Fifth that are productive in other areas are of indefinite value in these quadrangles. The Speechley sand, 800 to 900 feet below the Fifth, and the Bradford (?) sand, some 600

feet below the Speechley, have not been exhaustively tested. Productive "stray" sands may also be found. Still deeper sands that yield oil or gas in one place or another in the Appalachian region are possible sources of production. The most promising of the deep sands occur at or near the horizon of the Oriskany group and of the Albion sandstone of New York (the Albion is the approximate equivalent of the Tuscarora of Pennsylvania and of the so-called "Clinton" sand of Ohio). This sand has been the objective of deep drilling in southwestern Pennsylvania and northern West Virginia, where, however, it has not yet been reached.

Since the discovery of large quantities of natural gas on anticlines in the Wayne-Dundee field, New York, and in the Tioga field, Pennsylvania, there has been considerable drilling in search of gas in the Oriskany sand, including the two deep test wells that were put down in the Zelienople quadrangle. It should be realized, however, in selecting sites for drilling deep wells, that because of the convergence of the strata in this region, anticlines which are characterized by beds of low dip at the surface tend to become obliterated at depth.

SHALE AND CLAY

Shale and clay occur abundantly in these quadrangles, but only a few small shale pits have been opened for making common brick, and the clay deposits, although extensively worked for ceramic material in nearby areas, have not yet been exploited here.

Sandy and clayey shale occurs in inexhaustible quantity in the Conemaugh and Allegheny formations and less abundantly in the Pottsville. Clay occurs beneath the beds of coal, as alluvium in the valleys of the larger streams, and in the glacial deposits. The shale is widely distributed and well exposed, but the thinner and softer beds of clay are generally concealed. Plastic clay occurs beneath the Clarion, Scrubgrass, Lower, Middle, and Upper Kittanning, Lower and Upper Freeport, Mahoning, and Brush Creek coals, but in the Butler and Zelienople quadrangles none of these beds of clay have been prospected. The only data available concerning them are records of core-drill holes that have been put down in search of coal and references to clay in the sections of coal beds. The drill records show clay beds as much as 12 feet in thickness.

The most valuable bed of clay in this general region, although each bed in one place or another outside these quadrangles is mined, is the Lower Kittanning. This bed, which lies between 20 and 50 feet above the Vanport limestone, crops out in the valleys of Slippery Rock and Muddy Creeks and locally is situated conveniently near the Western Allegheny Railroad. Although over considerable parts of this area bedrocks are concealed by glacial deposits, the approximate position of the Lower Kittanning clay can be determined from

the outcrop of the Vanport limestone. (See pl. 4.) At one place in this locality, at the Thorman coal mine, in Slippery Rock Township, Lawrence County, between Gibsondale and Princeton station, within half a mile of the railroad, the Lower Kittanning clay is reported to be 7 feet thick.

SANDSTONE

Sandstone is of widespread occurrence in these quadrangles, but only a few quarries have been opened. It has been used in foundations and for rough masonry work, one quarry has been opened to supply sand for polishing plate glass, and a few buildings have been constructed of local sandstone.

Sandstone occurs abundantly in the Buffalo and Mahoning members of the Conemaugh formation, in the Butler member of the Allegheny, and in the Homewood and Connoquenessing members of the Pottsville. These sandstones are extremely variable. They range from thin beds to beds more than 100 feet thick; some beds are massive, and others occur in thin layers; some are coarse-grained and conglomeratic, and others are medium- to fine-grained. They are composed of quartz and feldspar in variable proportions and subordinate mica, with clay, silica, and calcite as interstitial binding material. In color they are gray to buff.

Good building stone has been obtained at some places. The courthouse at Butler and several churches in that borough are built of the Butler sandstone obtained from a nearby quarry. The chief use of these sandstones, however, has been for foundations and rough masonry work, for which small quarries have been opened to supply local needs at a number of places.

The sandstones are not pure enough for use as glass sand, but the output of a quarry on the Mahoning and Buffalo sandstone members of the Conemaugh formation in the valley of Little Buffalo Creek, below Cabot, has been crushed and washed and used for polishing glass at the Butler works of the Standard Plate Glass Co.

SAND AND GRAVEL

Sand and gravel occur in the glaciated area in the northwestern part of the Zelienople quadrangle at the places mentioned on page 27. Sand also occurs in the alluvium in the valleys of Connoquenessing and Muddy Creeks, and it can be obtained by crushing the sandstone members of the Pottsville, Allegheny, and Conemaugh formations and washing out the associated clay.

LIMESTONE

Limestone is widely distributed in these quadrangles. There are several beds, including the Ames and Mahoning limestone members of the Conemaugh formation, the Upper and Lower Freeport and

Vanport limestone members of the Allegheny formation, and the Upper and Lower Mercer limestones in the Mercer shale member of the Pottsville formation. All but the Vanport limestone, however, are thin beds that range from a few inches to a rather rare maximum of 5 feet and are of little value except for local use. The Vanport, on the other hand, is a relatively persistent bed which averages 12 to 15 feet in thickness and is the most valuable limestone in western Pennsylvania.

The Vanport limestone crops out in the valleys of Muddy and Slippery Rock Creeks, and records of oil and gas wells show that it is widely distributed throughout a large area, under a cover of the overlying rocks, at depths beneath the surface indicated on the maps (pls. 3 and 4) by the structure contours.

Like other beds in the †Coal Measures, however, the Vanport limestone is variable and disappears locally. In the valley of Connoquenessing Creek in the vicinity of Hazen, for instance, this limestone is apparently missing, although it is present in normal development only a few miles to the north and west.

The Vanport limestone has been quarried at several localities along its outcrop, especially on hilltops and in the valley of Muddy Creek, where it is under a thin cover of rocks. The overlying rocks are either shale or glacial sand and gravel, which can be readily removed. Between 1907 and 1915 this limestone was extensively quarried by the New Castle Portland Cement Co. in Worth Township, Butler County, between half a mile and a mile south of Paynes, on the Western Allegheny Railroad. There the limestone ranges from 15 to 20 feet in thickness. In part of the quarry the overburden is shale, and in other parts it is glacial drift between 10 and 35 feet thick. The limestone is overlain by a bed of low-grade siliceous iron ore, the removal of which was difficult. The quarry was abandoned in 1915, when the property was taken over by the Lehigh Portland Cement Co., which operates a large plant near New Castle and is reported to hold considerable limestone acreage in this region in reserve. A smaller quarry was formerly operated at Portersville, on the Western Allegheny Railroad 1 mile southwest of Paynes.

The only limestone quarry in operation when this area was examined by the writer is the quarry on the hill immediately south of Rose Point, in Slippery Rock Township, Lawrence County. There the Rose Point Stone & Lime Co. operates a quarry, which is connected with a short spur of the Western Allegheny Railroad, and burns the limestone with coal from a nearby mine in a battery of 10 kilns. The lime is used chiefly for fertilizer. At the Rose Point quarry there is between 12 and 17 feet of massive blue-gray limstone, which is overlain by sandy and clay shale containing scattered nodules of iron carbonate. In places the overburden is only about 15 feet thick.

Analyses of the limestone from the upper, middle, and lower parts of the bed at the Paynes quarry were made for the New Castle Portland Cement Co., as follows:

Analyses of limestone from Paynes quarry

Sample	$CaCO_3$	$MgCO_3$	SiO_2	Al_2O_3 and Fe_2O_3
Upper part	95.8	1.8	1.6	2.2
	87.9	1.9	5.9	4.4
	89.6	1.8	4.4	4.4
	90.6	1.7	3.8	4.1
Middle part	85.6	1.8	7.4	5.6
	78.4	2.1	10.7	7.2
	71.3	2.5	12.9	11.0
	91.6	1.8	3.2	3.1
	95.8	1.3	1.6	3.0
Lower part	95.1	1.6	2.0	2.5
	93.6	1.9	2.9	2.5
	91.4	1.9	4.0	3.4
	95.6	1.4	1.4	1.9
	93.1	1.7	3.1	2.9

A test of a sample from the Rose Point quarry showed a phosphorus content of 0.045 percent.

The analyses show that although the bed varies in composition the limestone in general has a low magnesium content. It is suitable for the manufacture of portland cement and for many purposes for which limestone is adapted.

IRON ORE

A number of charcoal-burning iron furnaces were in operation in western Pennsylvania in the middle of the last century. These furnaces were located near the source of the raw materials—ore, limestone, and wood—generally in out of the way localities. In this area there were three furnaces—the Hope and Wilroy, near Rose Point, and the Lawrence, in Hell Hollow, a tributary of Slippery Rock Creek 3½ miles southwest of Rose Point. The individual yield was small, although the total output of all the furnaces in western Pennsylvania was considerable. When the Lake Superior iron ores became available it was no longer profitable to work these furnaces, and they have long been abandoned. Their ruins remain as picturesque evidence of changed conditions.

