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COAL, OIL, AND GAS

OF THE

FOXBURG QUADRANGLE, PENNSYLVANIA

BY

EUGENE WESLEY SHAW

AND

MALCOLM J. MUNN

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COAL, OIL, AND GAS OF THE FOXBURG QUADRANGLE, PENNSYLVANIA.

By EUGENE WESLEY SHAW and MALCOLM J. MUNN.

INTRODUCTION.

The area discussed in this bulletin is a 15-minute quadrangle of the United States Geological Survey, bounded by meridians 79° 30′ and 79° 45′ and parallels 41° 00′ and 41° 15′. These inclose a rectangle about 13 miles wide from east to west and about 17 miles long from north to south, containing about 225 square miles. The area is in the central part of western Pennsylvania, about 75 miles north of Pittsburg (see Pl. I, in pocket), and embraces parts of Venango, Clarion, Armstrong, and Butler counties. Foxburg, from which the quadrangle is named, stands about 3 miles west of the center of the quadrangle. The other principal towns are Emlenton, Knox, St. Petersburg, Callensburg, Parkers Landing, West Monterey, Rimersburg, Petrolia, and Fairview. A description of the triangulation work upon which the topographic map of the quadrangle is based will be found in United States Geological Survey Bulletin 181.

The Foxburg quadrangle lies in the great coal, oil, and gas producing region of western Pennsylvania. It contains many beds of coal, all of which outcrop extensively and none of which lie under more than a few hundred feet of cover. The oil and the gas are found in wells that range in depth from 600 to 2,500 feet, the deeper wells reaching the lower oil and gas-bearing strata and the shallower ones stopping in the upper sands. The oil and gas-bearing strata, like the coal beds, are nearly horizontal, though in general the former appear to have slightly greater dips.

Although the quadrangle has yielded millions of dollars worth of coal, oil, and gas, its fuel resources are not half exhausted, and it also contains valuable deposits of clay, sand, gravel, limestone, shale, sandstone, and iron ore. The other mineral resources are not so important as the coal, oil, and gas, and, as they are described in the Foxburg-Clarion folio of the Geologic Atlas (folio 178), they will not be considered in the present report. Much of the coal mined is used in the quadrangle, but all of it is within easy reach of lines of transportation, and the part which is shipped finds a ready market in the great non-

coal-bearing area to the north, including northwestern Pennsylvania, New York, Ontario, and Quebec. The oil passes from the wells into pipe lines and is pumped to refineries, some of them near by and some at long distances. The gas flows into pipe lines also and is mixed with gas from other districts; some of it is consumed locally and practically all is burned in western Pennsylvania.

The region has been studied and described by several geologists, the most important reports being those of the Second Geological Survey of Pennsylvania, particularly Report VV, on Clarion County, by H. M. Chance, and Report III, on the oil regions, by John F. Carll.

In undertaking the present geological survey, the field work of which was done in 1908, it was considered unnecessary to duplicate the work of former surveys, except so far as to test by modern methods the results previously obtained. The aim of the present survey, therefore, was to devote especial attention to the features which received least attention in previous reports. Under this general plan the geologic structure, or lay of the beds, and the detailed distribution of various kinds of rocks have been carefully studied in the field and, so far as practicable, recorded on the maps. The geology of the coals is described by Mr. Shaw, the geology of the oil and gas by Mr. Munn.

TOPOGRAPHY AND DRAINAGE.

This quadrangle lies wholly within the basin of Allegheny River, which receives Clarion River from the east as its principal tributary in this area. These rivers have in comparatively recent time cut deep, narrow, gorge-like valleys across what was once a fairly level surface, and during the course of this downward cutting the smaller streams tributary to them have also deepened their valleys in a similar manner. Near the mouths of these smaller streams their valley walls are precipitous. Toward their sources, the hills rise less abruptly into flat or well-rounded summits. The difference in altitude of hills and adjacent valleys ranges from less than 200 to about 700 feet, the variation bearing a close relationship to the size of the streams. The lowest point in the area is about 815 feet above mean sea level and the highest is about 1,650, but the relief of every square mile amounts to several hundred feet. Thus the general elevation does not vary greatly and the hills are roughly concordant in height.

The brown lines on the map (Pl. I) are surface contours, indicating elevations above sea level and the shapes and sizes of the hills and valleys. Each contour passes through points of equal elevation. For example, the line bearing the figures 1,200 passes through points 1,200 feet above sea, the next higher passes through points 1,220 feet above sea, and so on. Thus almost the exact elevation of any point above sea level may be determined by locating the point on the map and noting its position with reference to the contours.

Perhaps the most striking topographic features are the canyon-like gorges of the rivers. Two miles southeast of Emlenton the Allegheny Valley is scarcely a mile wide, but is 660 feet deep. Flood plains are very narrow or absent, and the farming is on the upland, where there is much gently undulating country. The rivers are crooked and have some very long curves where the stream doubles back upon itself, but the valley is no shorter, because the walls follow the stream around its meanders. The entrenching of these streams is probably due in large part to Pleistocene or perhaps Pliocene uplift of the region, and in a lesser degree to increased volume of the Allegheny since the enlargement of its basin.

The contours of the hills depend, to some extent, upon the rocks of which they are composed. In areas where heavy sandstone predominates the hillsides are steep and rugged, and where sandstone is the cap rock the tops of the hills are broad and flat. The latter type of topography is well developed near Bonus, west of Foxburg, near Rimersburg, and generally in the northern part of the quadrangle. Elsewhere the rocks are prevailingly shaly, and the hills have rounded tops and gently sloping sides.

Another class of surface features consists of stream-cut terraces and abandoned channels, which are well developed along the lower part of the Clarion and continue down along the Allegheny below the mouth of the Clarion. They are developed to some extent also along Redbank Creek.

The Foxburg quadrangle is divided into three segments by Allegheny and Clarion rivers. The run-off from the western segment reaches Allegheny River by way of Sugar Valley, Bear Creek, Binker Valley, Crozier Hollow, and Birch, Armstrong, Whisky, Cove, and Pine runs, and numerous smaller streams and gullies. The principal streams in the northern segment are Shull Run, Mill Creek, and Richey Run, flowing into the Allegheny, and Turkey Run, Beaver Creek, and Canoe Creek, flowing into the Clarion. In the southeast segment the Allegheny receives water from Fiddlers, Black Fox, and Catfish runs, and several unnamed brooks; and the Clarion from Cherry Run and Licking Creek. A few small streams in the southeast corner of the quadrangle discharge into Redbank Creek, which flows parallel to the Clarion just off the southern boundary of the area.

Allegheny River is the most important artery of commerce. Though very little freight is transported by water, the river affords a very uniform gradient for the Pennsylvania Railroad, which follows a low narrow terrace along its eastern bank, and much local and through traffic is carried on along this route. The river flows in a narrow gorge and has a number of long curves. Therefore the railroad, in following the bank of the river in the bottom of the gorge,

is much longer than if it followed a straight line; but the cost of building and operating the railroad over the long course, in which little cutting and filling was necessary, is less than would be the expense of building a line across interstream areas, or even tunneling through the narrow necks, such as that at Wood Hill.

The making of Allegheny River navigable is a project which has often been considered, and the Government has made surveys with that end in view. But no improvement work has been done, and it is only at high water that any boats enter the Foxburg quadrangle. At low water there are many riffles where the water is less than a foot deep. The longest and most formidable rapid in the Allegheny between Olean, N. Y., and Pittsburg is located 3 miles north of Emlenton. Its length is 6,900 feet, and the fall of water in this distance is 11.23 feet. Some timber is floated down the river on rafts, but almost all the freight along the Allegheny is handled by the Pennsylvania Railroad.

The Clarion is more crooked even than the Allegheny, and though there is in some places a very narrow terrace, which may correspond to the one followed by the railroad on the Allegheny, no railroad has been built along the stream. There are almost no public wagon roads in the bottom of the valley.

The valley of Redbank Creek is, however, used by the "Low-Grade division" of the Pennsylvania—so called because it crosses the mountains at a lower altitude than the main line, between Pittsburg and eastern cities. The stream is not so crooked as the Clarion and the valley is more open.

Bear Creek valley, in the southwestern part of the quadrangle, is used by a branch of the Baltimore & Ohio Railroad. This road is standard gage as far as Foxburg, and thence is a narrow-gage line, with many steep grades. It runs through St. Petersburg, Knox, and Shippenville, to Clarion Junction.

A short distance east of the quadrangle the Pittsburg, Summerville & Clarion Railroad finds a way over the comparatively smooth uplands between Clarion River and Piney Creek, and the Franklin & Clearfield Railroad has just been built along Deer and Piney creeks. A branch of the Pennsylvania Railroad, called the Sligo branch, runs near the boundary of the quadrangle from Redbank Creek to Sligo. Over this route the grade is steep, but the road forms an outlet for the product of several coal mines.

The relation of the coal beds and other underground economic resources of the quadrangle to the hills is such that over the greater part of the region no shaft mining is done. The coal is mined by drifting and the clay and lime by stripping. Iron ore, which was formerly an important product, was mined also by open-cutting, or in some places by drifting.

The majority of farm houses are located very near coal outcrops, not for convenient access to the coal, but because along coal outcrops there are many springs, and springs were generally determining factors in the early days in locating farm houses. Coal beds are commonly underlain by clay, and this forms an impervious layer, causing ground water to travel along it until the surface is reached, where the water appears in the form of a spring. It is not uncommon to see the coal itself exposed in such springs.

STRATIGRAPHY.

CHARACTER AND THICKNESS OF THE ROCKS.

The rocks of the Foxburg quadrangle are all of sedimentary origin and consist chiefly of shale, sandstone, clay, limestone, coal, and alluvial deposits of sand and gravel. With the exception of the coal, most if not all of the materials of which these rocks are composed were transported and deposited by water and many of them were laid down in an ocean. The various strata were thus deposited in successive layers, one above another, and were spread out over large areas, some of them having an extent of thousands of square miles.

The composition and thickness of each stratum varies greatly from point to point because of differences in local conditions under which it was laid down. In places the currents were strong; and the sand and mud brought down by streams was washed and assorted, the light, fine mud being borne away to settle to the bottom in areas where the water was comparatively still, the remaining sand being spread out only so far as the currents were strong enough to carry it. From time to time there were developed local conditions favorable for the growth of lime-secreting animals and plants, which, when they had died, left shells and other calcareous remains that in time accumulated in such quantities as to form beds of limestone. Thus, there were deposited various kinds of sediments which were afterward consolidated by pressure and cementation into rocks of various compositions and appearances. The sand became sandstone; the fine mud became shale (or clay); and the remains of animals, and perhaps of certain plants, became limestone. Coal was formed from accumulations of plant remains in swamps and lagoons, and fire clay probably from the old soil in which the plants grew. Under such conditions, it should be expected that the sandstone beds would grade into shale or clay, or even would be in the same stratigraphic position as limestone or coal. This is in fact true, though there are certain beds that are uniformly persistent over comparatively large areas and represent stages of deposition in which thousands of square miles of the sea bottom was covered by material of practically the same kind.