The ore is the carbonate of iron, the mineral siderite, which occurs here in two forms—as concretions or nodules in shale and associated with limestone which it has replaced. In this vicinity the chief horizons are in the Mercer shale member of the Pottsville formation and the Vanport limestone member of the Allegheny formation. The ore is of variable thickness and occurrence, ranging from a few inches to a few feet, and in many areas is absent. It

was obtained by stripping, as it was too thin and variable for underground mining.

WATER

The annual precipitation of about 40 inches insures a good supply of water for agricultural and domestic use. The monthly distribution of rainfall at Butler is shown by the following figures, reported by the United States Weather Bureau, representing averages for a period of more than 20 years:

Average monthly and annual precipitation, in inches, at Butler, Pa., 1899–1920

January	3.00	August	4.81
February	2.27	September	2.87
March	3.24	October	3.23
April	3.12	November	2.66
May	3.36	December	2.66
June	5.01		
July	4.02	Year	40.25

Measurements of stream flow are available for Connoquenessing and Slippery Rock Creeks, gaging stations being maintained near Hazen and at Wurtemberg. The following figures show the maximum, minimum, and mean discharge of these streams compiled from annual reports published by the State.[18]

Annual discharge, in second-feet, of Slippery Rock Creek at Wurtemberg

[Drainage area, 404 square miles]

Year ending Sept. 30	Maximum	Minimum	Mean	Year ending Sept. 30	Maximum	Minimum	Mean
1915	10,500	22	535	1924	6,660	33	699
1916	7,050	22	712	1925	6,660	16	368
1917	5,010	19	538	1926	9,840	60	617
1918	8,490	32	538	1927	8,400	32	783
1919	4,770	54	476	1928	15,200	43	848
1920	9,100	48	472	1929	10,700	22	716
1921	2,110	59	386	1930	5,900	22	550
1922	3,760	52	531	1931	2,400	24	216
1923	5,940	29	370	1932	5,170	22	461

Estimated annual discharge, in second-feet, of Connoquenessing Creek near Hazen (Celia), Franklin Township, Beaver County

[Drainage area, 355 square miles]

Year ending Sept. 30	Maximum	Minimum	Mean	Year ending Sept. 30	Maximum	Minimum	Mean
1920	4,010	23	457	1927	6,920	25	748
1921	3,920	15	398	1928	8,560	18	815
1922	5,630	11	517	1929	7,730	14	483
1923	7,800	9	313	1930	6,800	8.2	514
1924	10,600	13	716	1931	3,880	8.2	221
1925	6,500	12	381	1932	3,630	6.9	385
1926	7,400	13	529	1933	9,450	8.6	426

[18] Reports of the Water-Supply Commission, 1915–21; Stream-flow records of Pennsylvania, State Dept. Forests and Waters, 1922–32.

The principal use made of the streams in this area is for the municipal water supply of Butler and Zelienople. Butler is supplied from reservoirs that have been formed by damming Connoquenessing Creek above Boydstown and Thorn Creek north of East Butler. Zelienople's water supply is obtained from Scholars Run north of the town. Water power is not now developed, although a generation or more ago small mills operated by water power were located along several of the streams. Commercial power on a small scale could possibly be obtained from Slippery Rock Creek by the construction of a dam in the gorge above Wurtemberg. A development between 5,000 and 10,000 horsepower is apparently possible by utilizing the mean annual flow of the stream.

Ground water is readily obtained in this area from springs and wells. Numerous springs are located along the outcrops of the relatively impervious beds—limestone, clay, coal, and clay shale—which intercept the percolation of water through more permeable overlying strata.

Wells are the chief source of water for domestic use in the rural and suburban areas, and satisfactory supplies are generally found at shallow depths. Water is obtained from beds of sand or gravel in the glaciated area and in the glacial outwash and alluvial deposits along the larger streams. Elsewhere wells are put down to one or more of the sandstone members of the Conemaugh, Allegheny, or Pottsville formations. Good supplies of potable water are generally encountered at depths of less than 100 feet, and rarely is it necessary to sink wells more than 250 feet. The yields of individual wells may differ considerably, owing to the irregular thickness, porosity, and permeability of the rocks. Water in the beds of sandstone that dip beneath relatively impermeable strata is generally confined under hydrostatic pressure and tends to rise in the wells above the depth at which it is encountered. In places the hydrostatic pressure is sufficient to cause the water to flow at the surface.

The occurrence of water in the rocks that lie below the outcropping beds is variable. The relatively persistent and thick Big Injun, Murrysville, and Hundred-foot sands usually contain abundant water. But the lower-lying thinner and more lenticular sands, in particular the Boulder, Third, Fourth, Fifth, and Speechley, in general yield little or no water when they are tapped by wells in this area.

Concentrated brine was found at or near the bottom of the two deep wells that were sunk in 1934–35 to the Oriskany (?) sandstone in the Zelienople quadrangle. (See p. 10.)

A pronounced difference between the deep-lying beds and those near the surface is that ground water, replenished by rainfall, circulates relatively freely in the upper beds that have drainage outlets,

whereas there is little or no circulation in the beds that lie below surface drainage in the closed Pittsburgh-Huntington Basin. This is an important cause of the difference in composition of the shallow and deep-seated ground waters. Ground water occurring in beds in which there is free circulation is of low concentration, the chief constituents being calcium and subordinate magnesium bicarbonate and smaller quantities of sodium, potassium, sulphate, and chloride radicles derived from the leaching of the rocks through which the water has percolated.

The deep-seated ground waters are more or less concentrated brines consisting of predominating chloride and sodium, considerable calcium, less magnesium, and little or no carbonate. The composition of the water is in part the result of a series of reactions involving the original water of sedimentation and water of meteoric origin. It has been suggested [19] that some brine may in part be due to diffusion from rock salt, in the Cayuga group, that lies less than 500 feet below the horizon from which sample 3 in the table on page 72 was obtained. Mills and Wells, who made an elaborate study of these waters, conclude that they have been concentrated mainly by evaporation into moving and expanding natural gas.[20]

Several analyses of ground water from the Butler and Zelienople quadrangles and vicinity are given in the table on page 72. Other analyses are contained in the bulletin by Mills and Wells and in a report by Piper.[21]

The samples of water from the two deep wells sunk in 1934 and 1935 in the northwestern part of the Zelienople quadrangle were collected by John T. Galey. The sample from the property of the Lehigh Portland Cement Co. in Muddy Creek Township, Butler County (No. 2, p. 72), was taken on March 12, 1935, when there was about 300 feet of water in the hole, the well having been completed on February 11, 1935. The sample from the well on the farm of J. Scott Munnell, in Slippery Rock Township, Lawrence County (No. 1, p. 72), was taken on September 26, 1934, when the fluid content of the hole was one bailer of oil and "B. S." and five bailers of water. This well had been completed on April 6, 1934.

Unusually complete analyses of the samples from these two wells, made by Margaret D. Foster, of the United States Geological Survey, show in addition to the more common substances the presence of several radicles which are less frequently tested for. These include noteworthy quantities of strontium, lithium, bromine, iodine, and

[19] Richardson, G. B., Note on the diffusion of sodium chloride in Appalachian oil field waters: Washington Acad. Sci. Jour., vol. 7, p. 73, 1917.

[20] Mills, R. Van A., and Wells, R. C., The evaporation and concentration of waters associated with petroleum and natural gas: U. S. Geol. Survey Bull. 693, 1919.

[21] Piper, A. M., Ground water in southwestern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W1, pp. 70-81, 1930.

boron. The dried salts from these waters and also from the deep well whose water was analyzed by George Steiger in 1913 (sample 3) were examined spectroscopically in 1935, by Steiger, who reports the presence of silver in minute quantity in all three samples.

Analyses of ground water from Zelienople and Butler quadrangles, Pa., and vicinity

[Parts per million]

	1	2	3	4	5
Silica (SiO_2)	20	7.4			13
Iron (Fe)	.5	1.2	160		.20
Aluminum (Al)	4.1	4.8			
Calcium (Ca)	24,720	28,400	25,190	11,080	60
Strontium (Sr)	1,847	882	3,550		
Barium (Ba)	0	0	Trace		
Magnesium (Mg)	3,340	2,920	2,480	1,940	13
Sodium (Na)	49,000	34,200	64,550	36,390	11
Potassium (K)	2,106	3,180	5,160	130	3.4
Lithium (Li)	490	489			
Rubidium (Rb)	0	0			
Cesium (Cs)	0	0			
Carbonate (CO_3)	0	0	0	0	
Bicarbonate (HCO_3)	84	300		0	234
Sulphate (SO_4)	112	477	50	130	25
Chloride (Cl)	133,800	115,900	161,800	82,160	3
Bromide (Br)	1,880	1,570	700		
Iodide (I)	64	31			
Boric acid (H_3BO_3)	234	508			
Total dissolved solids	217,700	188,700	263,640	131,890	236
Weight of 1 cc at 28° C. grams	1.1705	1.1468	1.211		

1. J. Scott Munnel well 1, Slippery Rock Township, Lawrence County, Pa. Sample from depth of 4,767± feet; collected Sept. 26, 1934; analyzed by Margaret D. Foster, 1935.

2. Lehigh Portland Cement Co. well 1, Muddy Creek Township, Butler County, Pa. Sample from depth of 5,170± feet; collected March 12, 1935; analyzed by Margaret D. Foster, 1935.

3. Peoples Natural Gas Co. well, 8 miles southwest of Imperial, Washington County, Pa. Sample from depth of "6,300" (6,260?) feet; analyzed by George Steiger in 1913 (Clarke, F. W., U. S. Geol. Survey Water-Supply Paper 364, p. 9, 1914).

4. Well on Hoffman farm, 5 miles northeast of Butler, Pa. Sample from depth of 1,359 feet; analyzed by W. B. Hicks and R. H. Bailey (Richardson, G. B., Note on the diffusion of sodium chloride in Appalachian oil-field waters: Washington Acad. Sci. Jour., vol. 7, p. 73, 1917).

5. Well on Steighner farm, half a mile west of Herman, Butler County. Sample from depth of 75± feet; analyzed by C. S. Howard (Piper, A. M., Ground water in southwestern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W1, p. 73, 1933).

Source: 1-3, in or near Oriskany (?) sandstone; 4, Hundred-foot sand; 5, Conemaugh formation.

THERMAL GRADIENT

For a depth of 50 to 100 feet below the surface the temperature of the rocks varies more or less with that of the atmosphere. Below this surface zone the temperature increases with depth but at varying rates in different districts. Van Orstrand,[22] who has measured the temperature in many deep wells throughout the United States, in 1935 made temperature measurements in the deep well on the property of the Lehigh Portland Cement Co., in Muddy Creek Township, Butler County (see p. 10), with the following results:

[22] Van Orstrand, C. E., Normal geothermal gradient in the United States: Am. Assoc. Petroleum Geologists Bull., vol. 19, pp. 78-115, 1935.

Temperatures in well on property of Lehigh Portland Cement Co., Muddy Creek Township, Butler County, Pa.

[Observations made February 6–9, 1935. Surface temperature at or near freezing. Annual mean temperature at New Castle, Pa., 50.0° F.]

Depth (feet)	Temperature (° F.)	Depth (feet)	Temperature (°F.)
100	50.1	2,500	82.1
500	54.8	3,000	91.2
1,000	60.6	3,500	101.4
1,500	67.0	4,000	111.1
2,000	73.5	4,500	121.4

ANALYSES OF PETROLEUM

The following analyses were made by the United States Bureau of Mines:

Analysis of petroleum from Berea (?) sand, Shanor No. 7, Muddy Creek Township, Butler County

[Specific gravity at 15° C., 0.795]

Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)	Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)
Up to 75	4.9	4.9	175–200	4.5	32.3
75–100	4.5	9.4	200–225	6.0	38.3
100–125	6.4	15.8	225–250	5.9	44.2
125–150	5.9	21.7	250–275	5.5	49.7
150–175	6.1	27.8	275–300	7.3	57.0

Analysis of petroleum from Hundred-foot sand, Heist farm, Center Township Butler County

[Specific gravity at 15° C., 0.795]

Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)	Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)
Up to 50	0.5	0.5	175–200	7.0	40.0
50–75	2.5	3.0	200–225	5.0	45.0
75–100	5.0	8.0	225–250	10.0	55.0
100–125	8.0	16.0	250–275	4.0	59.0
125–150	8.0	24.0	275–300	6.0	65.0
150–175	9.0	33.0			

Analysis of petroleum from Hundred-foot sand, Campbell No. 2, Oakland Township, Butler County

[Specific gravity at 15° C., 0.800]

Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)	Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)
Up to 75	2.0	2.0	175–200	9.0	35.0
75–100	4.0	6.0	200–225	8.0	43.0
100–125	6.0	12.0	225–250	7.0	50.0
125–150	6.0	18.0	250–275	6.0	56.0
150–175	8.0	26.0	275–300	9.0	65.0

Analysis of petroleum from Hundred-foot sand, Marshall No. 27, Penn Township, Butler County

[Specific gravity at 15° C., 0.808]

Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)	Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)
Up to 75	1.0	1.0	175–200	7.0	29.0
75–100	3.0	4.0	200–225	7.0	36.0
100–125	5.0	9.0	225–250	6.0	42.0
125–150	7.0	16.0	250–275	8.0	50.0
150–175	6.0	22.0	275–300	10.0	60.0

Analysis of petroleum from Snee sand, Kaufmann farm, Forward Township, Butler County

[Specific gravity at 15° C., 0.782]

Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)	Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)
Up to 50	3.0	3.0	175–200	6.0	40.0
50–75	3.0	6.0	200–225	5.0	45.0
75–100	5.0	11.0	225–250	6.0	51.0
100–125	9.0	20.0	250–275	5.0	56.0
125–150	7.0	27.0	275–300	7.0	63.0
150–175	7.0	34.0			

Analysis of petroleum from Snee sand, Kaltenbach farm, Connoquenessing Township, Butler County

[Specific gravity at 15° C., 0.805]

Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)	Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)
Up to 125	3.3	3.3	200–225	7.5	32.6
125–150	6.1	9.4	225–250	8.3	40.9
150–175	7.3	16.7	250–275	8.5	49.4
175–200	8.4	25.1	275–300	10.2	59.6

Analysis of petroleum from Third sand, White No. 5, Forward Township, Butler County

[Specific gravity at 15° C., 0.780]

Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)	Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)
Up to 75	4.9	4.9	175–200	7.1	45.1
75–100	6.1	11.0	200–225	6.5	51.6
100–125	10.6	21.6	225–250	6.1	57.7
125–150	8.0	29.6	250–275	5.6	63 3
150–175	8.4	38.0	275–300	5.7	69.0

Analysis of petroleum from Third sand, Kriegsberg No. 4, Forward Township, Butler County

[Specific gravity at 15° C., 0.799]

Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)	Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)
Up to 50	1.5	1.5	175–200	5.5	33.0
50–75	3.5	5.0	200–225	6.0	39.0
75–100	4.0	9.0	225–250	5.0	44.0
100–125	7.0	16.0	250–275	6.0	50.0
125–150	5.0	21.0	275–300	12.0	62.0
150–175	6.5	27.5			

Analysis of petroleum from Fourth sand, Jenkins No. 1, Fairview Township, Butler County

[Specific gravity at 15° C., 0.793]

Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)	Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)
Up to 50	1.0	1.0	175–200	6.0	38.5
50–75	4.0	5.0	200–225	6.0	44.5
75–100	7.0	12.0	225–250	9.0	53.5
100–125	8.0	20.0	250–275	4.0	57.5
125–150	5.5	25.5	275–300	6.0	63.5
150–175	7.0	32.5			

Analysis of petroleum from Speechley sand, Kuhn No. 11, Concord Township, Butler County

[Specific gravity at 15° C., 0.795]

Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)	Temperature (° C.)	Fractions (percent by volume)	Total distilled (percent by volume)
Up to 50	1.0	1.0	175–200	6.0	35.5
50–75	2.0	3.0	200–225	6.5	42.0
75–100	5.0	8.0	225–250	6.0	48.0
100–125	8.0	16.0	250–275	4.0	52.0
125–150	7.0	23.0	275–300	8.0	60.0
150–175	6.5	29.5			

CORE-DRILL RECORDS

The numbers of the following records correspond to those on the key map that shows the location of the holes (fig. 9).

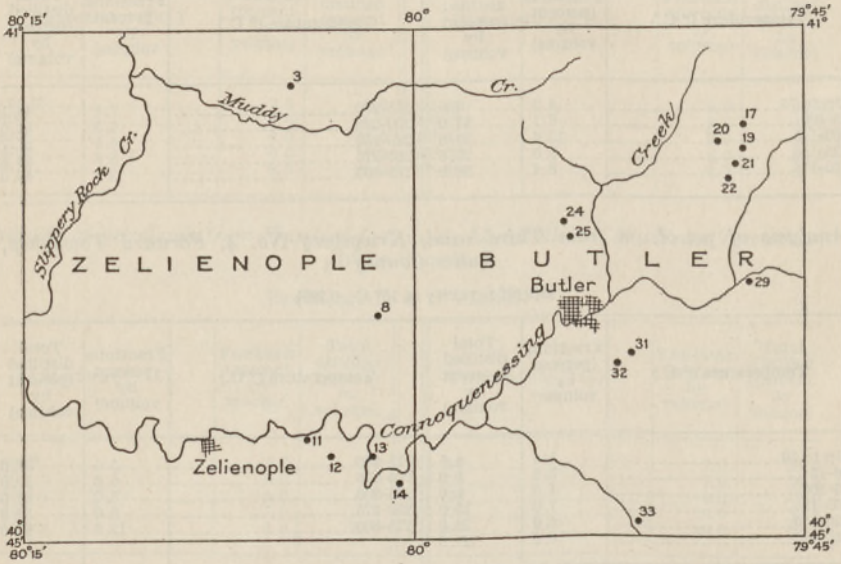


FIGURE 9.—Key map showing location of core-drill holes whose records are given or referred to in the text