The total thickness of the sedimentary rocks, including both the exposed rocks and those which lie beneath the surface, varies greatly in different parts of the United States. Those of the Foxburg quadrangle are several thousand feet thick, so deep in fact that no drill has ever penetrated to the old granite floor below.

For convenience of description geologists have separated this column of rocks into several groups according to their age, and have designated these groups, and important beds contained in them, by names. Below is given a brief description of these beds so far as they have been recognized and named in the Foxburg quadrangle.

ROCKS NOT EXPOSED AT THE SURFACE.

All that is known of the rocks which are concealed below the surface of the Foxburg quadrangle has been secured from a study of these rocks in other areas where they are exposed, and from data obtained from deep wells drilled for oil and gas in the quadrangle. A number of these wells have penetrated more than 3,500 feet of rocks and some of them have probably gone through more than 2,500 feet of strata that are not exposed at the surface. Detailed records of only a few of these deep wells were secured, and the data furnished by them are too meager to furnish good descriptions of the lower beds. Only a tentative grouping of them can therefore be made. A general idea of the character of these rocks may be secured by an examination of Plates II, III, and IV, which show a number of detailed well logs platted to a scale of 400 feet to the inch and arranged with reference to the Third or Gordon sand as a datum plane.

DEVONIAN SYSTEM.

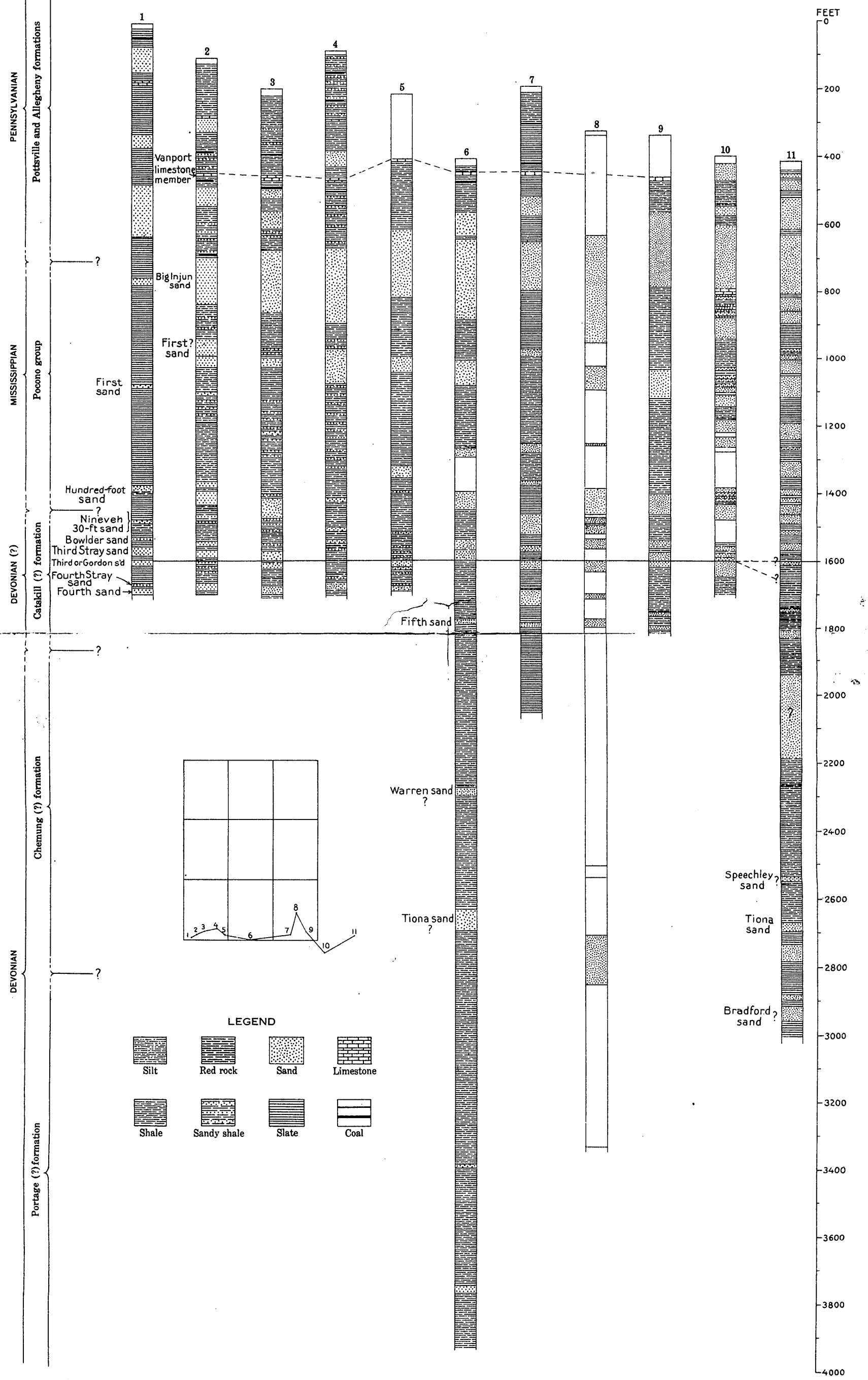
PORTAGE (?) FORMATION

The beds in western Pennsylvania which are assigned to the Portage formation by Butts[a] consist of about 1,000 feet of sandy shale and thin-bedded sandstone extending from the soft dark shale which is believed to represent the Hamilton formation upward to the top of the Bradford oil sand group of McKean County, Pa.

In the Foxburg quadrangle a number of deep wells have been drilled through a group of sands from 80 to about 200 feet thick, which are supposed to be equivalent to the Bradford oil sands, though this correlation is by no means positive. Of these deep wells only a few imperfect logs are now available. It is therefore evident that only the most general and tentative correlation can be made of the lowest rocks touched by the drill in these wells.

In the Bradys Bend well (No. 6 on Pl. II) no Bradford sand is recorded, but its horizon is probably about 350 feet below the top of

[a] Rept. Top. and Geol. Survey Comm., Pennsylvania, 1906–1908, p. 201.



SECTIONS OF DEEP WELLS IN THE FOXBURG QUADRANGLE, PENNSYLVANIA

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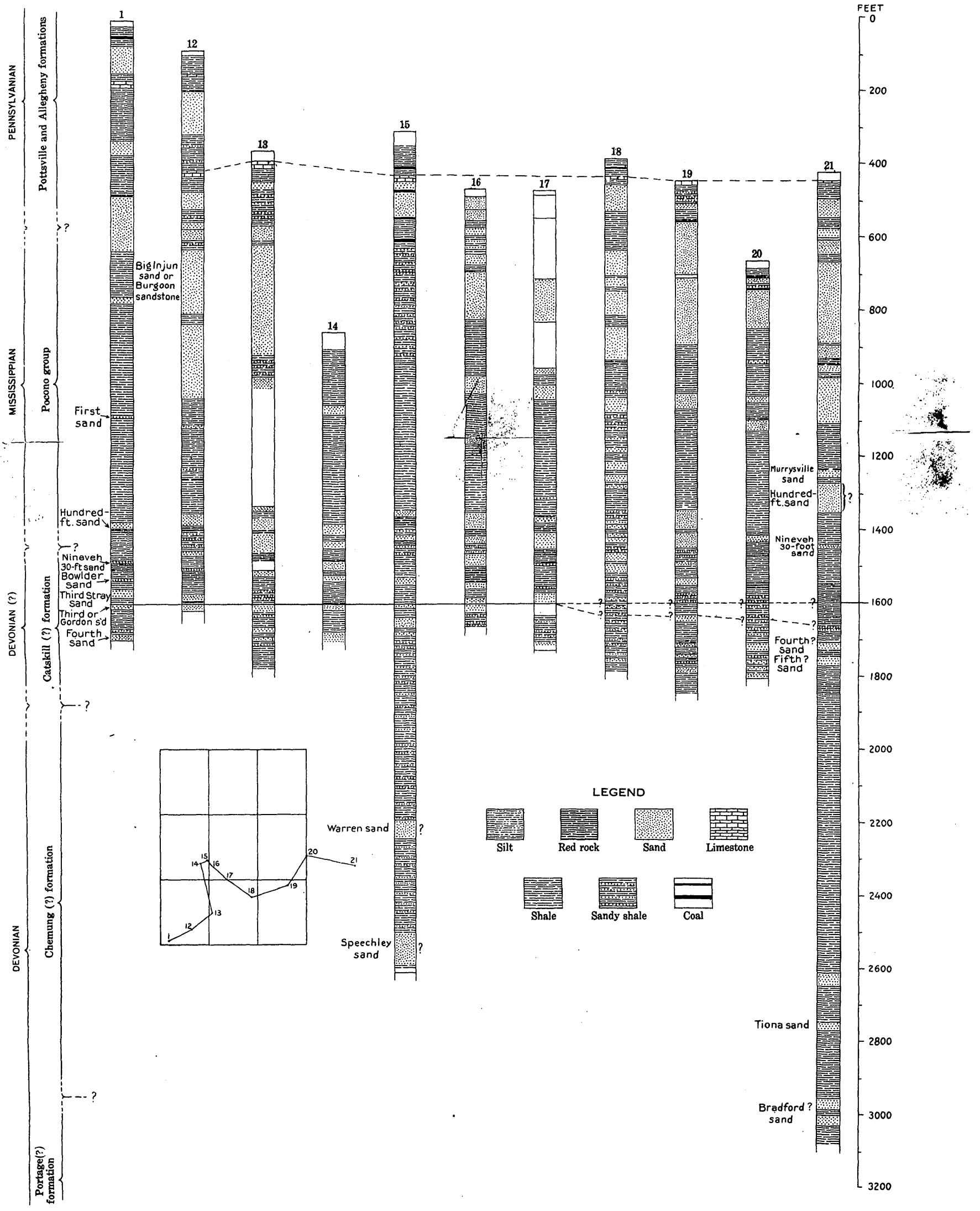
House Doc. 1425; 61st Cong., 3d Sess.