Records of core-drill holes in Butler and Zelienople quadrangles

3. Worth Township, Butler County

	Thickness		Depth			Thickness		Depth	
	Ft.	*in.*	*Ft.*	*in.*		*Ft.*	*in.*	*Ft.*	*in.*
Surface	21	0	21	0	Bony coal		1	148	1
Brown sandstone	2	0	23	0	Coal	1	2	149	3
Sandstone	6	8	29	8	Soft clay	2	4	151	7
Brown sandstone	13	6	43	2	Gray shale	8	0	159	7
Light shale	20	4	63	6	Sandy shale	8	0	167	7
Dark shale	2	0	65	6	Gray shale	4	0	171	7
Light shale	3	6	69	0	Dark shale	11	0	182	7
Dark sandy shale and coal	3	4	72	4	Sandy shale	12	0	194	7
Coal		9	73	1	Coal		2	194	9
Sandy clay	6	0	79	1	Clay	2	10	197	7
Light sandy shale	7	11	87	0	Gray sandy shale	28	0	225	7
Dark shale	6	0	93	0	Sandstone	20	0	245	7
Black shale	2	8	95	8	Coal		1	245	8
Bony coal		4	96	0	Dark sandy shale	9	0	254	8
Dark shale	2	0	98	0	Dark shale	16	5	271	1
Sandy shale	20	0	118	0	Bony coal		4	271	5
Clay	3	0	121	0	Shale		1	271	6
Bastard lime	3	0	124		Coal (Middle Kittanning?)	2	10	274	4
Gray shale	19	0	143	0	Clay	4	3	278	7
Black shale	5	0	148	0					

Records of core-drill holes in Butler and Zelienople quadrangles—Continued

8. Connoquenessing Township, Butler County

	Thickness		Depth			Thickness		Depth	
	Ft.	*in.*	*Ft.*	*in.*		*Ft.*	*in.*	*Ft.*	*in.*
Surface	15	0	15	0	Clay	2	0	320	4
Soft shale	9	0	24	0	Shale	20	3	340	7
Black slate	8	10	32	10	Coal		2	340	9
Sandstone	55	0	87	10	Sandy shale	10	0	350	9
Clay	2	4	90	2	Shale		6	351	3
Shale	25	4	115	6	Bony coal		5	351	8
Coal (Brush Creek)	1	6	117	0	Coal		3	351	11
Clay	3	4	120	4	Bony coal		3	352	2
Shale	14	0	134	4	Dark shale	1	6	353	8
Shale and sandstone	14	0	148	4	Sandy shale	3	5	357	1
Sandstone	12	2	160	6	Coal (Middle Kittanning)	1	3	358	4
Clay	1	0	161	6	Bony coal		1	358	5
Variegated shale	2	3	163	9	Shaly clay	7	0	365	5
Bastard lime	3	8	167	5	Sandy shale	6	0	371	5
Clay	6	3	173	8	Slate	1	0	372	5
Bastard lime		4	174	0	Clay	2	0	374	5
Shale with sand streaks	17	5	191	5	Sandstone	11	0	385	5
Sandstone	1	6	192	11	Green shale	11	7	397	0
Black shale	3	6	196	5	Sandy shale	14	0	411	0
Coal (Upper Freeport)	1	3	197	8	Dark shale	14	4	425	4
Bony coal		3	197	11	Lime (Vanport limestone member)	10	0	435	4
Clay	2	9	200	8	Shale		1	435	5
Sandy shale	22	10	223	6	Bone and sulphur		4	435	9
Black shale	11	0	234	6	Coal (Scrubgrass)		10	436	7
Coal		5	234	11	Clay	4	0	440	7
Shale and coal streaks	6	9	241	8	Sandstone and shale streaks	10	0	450	7
Bony coal		1½	241	9½	Shale	1	3	451	10
Shale and coal	1	4	243	1½	Coal (Clarion)	1	6	453	4
Clay	2	0	245	1½	Clay	4	0	457	4
Sandy shale	10	1½	255	3	Sandy clay	10	1	467	5
Sandstone and shale	8	0	263	3	Sandstone	2	5	469	10
Black slate	5	3	268	6	Shale	5	2	475	0
Dark shale	26	6	295	0	Coal and bone		6	475	6
Black shale	10	0	305	0	Sandstone and coal spars		3	475	9
Bony coal		6	305	6	Shale and clay	5	5	481	2
Coal (Upper Kittanning)	1	10	307	4	Black shale		7	481	9
Sulphur binder		1	307	5	Clay	4	0	485	0
Coal		8	308	1	Sandstone with coal spars (Homewood)	41	3	527	0
Clay		9	308	10					
Shale	9	6	318	4					

11. Jackson Township, Butler County

Surface	10	6	10	6	Shale	32	1	171	7
Lime	1	10	12	4	Dark shale	5	1	176	8
Clay	2	3	14	7	Shale	24	8	201	4
Clay and sandy shale	5	5	20	0	Lime (Vanport limestone member)		9	202	1
Sandy shale	15	1	35	1	Shale	4	7½	206	8½
Dark shale	29	6	64	7	Coal (Scrubgrass)	4	2½	210	11
Coal (Upper Kittanning)	3	3	67	10	Clay	6	8	217	7
Clay	4	5	72	3	Sandy shale	8	3	225	10
Light shale	5	7	77	10	Dark shale	4	6	230	4
Clay and shale	7	10	85	8	Shale		11	231	3
Dark shale	7	0	92	8	Clay	1	4	232	7
Shale	25	0	117	8	Shale	2	2	234	9
Bone		4	118	0	Coal (Clarion)	1	0	235	9
Coal (Middle Kittanning)	2	11	120	11	Dark shale	11	5	247	2
Clay	17	0	137	11					
"Lime"	1	7	139	6					

Records of core-drill holes in Butler and Zelienople quadrangles—Continued

12. Forward Township, Butler County

	Thickness		Depth			Thickness		Depth	
	Ft.	*in.*	*Ft.*	*in.*		*Ft.*	*in.*	*Ft.*	*in.*
Surface	94	0	9	0	Dark sandy shale	3	9	148	3
Sandy shale	2	0	11	0	Sandy shale	6	0	154	3
Coal		4	11	4	Hard sandy shale	10	8	164	11
Clay	14	10	26	2	Shale	33	6	188	5
Lime	1	4	27	6	Coal (Upper Kittanning?)	3	2	191	7
Light shale	4	0	31	6	Clay	11	11	203	6
Shale	5	6	37	0	Dark shale	2	2	205	8
Sandy shale	10	0	47	0	Clay	3	10	209	6
Hard sandy shale	28	5	75	5	Light shale	6	7	216	1
Sandstone	11	0	86	5	Shale	18	11	235	0
Coal and bone (Upper Freeport?)		4	86	9	Coal (Middle Kittanning)	1	7	236	7
Clay	2	1	88	10	Clay	5	1	242	8
Lime	2	2	91	0	Shale	5	11	248	7
Sandy shale	26	1	117	1	Sandy shale	8	0	256	7
Shale	5	8	122	9	Bone and shale	2	8	259	3
Sandy shale	8	9	131	6	Clay	2	8	261	11
Dark shale	3	11	135	3	Sandy shale	23	6	285	5
Coal and bone (Lower Freeport?)	1	6	136	9	Light shale	31	0	316	5
Clay	3	3	140	0	Dark sandy shale	16	11	333	4
Lime	2	6	142	6	Shale	5	2	338	6
Clay	2	0	144	6	Coal (Scrubgrass?)	4	0	342	6
					Clay		8	343	2

13. Forward Township, Butler County

Surface	7	0	7	0	Shale		4	120	5
Sandstone	35	0	42	0	Sandstone	5	0	125	5
Shale	15	0	57	0	Shale	27	2	152	7
Coal (Upper Kittanning)	2	6	59	6	Sandy shale	42	9	195	4
Clay		10	60	4	Clay	4	11	200	3
Sandy shale	4	9	65	1	Clay and sandy shale	6	6	206	9
Sandstone	1	10	66	11	Black shale	2	10	209	7
Sandy shale	12	6	79	5	Lime (Vanport limestone member)	1	11	211	6
Shale	2	10	82	3	Black shale (Vanport limestone member)		8	212	2
Clay	6	7	88	10	Lime (Vanport limestone member)	1	8	213	10
Sandy shale	1	4	90	2	Shale	3	5	217	3
Shale	25	6	115	8	Shale and bone		1½	217	4½
Coal (Middle Kittanning)	1	8	117	4	Coal (Scrubgrass)	4	10½	222	3
Clay	1	8	119	0	Clay	1	9	224	0
Sandstone	1	1	120	1					