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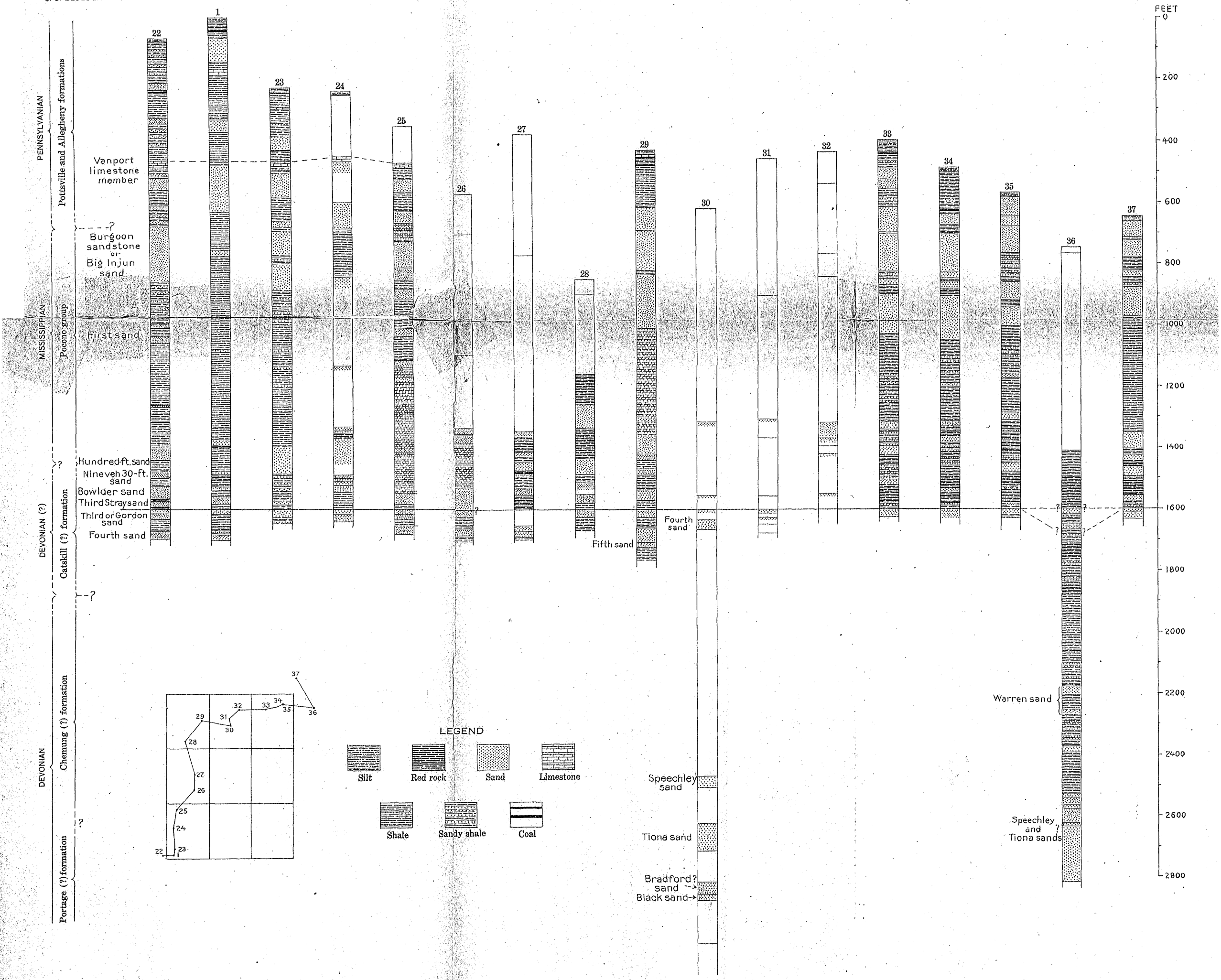

SECTIONS OF DEEP WELLS IN THE FOXBURG QUADRANGLE, PENNSYLVANIA

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House Doc. 1425; 61st Cong., 3d Sess.

the Speechley sand as given in that section. This well probably penetrated over 900 feet into the Portage (?) formation, but the record was too poorly kept to be of stratigraphic value. From 150 to 300 feet of strata at the top of the formation are reported in a few wells made up of sandy chocolate to grayish shale and sandstone interbedded with from one to three sandstones of what is supposed to be the Bradford oil sand group. Below these sands the drillers generally describe the rocks as "slate and shells," being equivalent to shale alternating with thin, hard, sandstone layers.

In the Foxburg quadrangle there are usually two oil sands in what is here called Bradford (?) oil sand group. The first or uppermost sand has a maximum thickness of about 50 feet, but is usually not more than 20 feet. It is grayish or chocolate colored, and is generally fine-grained and hard, in most cases making a poor reservoir for oil or gas. The second oil sand of this group is usually separated from the first by 20 to 80 feet of sandy grayish or chocolate-colored shale. It is from 10 to 150 feet in thickness and usually grayish in color, though in some wells 20 feet of black sand is reported at the base. The second Bradford (?) sand is usually fine-textured and hard, but in a few cases it carries soft porous "pay" streaks, which, in a few places, contain gas.

CHEMUNG (?) FORMATION.

Beds of doubtful age.—Overlying the Portage (?) formation and extending upward to the base of the Devonian (?) red beds (Catskill (?) formation) are greenish or chocolate-colored shale and thin sandstones having a total thickness of 900 to 1,100 feet in the region of the Foxburg quadrangle. Butts [a] considers these to belong to the Chemung formation, but the evidence on this point is not conclusive, and therefore the beds are not here definitely assigned to that formation.

In other reports [b] M. J. Munn has tentatively placed the top of the supposed Chemung at the base of the lowest red rock reported in well logs, about 800 feet below the Third or Gordon sand. In the light of recent stratigraphic and paleontologic studies of these beds by Butts, it seems very probable that the thin beds of red rock mentioned by drillers at from 500 to 800 feet below the Third sand are really the chocolate or "Pink rock" of the drillers farther to the north, which is shown to be Chemung. It therefore seems advisable to consider the top of this formation as being between 200 and 400 feet below the Third or Gordon sand in the Foxburg quadrangle.

Tiona sand.—The lowest well-defined oil and gas bearing sand of the Chemung (?) is known to drillers as the Tiona sand. In the Fox-

[a] Rept. Top. and Geol. Survey Comm. Pennsylvania, 1906–1908, p. 200.

[b] Geology of oil and gas fields of Sewickley quadrangle, Pennsylvania, and geology of oil and gas fields of Clarion quadrangle, Pennsylvania, to be published by Top. and Geol. Survey Commission of Pennsylvania.

burg quadrangle the top of this sand is from 180 to 200 feet above the so-called first Bradford sand. It ranges from a few inches to more than 100 feet in thickness, probably averaging not more than 30 feet. The sandstone is usually close-grained and hard, and hence of little value as a reservoir for oil or gas. In a few places within the quadrangle it is reported as carrying soft, porous, gas-bearing pay streaks, but the total yield of gas from this bed has been small. It does not seem to have produced oil in commercial quantities at any point in the quadrangle.

Speechley sand.—The top of this sand is from 100 to 150 feet above the Tiona sand. It ranges from a few inches to about 85 feet in thickness, and though a hard, close sandstone, it is in many places in the quadrangle sufficiently porous to afford storage room for large quantities of gas and some oil. It is usually found at depths ranging from 1,900 to 2,100 feet, the gas developing closed pressures of as much as 900 pounds per square inch.

Warren sand.—The upper half of the Chemung (?) in the Foxburg quadrangle is a mass of shale and thin layers of sandstone in which at certain places are found lenticular sandstones of considerable local thickness. The most prominent and persistent of these sandstones lies about 300 feet above the Speechley sand and is known to drillers as the Warren sand. This sand is reported in only a few wells, and in none of them is it known to have been productive. It probably varies from about 400 to 550 feet below the Third or Gordon sand and may in reality consist of sandstone lenses at slightly different horizons. No close correlation of this sand can be made, but it appears to be within 200 feet of the top of the Chemung, with chocolate or grayish shale and thin layers of sandstone above.

DEVONIAN (?) SYSTEM.

CATSKILL (?) FORMATION.

Shales and sandstones.—Upon the Chemung (?) formation lies 500 to 700 feet of red and green shales in which are interbedded white and gray and reddish sandstones. In some of the reports on areas to the south and east these shales have been included in what is here called Chemung, and in others they have been described as Catskill. To the north, in the Warren quadrangle, beds which overlie the Chemung, and which may be either Devonian or Carboniferous, are mapped as the Conewango formation (bottom) and the Knapp formation (top). The exact relations of these shales in the Foxburg quadrangle to the Catskill formation or to the Conewango formation have not been determined and in this report they will be called Catskill (?) formation. These beds include the lower part of the great oil and gas bearing group of sandstones known as the Venango oil sands, from which most of the oil of the Foxburg quadrangle has been obtained.

Correlation of oil sands.—Because of their great economic value, the correct correlation of the individual oil sands of this division over western Pennsylvania has often been attempted, and while these studies have in general settled the stratigraphic position of the more prominent sandstones, the work has not been done in sufficient detail to settle questions involving local variations. For the purpose of furnishing data which may be of value in such detailed stratigraphic work Plates II, III, and IV of well sections have been platted. A careful study of these sections will show the difficulty of tracing by well records alone a definite oil sand over any great area. It will be noticed that each of these beds not only varies greatly in thickness from well to well, but that in many places they disappear and are replaced by shale and in some places by red rock. In the Foxburg quadrangle none of these beds attain sufficient prominence or persistency to form a reliable datum plane, and in wells comparatively close together the variation is so great as to make any correlation questionable.

At Oil City, where the Venango oil sands were discovered and named, three distinct and clearly marked oil sands occur which were named by the operators the First, Second, and Third sands, in descending order. Later operations in that region developed a fourth sand of less extent and importance, overlying the original Third sand, which was called the Third Stray sand. In some portions of this field the First sand was also found to be made up of two sandstones separated by a few feet of shale.

Overlying the oil sands in the Oil City region are about 400 feet of soft shale, in which is embedded one or more thin beds of sandstone.

Below the Third sand in that region is soft shale for 200 or 300 feet, which in few places, if anywhere, contains sandstone of sufficient thickness to be recognized.

When drilling was begun in Butler and Armstrong counties, the same names were applied to sands found by the drillers which seemed to them to correspond to those found at Oil City, but unfortunately the sands do not correspond. The result was that what is known as the Venango First sand is equivalent to the Butler County Second sand or Hundred-foot, and the Third sand of Butler County seems to be more nearly comparable to the Second sand of Oil City and the Venango Third to the Butler Fourth sand. The exact correlation of the oil sands of these two fields is not to be solved as easily, however, as one might be led to infer from this statement. The chief difficulty to such a correlation lies in the fact that southeastward from Oil City the 300 to 380 feet of strata embracing the three Venango sands show a marked tendency to develop other fairly persistent sandstone lenses which, because of their close vertical range, similar lithologic character, and equal thickness, render continuous tracing of the beds from one section to the other by well logs extremely difficult.

Some idea of the uncertainty of such close correlations may be secured by a minute comparison of the sections shown on Plates II, III, and IV. If it be remembered that the factor of error in measurement must be considered, always, in making comparisons of these logs, the extreme difficulty of correlating positively the Third sand of one section with that of another even for only a few miles distant can readily be understood. In such close correlations of the lower portion of the Venango oil-sand group it must be remembered that oil developments did not as a rule expand from a single well, but that there were in reality several foci of growth, which in many cases developed marked variations in the number of sands found, in the intervals separating them, in the position and thickness of guiding beds of red rock, and in distance from the surface bed from which the distance to the oil sands was calculated. Considering these elements of uncertainty and the fact that more than a third of a century has elapsed since the large fields of the Foxburg quadrangle were first developed and that nearly all of the data then obtained have since been scattered and lost, the correlations suggested on Plates VI, VII, and VIII can be considered only tentative ones.

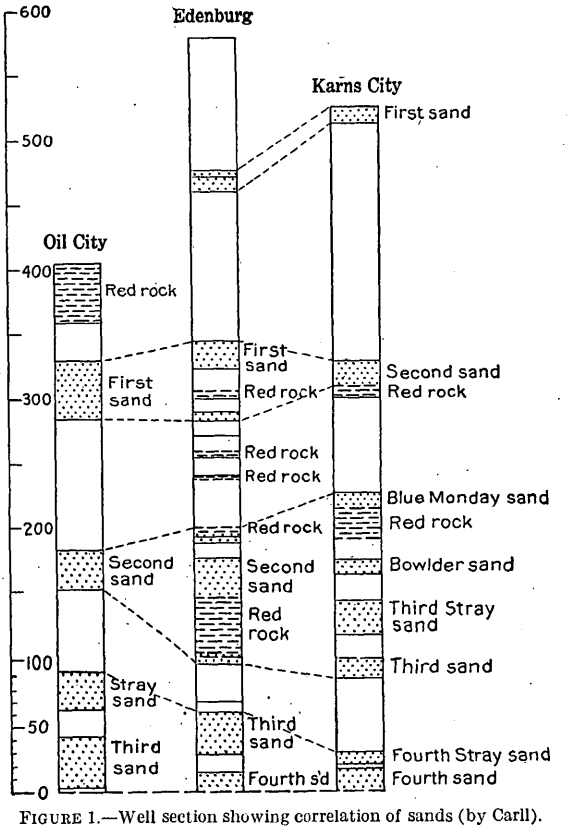
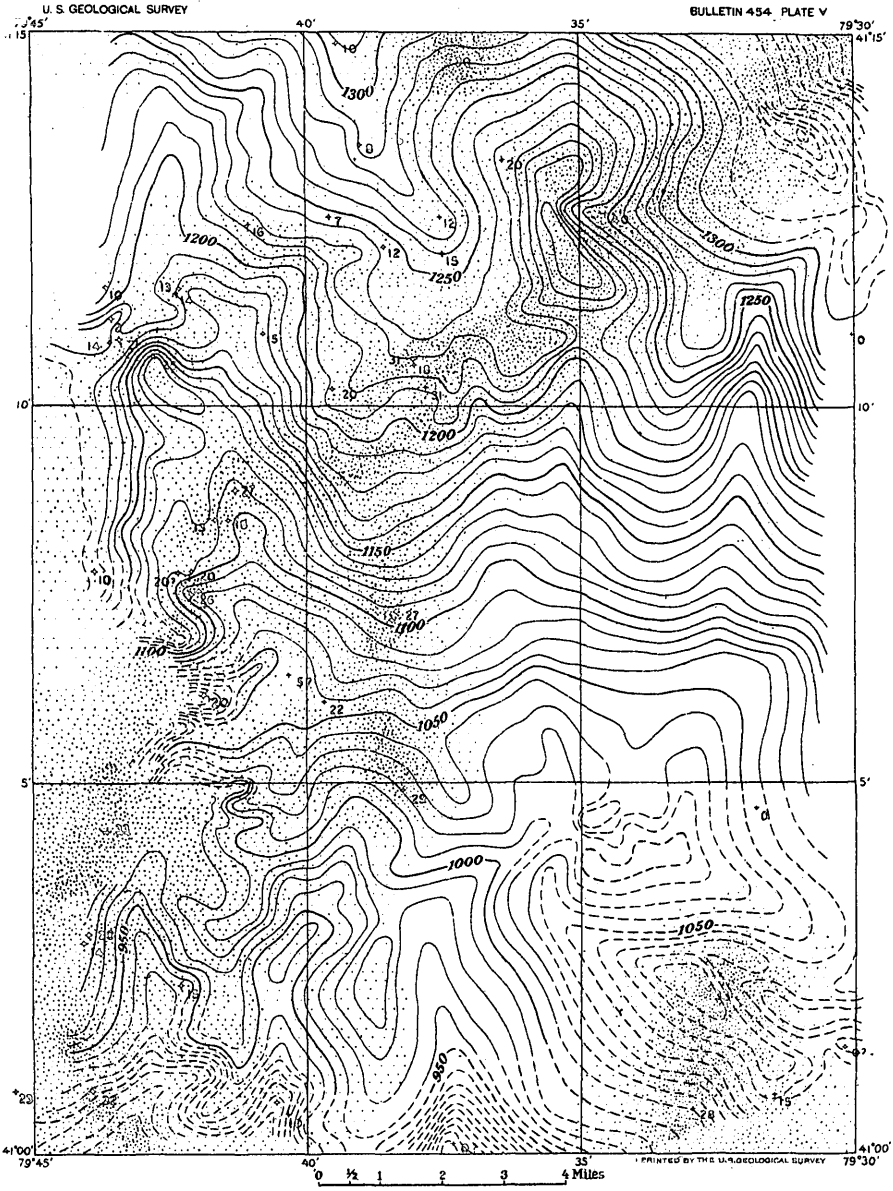


FIGURE 1.—Well section showing correlation of sands (by Carll).

Considerable attention was given by Carll[a] to a correlation of the oil-bearing sands of western Pennsylvania. In 1880 he traced the oil sands in a line of wells from Oil City to Edenburg in the Foxburg quadrangle, and thence southwest to Karns City near the southwest corner of that quadrangle. The records of a number of wells were used in this work and several typical sections were drawn to scale

[a] Second Geol. Survey Pennsylvania, vols. I, II, III, I4, I5, H5.



SKETCH MAP SHOWING THICKNESS, EXTENT, AND STRUCTURE OF THE THIRD OR GORDON SAND IN THE FOXBURG QUADRANGLE, PENNSYLVANIA

32

Pattern showing variation in thickness of Third or Gordon sand

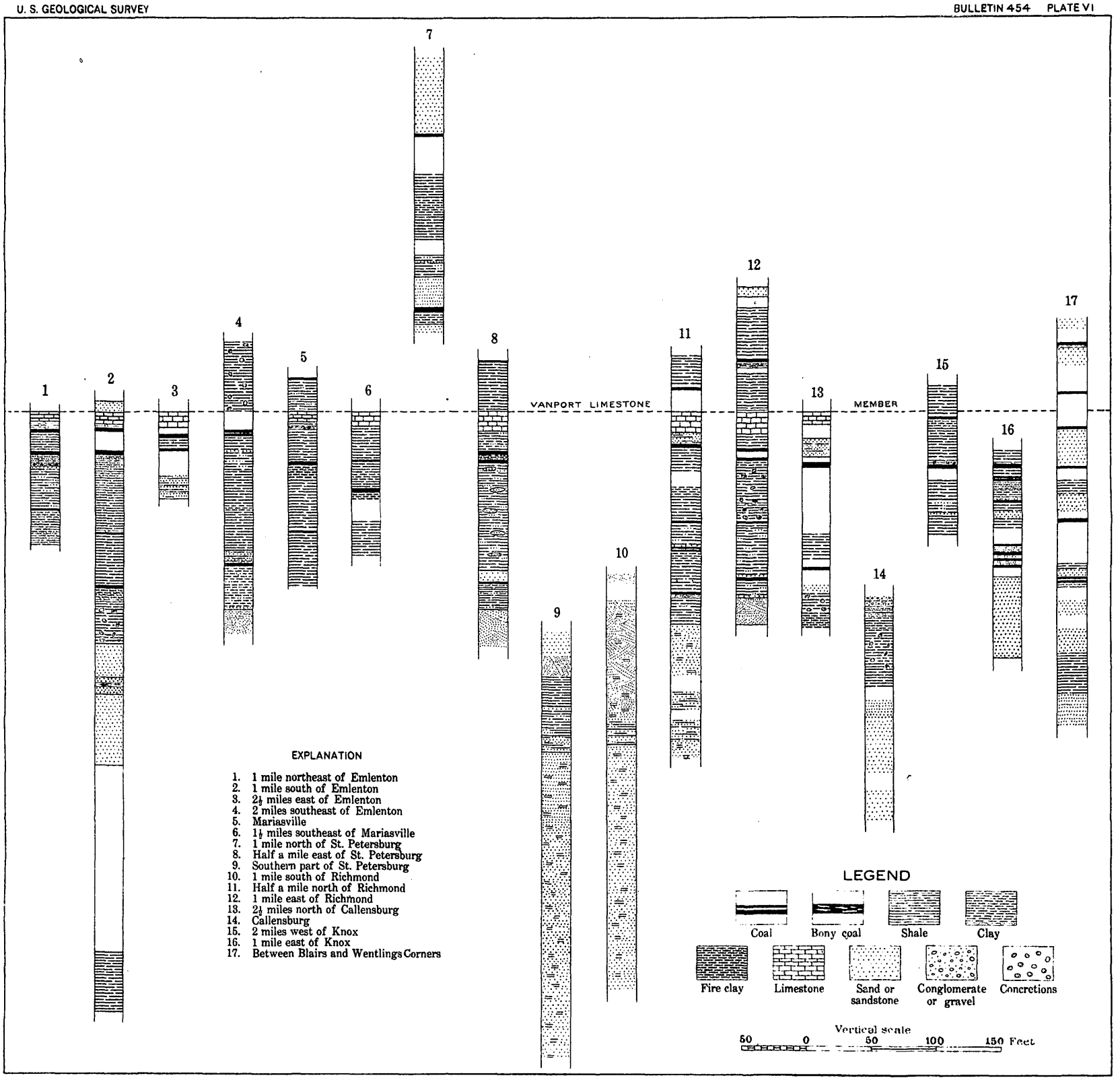
Greater or less thickness is shown by difference in density of dotted pattern: The more dots the greater the thickness. In undotted areas the sand is absent or has not been recognized. Numbers show thickness of sand in feet at points indicated by crosses

1000

Structure contours on top of Third or Gordon sand

Contour interval 10 feet, datum plane 1000 feet below sea level

House Doc. 1425; 61st Cong., 3d Sess.