14. Forward Township, Butler County

Surface	10	0	10	0	Black slate	22	6	156	3
Sandstone	12	2	22	2	Coal (Middle Kittanning)	2	0	158	3
Bony coal		2	22	4	Clay	17	8	175	11
Clay	11	0	33	4	Sandy shale	8	0	183	11
Sandstone	52	3	85	5	Sandstone	2	0	185	11
Slate	10	8	96	1	Shale	7	0	192	11
Coal (Upper Kittaning)	1	6	97	7	Sandstone	3	3	196	2
Clay	5	0	102	7	Sandy shale	6	9	202	11
Shale	8	0	110	7	Dark sandy shale	32	0	234	11
Sandstone	3	9	114	4	Dark slate	10	10	245	9
Shale	1	9	116	1	Lime (Vanport limestone member)	4	0	249	9
Sandstone	2	4	118	5	Slate	2	9	252	6
Slate	6	6	124	11	Coal	2	7½	255	1½
Coal and bone		8	125	7	Binder (Scrubgrass)		8	255	9½
Slate		2	125	9	Coal		9½	256	7
Clay	4	0	129	9	Clay	1	5	258	
Sandy shale	4	0	133	9					

19. Oakland Township, Butler County

Surface	26	0	26	0	Coal (Upper Freeport)	4	0	83	0
Red shale (Mahoning)	7	0	33	0	Clay	6	0	89	0
Light shale	7	0	40	0	Dark shale	62	0	111	0
Sandstone	27	0	67	0	Sandstone	26	0	177	0
Dark shale	10	0	77	0	Coal		3	177	3
Bony coal	2	0	79	0	Sandstone	1	9	179	0

Records of core-drill holes in Butler and Zelienople quadrangles—Continued

21. Oakland Township, Butler County

	Thickness	Depth		Thickness	Depth
	Ft. in.	*Ft. in.*		*Ft. in.*	*Ft. in.*
Surface	15 0	15 0	Dark sandy shale	34 0	191 0
Sandstone	10 0	25 0	Sandstone	6	192 6
Dark sandy shale	31 0	56 0	Coal	1 0	192 6
Clay	6 0	62 0	Sandstone with streaks of coal	1 4	193 10
Light sandy shale	24 0	86 0	Bony coal	7	194 5
Clay	4 0	90 0	Sandstone	5	194 10
Light sandy shale	20 0	110 0	Bony coal	9	195 7
Sandstone	24 0	134 0	Sandstone	5 5	201 0
Dark sandy shale	11 6	145 6	Coal	1 9	202 9
Shale and coal	2 6	148 0	Shale	10	203 7
Coal (Upper Freeport?)	4 4	152 4	Coal (Lower Freeport?)	2 6	206 1
Shale binder	2	152 6	Clay and shale	7	206 8
Coal	5	152 11	Dark shale	5 4	212 0
Clay	4 1	157 0			

22. Oakland Township, Butler County

Surface	10 0	10 0	Clay	4 4	144 0
Sandstone	14 0	24 0	Light shale	14 0	158 0
Dark shale	5 0	29 0	Sandstone	34 0	192 0
Sandstone	18 0	47 0	Coal	1 0	193 0
Dark shale	7 0	54 0	Shale	6	193 6
Clay and shale	20 0	74 0	Coal	1 6	195 0
Light shale	19 0	93 0	Clay	2 0	197 0
Sandstone	30 0	123 0	Dark shale	4 0	201 0
Dark shale	7 0	130 0			
Black shale mixed with coal	5 0	135 0			
Coal, Clay, Coal (Upper Freeport?)	2 0 8 2 0	137 0 137 8 139 8			

24. Center Township, Butler County

Surface	10 0	10 0	White sandstone	36 0	176 0
Shale	4 0	14 0	Black shale	16 0	192 0
Sandstone	3 0	17 0	Coal (Upper Kittanning?)	4 0	196 0
Shale	3 0	20 0	"Limestone"	4 0	200 0
Sandstone	20 0	40 0	Gray sandstone	13 0	213 0
Gray shale	15 0	55 0	Black shale	21 0	234 0
White sandstone	20 0	75 0	Coal	6	234 6
Black shale	21 6	96 6	Black slate	12 6	247 0
Coal (Upper Freeport?)	1 6	98 0	Coal (Middle Kittanning?)	2 5	249 5
Clay	3 0	101 0	Coal	9	250 2
Gray shale	14 0	115 0	Clay	2	250 4
Gray sandstone	25 0	140 0			

25. Center Township, Butler County

Surface	18 0	18 0	Shale	7 6	138 0
Sandstone	42 0	60 0	Sandy shale	8 0	146 0
Shale	16 0	76 0	Shale	6 0	152 0
Coal (Upper Freeport?)	2 6	78 6	Sandy shale	6 0	158 0
Clay	3 6	82 0	Shale	12 0	170 0
Sandy shale	40 0	122 0	Coal (Upper Kittanning?)	3 0	173 0
Coal (Lower Freeport?)	6	122 6	Clay	1 0	174 0
Clay	8 0	130 6			

29. Summit Township, Butler County

Surface	7 0	7 0	Coal (Upper Freeport)	2 11	142 4
Soft shale	10 0	17 0	Clay	3 0	145 4
Brown sandstone	22 0	39 0	Shaly clay	2 0	147 4
Dark sandy shale	19 0	58 0	Shale with lime spar	1 2	148 6
Clay	2 0	60 0	Clay	1 0	149 6
Green shale	10 0	70 0	Gray shale	7 6	157 0
Red shale	2 2	72 2	Light sandy shale	20 6	177 6
Shaly clay	7 0	79 2	Shale and sandstone	6 7	184 1
Sandy shale	6 0	85 2	Gray slate	2	184 3
Brown sandstone	27 0	112 2	Coal (Lower Freeport)	2 0	186 3
Sandstone	18 6	130 8	Clay	3 9	190 0
Dark shale	8 9	139 5			

Records of core-drill holes in Butler and Zelienople quadrangles—Continued

31. Summit Township, Butler County

	Thickness		Depth			Thickness		Depth	
	Ft.	*in.*	*Ft.*	*in.*		*Ft.*	*in.*	*Ft.*	*in.*
Sandstone	14	0	14	0	Clay	3	0	312	9
Gray shale	6	0	20	0	Gray shale	7	0	319	9
Gray sandy shale	31	2	51	2	Soft shale	2	9	322	6
Sandstone	11	0	62	2	Gray shale	12	0	334	6
Dark shale	2	0	64	2	Dark shale	27	3	361	9
Sandstone	1	10	66	0	Sandstone	1	0	362	9
Coal		3	66	3	Coal		3	363	0
Gray shale	10	9	77	0	Shale		9½	363	9
Variegated shale	17	0	94	0	Coal		3½	364	1½
Gray shale	6	0	100	0	Shale		3	364	4
Red shale	7	6	107	6	Coal		5	364	1
Soft shale	8	0	115	6	Clay and shale	3	0	367	9
Gray shale	15	6	131	0	Shale		5	368	2
Dark shale	23	0	154	0	Coal	1	3	369	5
Coal (Upper Freeport)	3	1	157	1	Clay	2	7	372	0
Clay	3	0	160	1	Shale	2	6	374	6
Gray shale	6	0	166	1	Coal	2	0	376	6
Dark shale	20	0	186	1	Bony coal		3	376	9
Gray sandy shale	28	11	215	0	Dark shale	1	0	377	9
Dark shale	29	0	244	0	Gray sandy shale	15	0	392	9
Sandstone	26	0	270	0	Dark shale	11	0	403	9
Gray sandy shale	8	0	278	0	Limestone (Vanport limestone member)	15	6	419	3
Dark sandy shale	14	0	292	0	Dark shale		2	419	5
Sandstone	12	0	304	0	Coal (Scrubgrass)	1	4	420	9
Sandstone with coal streaks	3	5	307	5	Clay	2	6	423	3
Shale		1	307	6	Gray shale	1	9	425	0
Coal (Middle Kittanning)	2	0	309	6					
Shale		3	309	9					

32. Summit Township, Butler County

Surface	4	6	4	6	Dark shale	10	6	171	6
Gray shale	8	6	13	0	Coal	1	2½	172	8½
Coal		1	13	1	Shale (Upper Freeport)		1¼	172	9¾
Gray shale	17	11	31	0	Coal	1	2¼	174	0
Coal		2	31	2	Clay	3	6	177	6
Dark shale	21	10	53	0	Limy shale	2	6	180	0
Gray sandy shale	8	0	61	0	Clay	1	4	181	4
Sandstone	3	6	64	6	Gray shale	6	6	187	10
Dark shale	1	6	66	0	Dark shale	4	0	191	10
Sandstone	33	6	99	6	Gray sandy shale	17	0	208	10
Coal		2	99	8	Dark shale	5	11	214	9
Soft dark clay	5	0	104	8	Coal (Lower Freeport)	1	3	216	0
Soft gray shale	4	4	109	0	Shale		1½	216	1½
Gray shale	16	0	125	0	Coal		3	216	4½
Variegated shale	20	0	145	0	Clay	3	0	219	4½
Gray shale	16	0	161	0	Gray shale	3	7½	223	0

33. Jefferson Township, Butler County

Surface	13	6	13	6	Dark shale		2	75	0
Broken shale	16	6	30	0	Sandstone	4	8	79	8
Red shale	8	0	38	0	Dark shale	2	3	81	11
Light shale	4	0	42	0	Coal (Upper Freeport)	3	0	84	11
Light sandy shale	7	4	49	4	Clay	3	1	88	0
Light shale	9	0	58	4	Limestone	1	0	89	0
Light sandy shale	16	6	74	10					

RECORDS OF WELLS DRILLED FOR OIL AND GAS

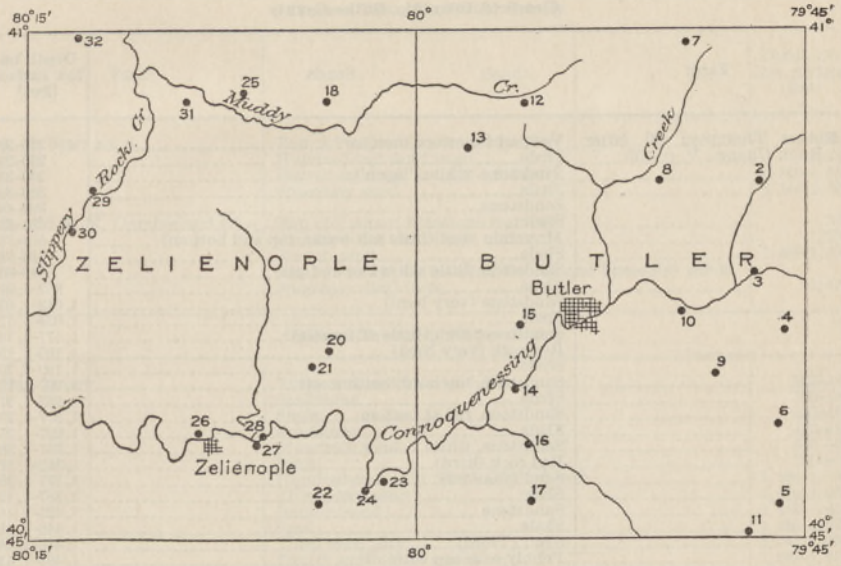


FIGURE 10.—Key map showing location of wells drilled for oil and gas whose records are given or referred to in the text.

The following records are given as reported by the drillers:

Records of oil and gas wells in and near Butler and Zelienople quadrangles

Fairview Township, Butler County

Farm [1]	Sands	Depth below surface (feet)
C. F. Hayes	Vanport limestone member	350
	Hundred-foot sand	1,275–1,385
	Third sand	1,523–1,542
	Fourth sand (oil at 1,580–1,588 feet)	1,580–1,613
M. Starr	Vanport limestone member	345–365
	Sand	400–450
	Sand	510–545
	Mountain sand	550–770
	Sand	900–940
	Gas sand (Murrysville)	1,115–1,200
	Hundred-foot sand	1,255–1,345
	Thirty-foot sand	1,380–1,425
	Boulder sand	1,480–1,500
	Third sand	1,517–1,542
	Fourth sand	1,579–1,604
	Speechley sand	2,447–2,455

Donegal Township, Butler County

Hickey No. 7	Vanport limestone member	360–380
	Mountain sand	660–875
	Sand	910–1,000
	Gas sand (no water)	1,192–1,217
	Hundred-foot sand	1,328–1,418
	Thirty-foot sand	1,450–1,480
	Boulder sand	1,518–1,550
	Third sand (oil at 1,603½ feet)	1,594–1,627
P. J. Zimmel (2)	Top of Vanport limestone member	422
	Hundred-foot sand	1,365–1,475
	Third sand	1,639–1,665
	Fourth sand (oil at 1,704 feet)	1,696–1,726

[1] Numbers in parentheses correspond to those on the index map (fig. 10) showing the location of the wells.

Records of oil and gas wells in and near Butler and Zelienople quadrangles—Contd.

Clearfield Township, Butler County

Farm	Sands	Depth below surface (feet)
Robert Thompson (3) (after Rept. Chance, V, p. 170).	Vanport limestone member	215–230
	Shale	230–290
	Sandstone, white, "open"	290–330
	Shale	330–390
	Sandstone	390–480
	Shale	480–530
	Mountain sand (little salt water, top and bottom)	530–740
	Shale	740–840
	Sandstone (little salt water and gas)	840–862
	Shale	862–1, 012
	Sandstone (very hard)	1, 012–1, 034
	Shale	1, 034–1, 177
	Sandstone, dark (little salt water)	1, 177–1, 192
	Red rock (very hard)	1, 192–1, 199
	Shale	1, 199–1, 207
	Sandstone, top hard, bottom soft	1, 207–1, 257
	Shale	1, 257–1, 277
	Sandstone, red at bottom	1, 277–1, 297
	Shale	1, 297–1, 357
	Sandstone, white	1, 357–1, 362
	Red rock (hard)	1, 362–1, 377
	Sand (Boulder)	1, 377–1, 387
	Shale	1, 387–1, 425
	Sandstone	1, 425–1, 446
	Shale	1, 446–1, 456
	Sand (Third)	1, 456–1, 486
	Pebbly near top with oil?	1, 486–1, 538
	Sand (Fourth; gas, no oil)	1, 538–1, 558?
Thomas Humes (4)	Vanport limestone member	304–319
	Gas sand (gas)	1, 215–1, 230
	Hundred-foot sand (oil and salt water)	1, 270–1, 370
	Third sand (no gas, oil, or water)	1, 520–1, 564
	Fourth sand (oil at 1,600 feet)	1, 578–1, 606

Winfield Township, Butler County

H. C. Keasey lot at Cabot (5)	Vanport limestone member	345–375
	Gas sand (Murrysville) (gas at 1,235 feet)	1, 175–1, 235
	Hundred-foot sand (gas at 1,385 feet)	1, 310–1, 435
	Snee sand	1, 515–1, 536
	Boulder sand (gas at 1,560 feet)	1, 548–1, 579
	Third sand	1, 618–1, 677
	Fourth sand	1, 692–1, 725
	Fifth sand	1, 740–1, 788
	Speechley sand (gas at 2,577 feet)	2, 525–2, 617
P. Cypher (6)	Vanport limestone member	355–383
	Sand	430–488
	Sand	587–643
	Mountain sand	660–857
	Sand	870–1, 020
	Gas sand (Murrysville)	1, 185–1, 210
	Hundred-foot sand	1, 300–1, 416
	Thirty-foot sand	1, 450–1, 510
	Boulder sand	1, 548–1, 566
	Third sand (oil at 1,632 feet)	1, 627–1, 655
	Fourth sand (oil at 1,671 feet)	1, 663–1, 684
Peter Kennedy	Top of Vanport limestone member	405
	Sand	1, 045–1, 065
	Gas sand (Murrysville)	1, 290–1, 315
	Hundred-foot sand	1, 430–1, 540
	Thirty-foot sand	1, 575–1, 620
	Third sand	1, 725–1, 750
	Fourth sand (bottom)	1, 780
	Fifth sand	1, 825–1, 860
	Speechley sand	2, 645–2, 680

Records of oil and gas wells in and near Butler and Zelienople quadrangles—Contd.

Concord Township, Butler County

Farm	Sands	Depth below surface (feet)
A. P. Starr no. 5	Top of Vanport limestone member	435
	Hundred-foot sand (top)	1,337
	Fourth sand (oil at 1,652–1,659 feet)	1,648–1,659
	Speechley sand	2,545–2,561
A. and E. N. Cumberland (7)	Top of Vanport limestone member	370
	Hundred-foot sand (top)	1,270
	Fourth sand	1,588–1,595
	Reported all shale between Fourth and Speechley sands.	
	Speechley sand (top)	2,478

Oakland Township, Butler County

Dan Lowry	Vanport limestone member	300–322
	Sandstone	360–400
	Shale	400–446
	Sandstone	446–480
	Mountain sand	510–690
	Sand	780–830
	Hundred-foot sand (show of oil on top)	1,284–1,390
	Thirty-foot sand	1,410–1,445
	Boulder sand	1,453–1,468
	Sand	1,498–1,522
	Third sand (dry)	1,542–1,560
	Fourth sand (little gas on top)	1,599–1,619
	Fifth sand (dry) (red rock at 1,685 feet)	1,660–1,668
	Red rock	2,020–2,070
	Sand (hard)	2,126–2,147
	Sand	2,275–2,287
	Sand (hard)	2,360–2,375
	Sand (bottom)	2,415
	Speechley sand	2,526–2,566
L. C. Martin (8)	Top of Vanport limestone member	310
	Hundred-foot sand (much water)	1,245–1,357
	Thirty-foot sand	1,417–1,432
	Boulder sand	1,470–1,485
	Third sand (gas and oil)	1,523–1,535
	Fourth sand	1,556–1,582

Summit Township, Butler County

Reott (9)	Vanport limestone member	443–468
	Mountain sand	710–920
	Sand	955–1,070
	Gas sand	1,250–1,280
	Hundred-foot sand	1,428–1,535
	Thirty-foot sand	1,557–1,590
	Snee sand	1,592, 1,614
	Boulder sand	1,654–1,672
	Third sand (oil at 1,686 feet)	1,680–1,733
	Fourth sand	1,759–1,779
Florence Stephenson (10)	Vanport limestone member	216–238
	Sand	700–760
	Gas sand	1,100–1,175
	Hundred-foot sand (first oil pay at 1,204–1,210 feet; second oil pay at 1,235–1,250 feet.)	1,200–1,300
	Thirty-foot sand	1,332–1,340
	Snee sand	1,360–1,385
	Boulder sand	1,420–1,444
	Third sand (oil at 1,464 feet)	1,459–1,482
	Fourth sand (gas at 1,511–1,517 feet)	1,507–1,529
	Fifth sand	1,567–1,574
William Yost	Hundred-foot sand	1,325–1,435
	Snee sand	1,460–1,475
	Boulder sand	1,485–1,512
	Sand (gas at 1,565 feet)	1,547–1,573
	Third sand	1,598–1,625
	Fourth sand	1,646–1,663
	Fifth sand	1,695–1,713

Records of oil and gas wells in and near Butler and Zelienople quadrangles—Contd.