MEASURED SECTIONS OF ROCKS EXPOSED IN THE NORTHERN PART OF THE FOXBURG QUADRANGLE, PENNSYLVANIA

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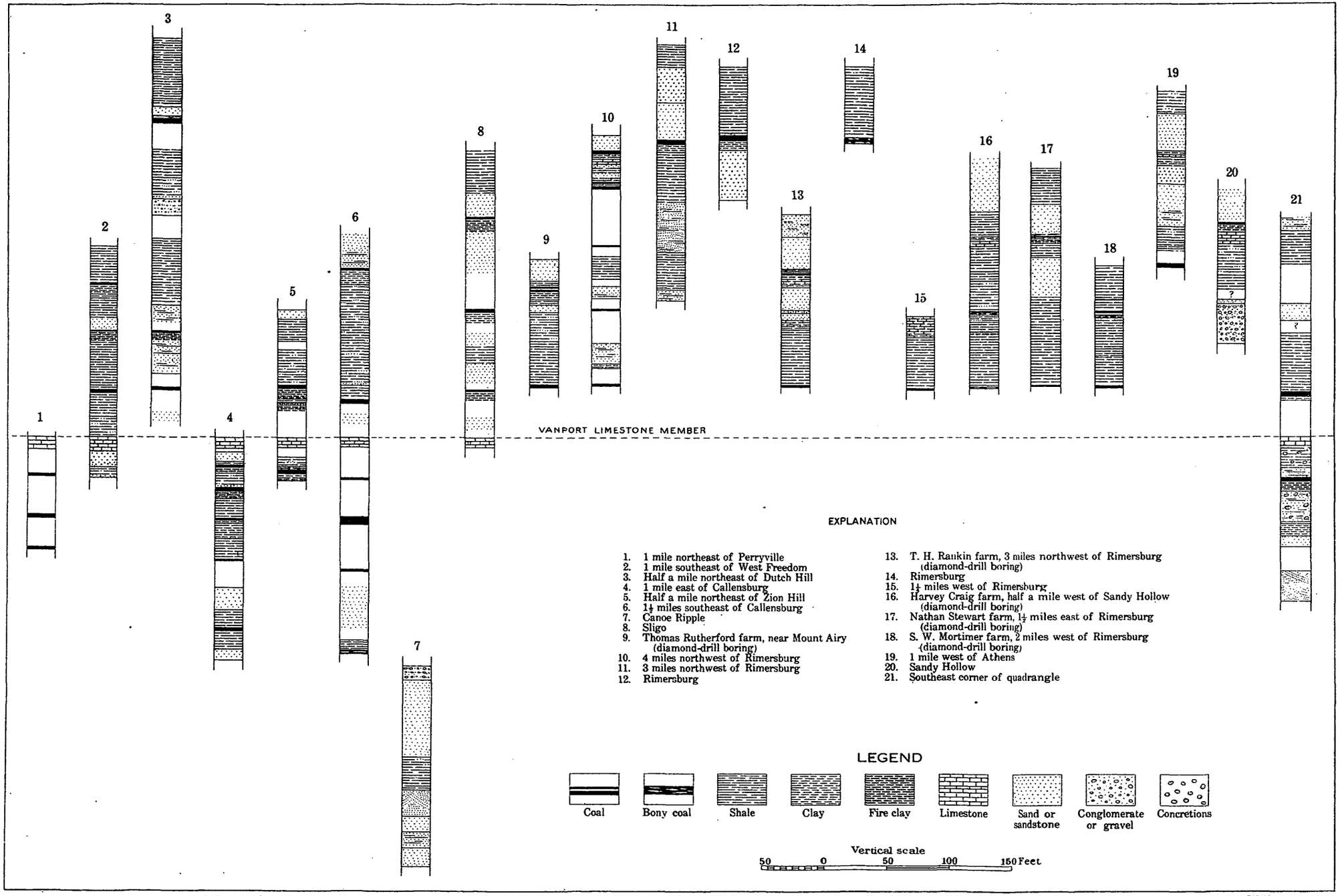

MEASURED SECTIONS OF ROCKS EXPOSED IN THE AREA LYING EAST OF THE ALLEGHENY RIVER AND SOUTH OF THE CLARION RIVER

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House Doc. 1425; 61st Cong., 3d Sess.

EXPLANATION

1. Cuyahoga shale in bank of river at Dotter station
2. "Brick road" across the river from Emlenton
3. 1 mile west of Emlenton
4. 2 miles southwest of Emlenton
5. 1 mile west of Foxburg
6. 2 miles south of Foxburg
7. Parkers Landing
8. Half a mile west of Parkers Landing
9. 1¼ miles north of the Stonehouse
10. 1 mile south of Parkers Landing
11. 1¼ miles south of Bonus
12. 1½ miles northeast of Glenora
13. Half a mile south of Parkers Landing
14. Half a mile west of Parkers Landing
15. Half a mile north of Monterey
16. Half a mile west of Monterey
17. 1 mile west of Monterey
18. Stonehouse
19. Fairview
20. Petrolia
21. 1 mile northeast of Petrolia

VANPORT LIMESTONE MEMBER

LEGEND

Coal | Bony coal | Shale | Clay | Fire clay | Limestone | Sand or sandstone | Conglomerate or gravel | Concretions

Vertical scale
50 0 50 100 150 Feet

MEASURED SECTIONS OF ROCKS EXPOSED IN THE AREA LYING WEST OF THE ALLEGHENY RIVER

PRINTED BY THE U.S.GEOLOGICAL SURVEY

House Doc. 1425; 61st Cong., 3d Sess.

and published.[a] Of these he selected the following three sections as indicative of the change in the stratigraphy and nomenclature of the Venango oil-sand group from Oil City southeastward. In the main this work by Carll is considered to be correct, as shown by the following figure reproduced in a slightly different form from his report.

It will be seen from these figures that the First sand at Oil City is considered by Carll to be equivalent to the First sand of the drillers at Edenburg and their Second sand at Karns City. Also the Second sand of Oil City is equivalent to three sands including the drillers Second sand of Edenburg, and their Blue Monday, Bowlder, Third Stray, and Third of Karns City. In like manner he considers the Third Stray of Venango County equivalent to the Third of the drillers at Edenburg and the Fourth Stray of Karns City, the Third sand of Oil City being equivalent to the Butler Fourth sand at Karns City.

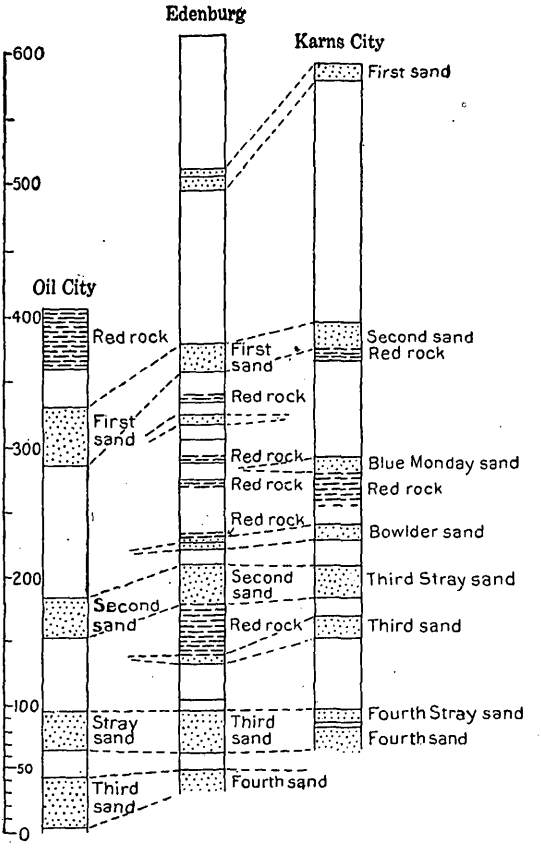


FIGURE 2.—Well section showing possible correlation of the sands in the same wells as shown in figure 1.

From a study of the well sections shown on Plates II, III, and IV the writer believes that the correlation of the sands of the sections in figure 1 by Carll is more nearly correct as shown in figure 2, in which it will be seen that the Venango First sand of Oil City is equivalent to the Butler Second sand at Karns City; the Venango Second sand is equivalent to what in this particular well is termed the Third Stray sand at Karns City, and the Venango Third Stray sand is the Butler Fourth Stray and Fourth combined at Karns City. This correlation therefore makes the original Venango Third sand equivalent to the Fourth sand at Edenburg, and to the Butler Fifth sand, not

[a] Carll, Second Geol. Survey Pennsylvania, vol. III, p. 178.

shown in these sections. The third section of the above figures is the McClyman farm well, near Karns City, the complete section of which is shown as No. 1 of Plates II, III, and IV, and from a comparison of the sections in those plates a wider correlation with Venango oil sands may be made.

At Petrolia this group of sands has a minimum thickness of about 300 feet and is composed in ascending order of the Butler Fourth, Fourth Stray, Third, Third Stray or Gordon Stray, Bowlder, Nineveh, Thirty-foot, Fifty-foot, and Second sands, the First sand of this vicinity being regarded as equivalent to the Sharpsville sandstone member of the Cuyahoga formation and as lying about 185 feet above the top of the true Venango oil-sand group. It should therefore be grouped with distinctly younger beds. Farther to the east the Fifth sand comes in as a lenticular sandstone, underlying the Fourth at a distance of from 40 to more than 100 feet.

Butler Fifth sand.—In the Foxburg quadrangle the Fifth sand in few places reaches a thickness of more than 30 feet. It is generally a fine-grained white to grayish sandstone, hard, but in places containing thin streaks of softer, porous, somewhat pebbly sand, carrying more or less gas. It seems to be absent over the northwestern half of the quadrangle and in general is found to be thickest and most persistent in the southeastern part.

On Plate II the Fifth sand is called the Fourth sand in section 6, the true Butler Fourth sand being absent. From this point eastward the sand is noted in the four wells drilled to that horizon. In section 11 the Fifth sand is probably equivalent to what is called the Fourth sand by the driller. The enormous sandstone designated by the driller as "limy sand" is such an uncommon thickness of sandstone at this horizon that its presence is to be taken with due allowance for error which might have been made by the driller in classifying the rock. Numerous well-kept records in the immediate vicinity of this well report only a normal thickness of 10 to 30 feet of Fifth sand, the underlying beds being designated as "slate and shells." The rocks occupying this interval, whatever they may be, are near the top of the Chemung.