Jefferson Township, Butler County

Farm	Sands	Depth below surface (feet)
John Wallet	Top of Vanport limestone member	455
	Gas sand (top)	1,330
	Hundred-foot sand (top)	1,470
	Thirty-foot sand (top) (gas at 1,660 feet)	1,585
	Boulder sand (top)	1,705
	Third sand (top)	1,730
	Fourth sand	1,805–1,845
	Fifth sand	1,890–1,905
	Speechley sand (top) (gas at 2,693 feet)	2,685
	Sand (top)	2,866
	Sand (top)	3,065
	Sand (top)	3,170
	Bradford (?) sand	3,360
	Bottom of hole	3,412
Greer heirs (11)	Vanport limestone member	394–420
	Gas sand	1,284–1,353
	Hundred-foot sand	1,416–1,541
	Thirty-foot sand	1,566–1,622
	Boulder sand	1,667–1,692
	Third sand	1,700–1,735
	Fourth sand	1,755–1,780
	Fifth sand	1,819–1,840
S. B. Campbell	Vanport limestone member	470–498
	Mountain sand	740–955
	Sand	990–1,110
	Gas sand	1,300–1,400
	Hundred-foot sand (salt water at 1,479 feet; gas at 1,520 feet)	1,452–1,540
	Thirty-foot sand (top)	1,580
	Third sand (oil at 1,720–1,732 feet)	1,714–1,736

Clay Township, Butler County

Geo. Bighley (12)	Vanport limestone member	210–230
	Hundred-foot sand (red shale at 1,140 feet)	1,095–1,200
	Boulder sand (gas)	1,375–1,390
	Third sand	1,417–1,437
	Fourth sand (top) (pebbly)	1,479
	Sand	2,185–2,205
	Upper Speechley sand, black (top)	2,320
	Speechley sand, chocolate-colored (top) (little oil)	2,539

Center Township, Butler County

Adam Dunbaugh (13)	Vanport limestone member	295–307
	Sand	417–455
	Mountain sand	460–685
	Sand	727–818
	Sand	985–1,040
	Red rock at 1,145 and 1,165 feet.	
	Hundred-foot sand (top)	1,197
Warren Aggas	Vanport limestone member	188–212
	Mountain sand (top)	495

Records of oil and gas wells in and near Butler and Zelienople quadrangles—Contd.

Butler Township, Butler County

Farm	Sands	Depth below surface (feet)
White (Alameda Park)	Top of Vanport limestone member	220
	Hundred-foot sand	1,120–1,231
	Thirty-foot sand (top)	1,290
	Snee sand (top)	1,335
	Boulder sand (top)	1,358
	Third sand (top) (oil, 15 barrels)	1,437
McCalmont (14)	Top of Vanport limestone member	210
	Gas sand (top)	1,015
	Hundred-foot sand (top)	1,168
	Thirty-foot sand	1,320–1,380
	Fourth sand (oil at 1,483 feet)	1,476–1,530
Butler Highfield (15)	Vanport limestone member	455–475
	Hundred-foot sand	1,390–1,476
	Thirty-foot sand (top)	1,495
	Boulder sand (top)	1,640
	Third sand	1,692–1,700
	Speechley sand	2,585–2,615
	Sand	2,760–2,775
	Bradford (?) sand	3,170–3,202
	Shale to bottom of hole	3,202–3,717

Penn Township, Butler County

Farm	Sands	Depth below surface (feet)
Marshall No. 18 (16) (Pennsylvania 2d Geol. Survey Ann. Rept. for 1886, p. 711.).	Vanport limestone member	210–236
	Mountain sand	430–650
	Sand	800–840
	Gas sand (salt water at 1,075 feet)	1,045–1,090
	Hundred-foot sand	1,185–1,282
	Thirty-foot sand	1,355–1,380
	Blue Monday (Snee sand)	1,400–1,425
	Boulder sand	1,460–1,475
	Third and Fourth sands	1,500–1,542
D. B. Dodge (17)	Top of Vanport limestone member	553
	Gas sand	1,355–1,470
	Hundred-foot sand	1,509–1,600
	Shale "break" at 1,569 feet (no water or oil).	
	Thirty-foot sand	1,663–1,682
	Blue Monday (Snee sand)	1,719–1,735
	Boulder sand	1,768–1,794
	Third sand (oil in top of sand)	1,826–1,842

Brady Township, Butler County

Farm	Sands	Depth below surface (feet)
W. H. Yerkey No. 1	Vanport limestone member	85–99
	Berea (?) sand (oil, gas, and water)	830–840
	Hundred-foot sand	1,005–1,059
	Sand	1,203–1,221
	Bottom of hole	1,440
John Smith (18) (Pennsylvania 2d Geol. Survey Rept. I³, p. 418).	Vanport limestone member	230–245
	Shale and clay	245–272
	Sandstone	272–290
	Shale (black)	290–400
	Sandstone	400–465
	Shale	465–468
	Sandstone	468–568
	Sandstone	640–690
	Sandstone	700–730
	Sandstone	910–936
	Red rock	1,055–1,115
	Sandstone	1,275–1,295
	Shale	1,295–1,305
	Sandstone	1,305–1,340
	Sand, "shelly"	1,431–1,450
	Stopped at	1,458½
	Later deepened to	1,596
	"A thick mass of red rock near the bottom."	

Records of oil and gas wells in and near Butler and Zelienople quadrangles—Contd.

Franklin Township, Butler County

Farm	Sands	Depth below surface (feet)
Schaffer (19)	Vanport limestone member	90–95
	Mountain sand	290–650
	Amber sand	837–872
	Berea (?) sand	873–898
	Clover Seed sand	998–1,003
	Hundred-foot sand (salt water)	1,065–1,105
	Sand	1,184–1,194
	Sand	1,226–1,260
	Sand (Third?)	1,298–1,303
	Sand (Fourth?)	1,370–1,390
	Sand	1,825–1,875
Muddy Creek field (general section).	Vanport limestone member	0
	Berea (?) sand	720–750
	Hundred-foot sand (top)	920

Connoquenessing Township, Butler County

Ed. Young (20)	Vanport limestone member	420–430
	Sand	535–555
	Sand	580–640
	Mountain sand	675–819
	Sand	880–950
	Berea (?) sand	1,128–1,148
	Gas sand	1,160–1,240
	Hundred-foot sand (oil at 1,347 feet)	1,340–1,398
	Thirty-foot sand	1,475–1,485
	Snee sand	1,519–1,529
	Boulder sand	1,560–1,566
	Third sand	1,595–1,603
S. Cabel (21)	Vanport limestone member	295–320
	Sand	445–500
	Sand	515–545
	Mountain sand (cased off fresh water)	555–685
	Sand	817–825
	Berea (?) sand	991–1,021
	Gas sand	1,056–1,140
	Hundred-foot sand (cased off salt water)	1,214–1,272
	Snee sand	1,399–1,407
	Boulder sand	1,447–1,452
	Third sand (shells)	1,493–1,495
A. D. Nicklas	Vanport limestone member	465–480
	Mountain sand	730–870
	Sand	960–1,070
	Gas sand	1,295–1,345
	Hundred-foot sand (oil at 1,455–1,473 feet)	1,390–1,486
	Snee sand (oil at 1,610–1,620 feet)	1,605–1,625
William Anderson	Vanport limestone member not recorded.	
	Coal (base of Allegheny formation?)	352
	Sandstone	352–413
	Shale	413–516
	Sandstone	516–663
	Shale	663–680
	Sandstone	680–785
	Shale	785–957
	Sandstone	957–987
	Sandy shale	987–1,015
	Sandstone	1,015–1,045
	Gas sand	1,045–1,120
	Red rock and dark sand	1,120–1,178
	Hundred-foot sand (oil at 1,211 feet; pebbles and gas at 1,240 feet).	1,178–1,270

Records of oil and gas wells in and near Butler and Zelienople quadrangles—Contd.