Butler Fourth sand.—The Fourth sand overlies the Fifth from 40 to over 100 feet, the interval being filled by soft shale. This is prevailingly green with thin red streaks in the vicinity of Petrolia, but eastward the red rock increases in thickness until in places it occupies the whole interval between the sands. The Fourth sand ranges from less than 10 feet to more than 50 feet in thickness. It is usually white, with soft, porous pay streaks from which enormous quantities of oil have been secured at many places in the quadrangle. Toward the north and northeast the identity of the Fourth sand is not always clear, as may be seen from an examination of the well-section plates.

In many places where the Third Stray sand is wanting the Fourth has possibly been mistaken by drillers for the Third and vice versa.

Butler Third or Gordon and the Butler Third Stray or Gordon Stray sands.—These two sands taken together are fairly persistent beds throughout this quadrangle, but much difficulty is experienced in positively identifying and tracing them by means of well records. This is due in many cases to local variations in thickness of the sands, to their varying distance from the Vanport limestone member, and other marking strata, and to the variation in position and thickness of the beds of red rock. In general these sands have a combined thickness of a few inches to 75 feet. (See Pl. V.) They are absent over much of the eastern part of the quadrangle, in Licking, Perry, Toby, southern Beaver, and parts of Madison townships, Clarion County, and along the southern border of Perry Township, Armstrong County. In many places in this area these sands are represented only by thin beds of hard sandstone embedded in soft green or red shales, and in such places they have been found to contain little or no oil or gas. The thickness and extent of this sand is shown on Plate X (in pocket).

The Third and Third Stray sands are well developed along a broad belt from Petrolia to Elk City and throughout most of the northwest half of the quadrangle. In this region the bottom of the Third sand is from 40 to 80 feet above the Fourth sand, the interval being usually occupied by dark green and red shales and some red rock. Toward the southeast this distance increases to about 120 feet, and in many places it is occupied mostly by red shale. The Third and Third Stray sands are usually soft, white, pebbly, and loosely cemented, and offer fine reservoirs for the enormous quantities of oil and gas which have been found in them.

Bowlder sand, Snee or Blue Monday sand, and Nineveh Thirty-foot sand.—Throughout the quadrangle and to the southwest these names are used interchangeably to designate from one to three thin sands overlying the Third Stray. In fact the name Bowlder is often applied to the Third Stray itself. Perhaps the widest usage is to designate in ascending order the first three sands above the Third Stray, when all are present, as the Bowlder, Snee or Blue Monday, and Nineveh Thirty-foot sands. Where they occur within 150 feet of the top of the Third Stray sand, the names are probably correctly applied, but if the interval is much greater than 150 feet the uppermost of the three sands is more likely to be equivalent to the lower member of the Hundred-foot (Butler Second or Venango First) sand. Each of these three sands seldom exceeds 25 feet in thickness, but all are subject to rapid local thickening to 60 or 80 feet. They are white or gray, in many places soft and pebbly, and are both oil and gas bearing. The Thirty-foot sand is considered by Butts[a] to be the

[a] Rept. Top. and Geol. Survey Comm., Pennsylvania, 1906–1908, p. 1999.

uppermost sandstone of the Knapp formation, the boundary being fixed by him at or near the base of the Hundred-foot sand, the former including the red shale interval between the Hundred-foot and the Nineveh Thirty-foot sands.

CARBONIFEROUS SYSTEM.

POCONO GROUP (LOWER PART).

The Pocono group overlies the Catskill formation, and includes from 700 to 900 feet of sandstone and shale from the base of the Hundred-foot sand to an unconformity at the top of the Burgoon sandstone (Big Injun or Mountain sand of the drillers).

The basal member of the Pocono group is one of the great sandstones of the Appalachian province, for it underlies thousands of square miles in Ohio, Pennsylvania, and West Virginia. Recent studies by Butts [a] seem to show that the Butler County Second sand is equivalent to the Venango First oil sand and the Berea sandstone of northern Ohio. In the Foxburg quadrangle the Butler Second apparently divides into the Hundred-foot sand below and the Murrysville or Butler gas sand above. The Hundred-foot sand is divided into the Gantz and Fifty-foot sands in southern Allegheny and Washington counties. Westward into Ohio in the vicinity of Beaver and to the southwest, the Murrysville or Butler gas sand apparently is the same as the Berea oil sand, and if so, is equivalent to the upper portion of the true Berea sandstone of northern Ohio. However, this point is not definitely settled, and it is possible that further studies will show that the Berea oil sand of southeastern Ohio and Pennsylvania is really equivalent to the Butler First, which is the first persistent sand overlying the Murrysville gas sand.

In the Foxburg quadrangle the Hundred-foot sand is in places separated into as many as five different sandstones, embedded in soft shale, some of which is red. The topmost member of this group, which is frequently called the First sand, lies from about 200 to 350 feet above the top of the Butler Third sand, this variation occurring between Petrolia and the eastern border of the quadrangle. (See Pl. II.) The sands are gray, white, and sometimes dark in color. They are usually hard and close, but in many places carry lenses of soft, pebbly sand containing oil, gas, and salt water.

In the Foxburg quadrangle from 400 to 500 feet of soft gray, green, and infrequently red shales overlie a sand commonly known to drillers of this locality as the First or Venango First sand. This shale is generally recognized by drillers because it affords a zone of easy drilling between the Burgoon sandstone above and the Venango oil sands below. The upper 20 feet of this shale outcrops in the bottom of the Allegheny gorge and has been correlated, both from lithology and

[a] Rept. Top. and Geol. Survey Comm. Pennsylvania, 1906–1908, p. 195.

from contained fossils, with the Meadville shale member of the Cuyahoga formation. Embedded in this shale are one or more persistent beds of sandstone. The most important of these is generally from 10 to 40 feet and locally 100 feet or more in thickness, and divides the shale into two fairly equal divisions. In the lower shale division occurs another sandstone in the Foxburg quadrangle, which is probably equivalent to the Butler First sand. This sandstone apparently pinches out northwest but increases in thickness and stratigraphic importance east, south, and southwest. Some oil and gas have been found in both these sands in the Foxburg quadrangle, but the total quantity was relatively small. Above this sandstone the shale is darker and more reddish, thin beds of "red rock" being frequently reported.

Above this shale is the Burgoon sandstone, a great mass of sandstone known to drillers as the Mountain or Big Injun sand. All of these overlying rocks outcrop at the surface within the Foxburg quadrangle, and are therefore discussed below under "Outcropping Rocks."

OUTCROPPING ROCKS.

CARBONIFEROUS SYSTEM.

With the exception of the unconsolidated Quaternary stream deposits the rocks which outcrop in the Foxburg quadrangle belong to the Mississippian and Pennsylvanian series of the Carboniferous system. They are classified as follows:

Carboniferous system.
- Pennsylvanian series.
  - Conemaugh formation.
    - Mahoning sandstone and overlying shale.
  - Allegheny formation.
  - Pottsville formation.
    - Homewood sandstone member.
    - Mercer shale member.
    - Connoquenessing sandstone member.
- Mississippian series.
  - Pocono group.
    - Burgoon sandstone.
    - Cuyahoga formation.
      - Meadville shale member.

The rocks will be described in order of deposition.

MISSISSIPPIAN SERIES.

POCONO GROUP.

CUYAHOGA FORMATION.

The outcrop of the Cuyahoga formation occupies a limited area in the bottom of the Allegheny gorge between Emlenton and Wood Hill. The best exposure is in a cliff on the west side of the river 1 mile north

of Dotter Station, or 5 miles north of Emlenton. At this point about 20 feet of dark-gray sandy shale are laid bare and in the uppermost foot or so there are more or less numerous pebbles. The layer bearing these pebbles is considered as marking the top of the formation. A mile farther north the top of the formation lies about 37 feet above low water, but at this point most of the section is concealed.

In the northwestern part of Pennsylvania there are many good exposures of the Cuyahoga, and it has been divided into three members: The lower one has been called the Orangeville shale; the middle one has been called the Sharpsville sandstone; and the upper member is known as the Meadville shale. The part of the Cuyahoga which outcrops in the area under discussion belongs to the uppermost or Meadville shale member.

BURGOON SANDSTONE.

The Burgoon sandstone, named from Burgoon Creek, in Cambria County, Pa., is irregular in most characters, but consists principally of sandstone, though it also includes considerable amounts of shale. Where exposed in the Foxburg quadrangle this sandstone, which is known to the drillers as the Mountain or Big Injun, sand is not evenly bedded, though layers 4 to 6 inches thick are common. On weathering the shale crumbles and is washed away, leaving slabs of sandstone, which make the outcrop appear like ruins of old masonry. The sandstone is generally coarse and not very pure. In some places, as near Foxburg, it displays considerable cross-bedding. Lenses of shale of all sizes ranging up to 60 feet or more in thickness are included, and in the lower part of the formation this rock predominates. The shale is light-gray or greenish, soft, and more or less clayey.

The formation outcrops along the gorges of the rivers and in many of the tributary valleys. It is almost devoid of fossils. In some places there is a layer of carbonaceous shale, or even thin coal, near the top, which contains plant remains. The entire formation is exposed, and the thickness is 300 to 320 feet. The lower limit is believed to lie at the top of the peculiar conglomerate previously mentioned as forming the uppermost layer of the Cuyahoga formation. The upper limit of the Burgoon is not marked by any stratum which is everywhere recognizable. Several factors are commonly employed in locating the boundaries between it and succeeding formations. The coaly layer previously referred to is, when present, about 15 feet below the top of the Burgoon. A somewhat similar coaly bed lying at many places between beds of heavy resistant sandstone is found about 40 feet above the boundary. The horizon of the Brookville coal is about 130 feet and that of the Vanport limestone member, to be described later, about 240 feet above the top of the Burgoon.

The indistinctness of this upper limit of the Mississippian is remarkable when we consider that there is good evidence of a great uncon-

formity at this horizon. Probably hundreds of feet of Mississippian strata were eroded from this region before the deposition of the Pennsylvanian, but that erosion left such a smooth surface and the succeeding strata were so much like those below, that in few places, if anywhere, can the unconformity be located with exactness. For example, along the "brick road" opposite Emlenton is a very good exposure of the Mississippian and the Pennsylvanian strata adjacent to the unconformity, but there is no pronounced break discernible. There are many minor breaks, and it is probable that one of these is the unconformity. One break in particular lies at the top of an irregular layer of sandstone which has certain vertical markings, suggesting that cracks had formed after the sand had consolidated and before the succeeding strata were laid down upon it. These cracks apparently filled with sand when the layer above was deposited, but the data are not considered decisive.

MAUCH CHUNK FORMATION.

The uppermost Mississippian formation, the Mauch Chunk, is not present in this quadrangle. It is thought that it was deposited and eroded in the period of time represented by the Mississippian-Pennsylvanian unconformity. At Mauch Chunk the formation is 2,200 feet thick, but it thins to the west to 180 feet at the Allegheny Front and to 250 feet in the southwestern part of Pennsylvania. This thinning is probably due in part to erosion.

PENNSYLVANIAN SERIES.

POTTSVILLE FORMATION.

Definition.—Although the Mauch Chunk formation has been eroded from this area, and the Pottsville rocks lie unconformably on the Burgoon sandstone, the line of separation is not lithologically clear, and fossils are very scarce. In many places thick-bedded sandstones are found both at the top of the Burgoon and at the bottom of the Pottsville. Such sandstones are very similar, both in megascopic and microscopic characters. The grains of sand are of approximately the same size and equal degree of rounding. The only visible difference is that the sandstone of the Pottsville formation is, as a whole, somewhat thicker-bedded, slightly coarser, and approaches more closely to pure silica.

The upper limit of the Pottsville, like the lower, is difficult to determine in the field. Its approximate position can be located without difficulty, for it is above the sandstone just mentioned and below the Brookville coal; but difficulties arise from the fact that just between the sandstone and the coal there is generally a variable thickness of shale and also from the fact that the coal is absent throughout considerable areas. However, the coal bed holds a fairly uniform

position with reference to other recognizable strata, so that its horizon can be located when it is absent. In the Foxburg quadrangle the upper boundary of the Pottsville is drawn at the base of the clay underlying the Brookville coal and known as the Brookville clay.

The Pottsville formation is found along the gorges of the rivers just above the Burgoon sandstone, and extends a mile or two farther up the tributary streams. On Mill, Beaver, Canoe, Licking, and Bear creeks, and on Turkey and Cherry runs its upper limit varies from 4 to 7 miles from the main stream. At the north boundary the Pottsville is 470 feet above the river and at the south boundary it is only 175 feet. Along the Clarion gorge it extends from 260 to 350 feet above the stream.

Connoquenessing sandstone member.—The Connoquenessing sandstone, the lowest member of the Pottsville formation in this region, is a thick-bedded, resistant, saccharoidal sandstone which varies in color from buff to white and is nonfossiliferous. Some layers are not well consolidated, and appear much like granulated sugar. On the whole, the rock is very pure and free from everything but silica. On account of these characters it is extensively quarried for glass sand and silica brick. The beds are more or less lenticular, but one at the top of the member can be traced over a considerable area in the northwest part of the quadrangle. This is a very resistant layer 3 to 6 feet thick, and is overlain by a shaly coal 4 inches to 2 feet 6 inches thick. The thickness of the Connoquenessing sandstone ranges from 30 to 50 feet.

Mercer shale member.—In the midst of the Pottsville formation there is a series of shales, thin coals, and clays which have received the name Mercer, because in Mercer County the member is a prominent part of the section and one of the coal beds is worked. The coal is locally workable elsewhere, and in some places the member contains a valuable bed of refractory clay. In this quadrangle the coal is not workable, and the clay seems to be of little value. The coal, however, is usually present in one or more beds, which vary from an inch or less to 16 inches in thickness.

The thickness of the Mercer shale member varies from 6 inches to 40 feet or more. In the northwest part of the Foxburg quadrangle the member seems to be represented by only 6 inches to 2 feet of coaly shale. Fossils of the Mercer member consist almost entirely of plant remains, and are comparatively abundant. They are very distinctive.

Homewood sandstone member.—The Homewood sandstone, the topmost member of the Pottsville, is a coarse-grained, massive sandstone, averaging about 40 feet in thickness. In some places, however, the member is represented by shale. This seems to be the condition

near Parker. In the Foxburg quadrangle the Homewood is generally a clean white, finely cross-bedded, and loosely cemented sandstone. In the more or less weathered outcrops the member is very white and porous and the cross-bedding is a prominent feature, the rock resembling a thin-bedded sandstone tilted to a high angle.

ALLEGHENY FORMATION.

Character and thickness.—The Allegheny formation is composed of shale and sandstone, interbedded with coal, clay, and limestone. Economically it is by far the most important formation of those which outcrop in the area. In earlier reports on this area it was called the "Lower Productive Coal Measures," but it is now called the Allegheny formation, from the river along which it is typically developed. Coarse sandstone is much less prominent than in the Pottsville and Burgoon formations, and in some localities no heavy beds of sandstone occur. The shales are predominantly brownish, owing to a large content of iron oxide, but olive tints are conspicuous in the central and upper part.

The thickness of the Allegheny is from 345 to 370 feet, and it extends from the top of the Pottsville to the top of the Upper Freeport coal. The formation is much more uniform in thickness than would be indicated by the variations of the members. In a general way, there is a slight thickening to the northwest. The outcrop occupies a far larger area than that of any other formation in the quadrangle.

It is not possible to make a tabular section of the Allegheny formation which will apply over the whole area, because the succession of strata varies considerably. On a basis of lithologic character the Allegheny formation in the Foxburg quadrangle is naturally divisible into three parts. The boundary between the northeastern and the central parts runs from about 1 mile south of the point where Clarion River enters the quadrangle through a point about midway between Turkey City and Monroe to 1 mile southwest of Lamartine, and thence slightly east of north to the boundary of the quadrangle. Between the central and the southern segments the line runs through Huey, 1 mile south of Toby, 1 mile north of West Monterey, and thence through Bruin to the western boundary of the quadrangle. The following are generalized sections of the Allegheny formation in these divisions:

Generalized section of Allegheny formation in northeastern segment of Foxburg quadrangle.

Kind of rock.	Range.	Average.
	Feet.	*Feet.*
Shale, light gray, sandy	35	35
Coal, Lower Freeport	0– 3	2
Clay, Lower Freeport	4– 6	5
Sandstone, buff, and shale, sandy	50	50
Coal, Upper Kittanning	0– 3	2
Clay	0– 6	4
Shale, olive, with lenses of sandy shale and sandstone	35	35
Coal	1½	1
Shale, dark gray, with lenses of sandstone	30	30
Coal	0– ¾	½
Shale, brownish gray, and thin buff sandstone	30	30
Coal, Lower Kittanning	2– 3	2½
Clay, Lower Kittanning	4–10	7
Shale, brownish, and sandstone, pinkish	20	20
Coal	0– 2	1
Clay and iron ore	0– 6	4
Sandstone and sandy shale	20	20
Coal, Upper Clarion	0–13	2
Shale	4–15	8
Coal, Lower Clarion	2– 4	3
Clay, Lower Clarion	3–12	8
Shale, with thick layers of coarse sandstone	30	30
Coal, Craigsville	0– 1½	1
Shale, and sandstone, shaly	32	32
Coal, Brookville, with thick partings of sandstone, brown shale, and cannel shale	6–18	12
Clay, sandy, Brookville	8–15	12
		357

Generalized section of Allegheny formation in central segment of Foxburg quadrangle.

Kind of rock.	Range.	Average.
	Feet.	*Feet.*
Coal, Upper Freeport	3½– 5½	4
Clay, Upper Freeport	4 –10	7
Limestone, Upper Freeport, and iron ore	0 – 8	4
Sandstone, coarse to fine, and shale	35 –45	40
Coal, Lower Freeport, with shale parting of 2 feet	3 – 7	5
Clay, Lower Freeport	0 – 6	3
Sandstone, coarse, with lenses of shale in lower part	35 –60	45
Coal, Upper Kittanning	0 – 3	2
Clay	0 –10	3
Shale, light to dark gray, and sandy shale	40 –60	55
Coal, Middle Kittanning	10 –18	1
Clay	0 – 6	2
Shale, sandy, and sandstone, thin	30 –45	40
Coal, Lower Kittanning	0 – 2	1
Shale and sandstone, thin	20 –45	35
Limestone, Vanport, and ore	0 –20	9
Shale, with concretionary iron ore	2 –30	12
Coal, Upper Clarion	1 – 3	2
Shale, hard gray to black	7 –20	12
Coal, Lower Clarion	2 – 6	4
Clay, Lower Clarion	2 –10	7
Sandstone, thick coarse, and shale, brown	25 –35	30
Coal, Craigsville	0 – 3	1
Clay	½– 2	1
Shale	20 –35	35
Coal, Brookville	0 – 2	1
Clay, Brookville, sandy clay and clay shale	6 –12	8
		369

Generalized section of Allegheny formation in southern segment of Foxburg quadrangle.

Kind of rock.	Range.	Average.
	Feet.	*Feet.*
Coal, Upper Freeport	0– 5½	3
Clay, Upper Freeport	3– 8	5
Limestone, Upper Freeport, and ore	0– 6	4
Sandstone, thin, and shale, gray	30–45	35
Coal, Lower Freeport	0– 4	2
Clay, Lower Freeport	0– 6	2½
Sandstone, coarse, ranging to fine gray conglomerate, with a little shale	30–60	40
Coal, Upper Kittanning	0– 8	2
Clay, Upper Kittanning	0– 5	2
Sandstone, sandy shale, and shale	35–50	40
Coal, Middle Kittanning	0– 2	1
Clay, Middle Kittanning	0– 6	3
Shale, olive, and sandstone, thin-bedded gray	20–40	30
Coal, with shale partings	0– 2	½
Shale, sandy	35–60	45
Coal, Lower Kittanning	2– 4	3
Shale, and sandstone, thin	25–45	30
Limestone, Vanport, and ore	0–18	9
Shale	20–40	30
Coal, Clarion	1– 5	3
Clay, Clarion	3– 8	5
Sandstone, coarse	0–15	6
Shale, with thin layers of sandstone	15–25	20
Coal, Craigsville	0– 2	1
Shale	20–30	25
Coal, Brookville	0– 2	1
Clay, Brookville	3–12	7
		355

The economic value of certain beds of the Allegheny formation warrants a detailed description of the various members.

Brookville coal.—Lying above the Pottsville formation, and separated from it by a few feet of clay, clay shale, or argillaceous sandstone, is the Brookville coal. This bed is generally too thin to be workable, but locally it reaches a thickness of 2 feet or more. In places it is so free from sulphur that it has been used as a blacksmith coal. There is usually a peculiar argillaceous sandstone below or within the coal bed. Generally the underclay is very sandy and contains impressions of plant roots. Near Blairs Corners small lenses of argillaceous sandstone and partings of shale in and near the coal are especially abundant. The shale varies from cannel coal to a rock that is scarcely, if at all, carbonaceous. Four of these partings persist and thicken to the north, so that at the road exposure 1 mile east of Knox it seems to be 18 feet from the top to the bottom of the Brookville coal.