Forward Township, Butler County

Farm	Sands	Depth below surface (feet)
Ida Graham lot (22) (Evans City).	Vanport limestone member	225–235
	Sand	380–460
	Sand	465–550
	Sand	675–780
	Gas sand	980–1, 070
	Hundred-foot sand	1, 120–1, 210
	Snee sand	1, 325–1, 335
	Third sand (oil and gas at 1,430–1, 438 feet)	1, 423–1, 453
D. Markel (23) (Glade Run pool).	Vanport limestone member	268–286
	Gas sand (water)	1, 060–1, 130
	Hundred-foot sand	1, 175–1, 295
	Third and Fourth sands (oil at 1,500 feet)	1, 479–1, 525
Near bend in Connoquenessing Creek, 2 miles northeast of Evans City (24).	Vanport limestone member	250–255
	Big Injun sand	655–790
	Gas sand	1, 018–1, 103
	Hundred-foot sand	1, 130–1, 250
	Snee sand	1, 345–1, 360
	Boulder and Third (?) sands	1, 436–1, 489
	Speechley (?) sand	2, 340–2, 400
	Dark-gray shale	4, 350–4, 725
	Black shale	4, 725, 4, 839
	Abandoned in black shale at	5, 180

Worth Township, Butler County

A. and J. Leise (25)	Vanport limestone member	46–65
	Sandstone	140–220
	Sandstone	280–315
	Sandstone	320–435
	Sandstone	482–595
	Sandstone	760–809
	Berea (?) sand (gas)	820–845

Lancaster Township, Butler County

J. H. Brenner	Upper Freeport coal about 5 feet above well.	
	Vanport limestone not recorded.	
	Sandstone	390–480
	Sandstone	485–595
	Sandstone	660–753
	Sandstone	925–960
	Sandstone (gas at 995–1,0001 feet)	981–1, 005

Jackson Township, Butler County

Pasavant (26)	Vanport limestone member	200–215
	Sand (Homewood sandstone member)	295–370
	Sand (Connoquenessing sandstone member)	430–517
	Sand	562–652
	Sand	845–870
	Gas (?) sand (water)	900–1, 000
	Hundred-foot (?) sand (oil and water at 1,105 feet)	1, 093–1, 136
	Snee (?) sand	1, 250–1, 256
	Boluder (?) sand (shells)	1, 297–1, 304
	Third (?) sand (show of gas at 1,338 feet)	1, 337–1, 343
M. Ziegler (27)	Vanport limestone member	118–126
	Sand	345 390
	Sand	412–450
	Sand	470–540
	Sand	565–635
	Sand	800–820
	Gas sand	855–950
	Hundred-foot (?) sand	980–1, 070
	Thirty-foot (?) sand	1, 110–1, 125
	Sand	1, 175–1, 180
	Sand	1, 202–1, 208
	Sand	1, 243–1, 253
	Third (?) sand	1, 283–1, 290
W. Stamm (28)	Vanport limestone member	130–140
	Sand	360–410
	Sand	420–490
	Sand	525–620
	Sand	655–705
	Sand	800–815
	Gas (?) sand	855–942
	Hundred-foot (?) sand	995–1, 090
	Thirty-foot sand	1, 110–1, 120
	Snee (?) sand	1, 207–1, 217
	Boulder (?) sand	1, 252–1, 262
	Third (?) sand	1, 293–1, 307

Records of oil and gas wells in and near Butler and Zelienople quadrangles—Contd.

Slippery Rock Township, Lawrence County

Farm	Sands	Depth below surface (feet)
A. Rohr	Vanport limestone member	34–48
	Shale	48–133
	Sixty-foot (?) sand	133–188
	Shale	188–278
	Mountain sand	278–338
	Shale	338–388
	Slippery Rock sand (oil at 415 feet)	388–448
Shaffer (29) (Pennsylvania 2d Geol. Survey Rept. I³, p. 417).	Well started about 15 feet below Lower Mercer limestone.	
	Conductor	8
	Sand	8–38
	Shale	42–80
	"Limestone," blue	80–83
	Shale	83–95
	Sixty-foot (?) sand	95–170
	Shale	170–510
	Sandstone, gray, Berea (?) (little amber oil)	510–550
	Shale	550–700
	Red rock	700–726
	Shale (black oil in sand "shell" at 800 feet)	726–890
	Red rock	890–930
	Shale, a few "shells"	930–1,273
	Conglomerate (black and red shale and pebbles)	1,273–1,283
	Sandstone, brown or light gray, fine	1,283–1,288
	Sandstone, black, dark gray when dry	1,288–1,320
	Shale, dark, a few "shells"	1,320–1,436
J. Scott Munnel (32)	Well mouth in glacial drift near horizon of Vanport limestone member of Allegheny formation.	
	Berea sand of driller (show of oil at 664 feet)	664–711
	Onondaga (?) limestone	4,501–4,635
	Oriskany (?) sandstone (show of oil at 4,638 feet)	4,635–4,653
	Limestone (show of oil at 4,683 feet, shows of gas at 4,735 and 4,748 feet).	4,653–4,767

Perry Township, Lawrence County

Chew (30) (Pennsylvania 2d Geol. Survey Rept. Q², p. 89).	Well started at top of Upper Mercer limestone.	
	Conductor	10
	Shale, sandy	10–45
	Limestone, Lower Mercer	45–47
	Coal, Lower Mercer	47–49
	Shale	49–69
	Sandstone, massive, hard	69–114
	Shale, dark	114–169
	Sandstone, white (fresh water)	169–236
	Shale, sandy	236–286
	Sandstone	286–307
	Shale	307–327
	Sand (gas, oil, and salt water)	327–352
	Shale	352–565
	Sandstone, white (amber oil at 575 feet)	565–595
	Shale	595–689
	Shale (with red rock at bottom of hole)	689–790

INDEX

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GEOLOGIC MAP OF BUTLER QUADRANGLE, PENNSYLVANIA

EXPLANATION

Pleistocene and Recent — QUATERNARY

Qpal — Ponded deposits and recent alluvium

Pennsylvanian — CARBONIFEROUS

Cam / Ccm — Conemaugh formation
(Shale and sandstone including some red beds, limestone, and coal; Cam, Ames limestone member)

Ca — Allegheny formation
(Shale and sandstone with important coal beds; Upper Freeport coal at top; only upper part of formation crops out)

R. B. Marshall, Chief Geographer.
Frank Sutton, Geographer in charge.
Topography by Wm. O. Tufts, R. H. Reineck, and S. P. Floore.
Control by C. B. Kendall and C. B. Burns.
Surveyed in 1908-1909.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

Scale 1/62500

1 0 1 2 3 4 Miles

1 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.

1936

Geology by G. B. Richardson
assisted by R. Van A. Mills
Surveyed in 1915, 1928, and 1931

GEOLOGIC MAP OF ZELIENOPLE QUADRANGLE, PENNSYLVANIA

EXPLANATION

- Qpal — Ponded deposits and recent alluvium
- Qt — Terminal moraine
- Qo — Outwash and valley train
- Qmt — Ground moraine *(Heavy dashed line shows Wisconsin drift border)*

Pleistocene and Recent / Pleistocene — QUATERNARY

- Ccm — Conemaugh formation *(Shale and sandstone including some red beds, limestone, and coal)*
- Ca Cv — Allegheny formation *(Shale and sandstone with Vanport limestone member (Cv) and important coal beds. Upper Freeport coal at top; Vanport limestone, indicated by dashed line where concealed by glacial deposits)*
- Cp — Pottsville formation *(Chiefly sandstone, locally conglomeratic; subordinate shale and thin beds of coal, clay, and limestone)*

Pennsylvanian — CARBONIFEROUS

Geology by G. B. Richardson, assisted by T. C. Brown and R. Van A. Mills
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EXPLANATION

- Structure contours (1000) — *(Drawn on top of Vanport limestone member; contour interval 50 feet, datum mean sea level)*
- Outcrop of Upper Freeport coal horizon (uf)
- Coal mine (×10) — *(Figures refer to measured sections of coal beds on plates or in text)*
- Country coal bank (×42) — *(Figures refer to measured sections of coal beds on plates or in text)*
- Oil well — *(Oil fields lettered in green)*
- Gas well
- Sandstone quarry (×ss)

MAP SHOWING STRUCTURE AND ECONOMIC GEOLOGY OF BUTLER QUADRANGLE, PENNSYLVANIA

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Frank Sutton, Geographer in charge.
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EXPLANATION

- Structure contours (1000) — (Drawn on top of Vanport limestone member; contour interval 50 feet, datum mean sea level)
- Outcrop of Upper Freeport coal horizon (uf)
- Coal mine (×5) — (Figures refer to measured sections of coal beds on plates or in text)
- Country coal bank (×10) — (Figures refer to measured sections of coal beds on plates or in text)
- Oil well — (Oil fields lettered in green)
- Gas well
- Limestone quarry (Is)

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