Craigsville coal.—In a few places in the Kittanning quadrangle a coal occurs between the Brookville and the Clarion which has been named the Craigsville on account of its development near the place of that name. It lies 40 or 50 feet below the Vanport limestone member and 40 or 50 feet above the Brookville coal. In the Foxburg quadrangle, which joins the Kittanning on the north, a coal was found about 55 to 70 feet below the Vanport limestone and 20 to 30 feet above the Brookville, and it is assumed that this bed is the Craigsville coal. The interval between it and the Brookville is generally

filled with brown shale, containing much iron sulphide, carbonate, and oxide, usually in the form of concretions. In some districts there is more or less sandstone in the interval. The coal is generally thin, and in a few places only is it underlain with clay. It is of irregular development and general distribution. Near Callensburg and northward to Knox it is very well developed, but is absent over much of the western part of the area.

Lower Clarion coal.—The interval between the Craigsville coal and the Lower Clarion coal, the next coal above, is generally occupied by shale, but in much of the southwestern quarter of the Foxburg quadrangle the Craigsville is absent, and a coarse, thick-bedded, resistant sandstone 5 to 20 feet thick is found 2 to 10 feet below the Lower Clarion coal. This sandstone so much resembles the typical Homewood sandstone member that in the older surveys it was in some places supposed to be that stratum; in other places it was called Clarion sandstone.

Over most of the area of its occurrence the Clarion coal is known as a single bed. In 1880, however, Chance called attention to an apparent split in this bed, which takes place in Clarion and Venango counties (Second Geol. Survey Pennsylvania, Rept. VV, p. 50). The evidence gathered for this report sustains the view of Chance, but the members now known as Upper and Lower Clarion coals do not spread apart as regularly as was suggested in that work. The distance between them is variable, in some places reaching as much as 25 feet. The boundary of the area in which the separation takes place seems to pass near Bruin, for there is but a single Clarion coal bed south of that town, whereas to the north there are two, and in a section at Bruin there is a parting of over a foot of shale.

The Lower Clarion coal is recognized in the field by its position, thickness, sulphur content, and binder. It lies about 40 to 70 feet above the Brookville coal and 20 to 50 feet below the Vanport limestone member. The bed is of workable thickness almost everywhere through the Foxburg quadrangle and is as a rule the thickest coal below the Vanport limestone. It is nowhere free from iron pyrite and partings. A ½-inch to 2-inch binder near the middle of the bed is of wide extent.

In roadside outcrops the coal is generally thin, with several feet of white plastic clay beneath. This clay has not been worked, but appears to be of very good quality.

Upper Clarion coal.—The upper division of the Clarion coal is separated from the lower by a body of shale from 2 to 25 feet thick, and a similar body of shale separates it from the Vanport limestone above. In most sections there is no underclay, but the coal rests directly upon a hard, black, nonfissile mudstone. With the exception of a few places where there is a layer of sandstone the strata between the

Clarion coal beds consists of dark-gray shale, which on weathering turns brown.

The Upper Clarion coal is workable throughout much of the area where it is found, but in the Clarion quadrangle it is thin or absent. On the whole the quality seems to be somewhat above that of the Lower Clarion.

Vanport limestone member.—The Vanport limestone, sometimes designated "Ferriferous" limestone, is one of the most persistent and best known strata of western Pennsylvania. It takes its name from the town of Vanport, Beaver County, Pa., where it is typically developed. Wherever it is found, it is a valuable key rock for identifying other beds and for determining the position of oil and gas sands. The top of the limestone is 110 to 130 feet above the base of the Allegheny formation, the average distance being about 120 feet.

Most of the interval between the Clarion coals and the Vanport limestone is occupied by dark drab shale, which contains numerous iron nodules. In much of the area a coarse sandstone lies immediately below the Vanport and is generally 1 or 2 feet thick, but locally is much thicker. In many places there is no sandstone below the Vanport, and the Upper Clarion coal lies almost immediately under the limestone.

In quality the Vanport limestone is very pure, an analysis showing nearly 95 per cent carbonate of lime with little magnesia. The rock is dark-gray in color and fossiliferous. Brachiopods and fragments of crinoid stems are abundant, and corals, pelecypods, and gastropods are common. All of these fossils indicate that the rock is of marine origin. The average thickness of the limestone is about 10 feet, but this increases to 20 feet south of Callensburg. The rock is generally broken both horizontally and vertically by seams, which under light cover cause the limestone to weather into large bowlders. Near or at the top of the limestone there is commonly a band of chert about 1 foot thick. This chert, because of its resistance to weathering, indicates the presence of the limestone at many places where the limestone itself can not be seen.

Immediately above the limestone is a layer of iron ore in the form of siderite or limonite. The cherty layer which is found between the ore and the limestone has given the former the name buhrstone ore, a term frequently used in Pennsylvania. Exposures in limestone quarries reveal only a few inches of the ore, and in some places, as, for example, 2 miles northwest of Knox, the ore is very fossiliferous.

The limestone is found almost continuously along Allegheny River and along the Clarion up as far as Callensburg, lying 100 feet or so higher than the old high terraces or very near the top of the valley bluff. It is found also along most of the smaller streams.

In considerable areas, however, as shown in figure 3, the limestone is absent. Whether calcareous material was never deposited or was deposited and eroded before the succeeding sediments were laid down is unknown, but certain facts indicate that the limestone never

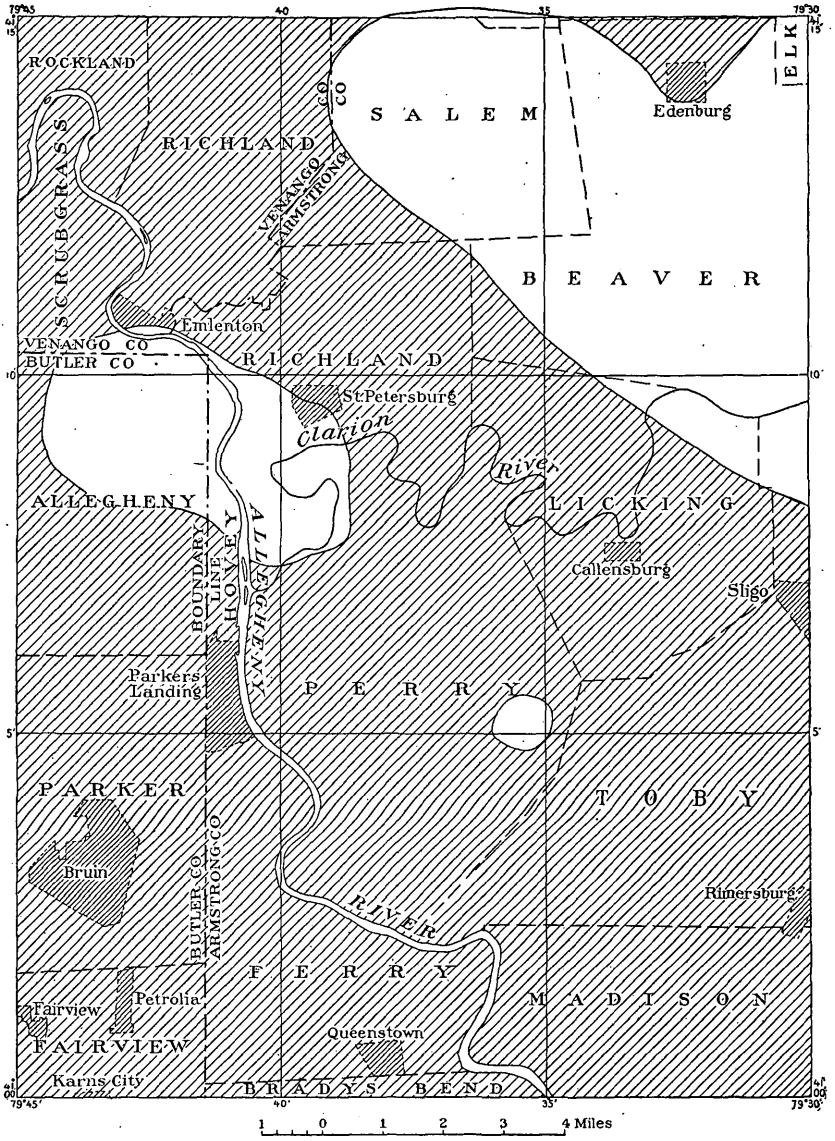


FIGURE 3.—Map showing original extent of Vanport limestone member in Foxburg quadrangle. Shaded portion indicates area in which Vanport limestone occurs. Darker shading shows towns.

existed in the areas where it is now absent. First, such areas are rounded and smooth in outline, and thus do not resemble the usual products of stream erosion or wave cutting. Second, near the boundary of such limestone areas the strata below seem to thicken at the

expense of the limestone and to occupy its position. For example, 2½ miles south of West Freedom and 1 mile north of Concord Church, a coarse sandstone seems to have been deposited contemporaneously with the limestone and take its place in the horizon. Third, the general varied character of the Carboniferous strata in western Pennsylvania shows that there was contemporaneous deposition of different kinds of sediment in different places. Fourth, as Butts has pointed out, the limestone is found over large areas as a very thin stratum, and it seems hardly possible that erosion would have proceeded in such places just far enough to have removed all but the thin layer of limestone remaining. It thus seems more reasonable to assume that the districts in which the limestone is thin or absent either projected temporarily above water or that wave action prevented for a time the accumulation of calcareous sediments.

The interval between the Vanport limestone member and the Lower Kittanning coal is occupied by sandy shale and beds of sandstone of variable thickness.

Kittanning sandstone member.—In the large area in the northern part of the quadrangle wherein the Vanport limestone member is absent, the interval between the Clarion coals and Lower Kittanning coal is generally occupied by a more or less massive, coarse-grained, pinkish sandstone above 60 feet thick. From considerable portions of the area the softer rocks have been eroded, and the heavy sandstone forms extensive flat uplands, such as those south of Knox, north of Lamartine, and west of Mariasville. Probably only the upper part of this sandstone is equivalent to the Kittanning sandstone member. The towns of Knox (in part) and Lamartine are located on this sandstone. In parts of the area of this sandstone, as, for example, east of Knox, the interval between the Clarion and the Lower Kittanning coal beds is occupied by sandy shale and several thin beds of coal.

Lower Kittanning clay.—The Lower Kittanning clay is generally gray, and varies from 3 to 8 feet in thickness. So far as known, it is everywhere present in this quadrangle. Near Zion Hill and over a large area lying near the northeast corner of the quadrangle a bed of flint clay also is found below the Lower Kittanning coal.

Lower Kittanning coal.—The Lower Kittanning coal lies generally about 35 feet above the Vanport limestone member, but the distance varies from 20 to 50 feet. It is a bed famous for its uniformity and persistency, and is mined throughout the southern half of the quadrangle. Over most of this district it does not vary more than a few inches from 3 feet in thickness. In general, the Lower Kittanning coal thins to the northwest, and is very thin or absent in the large district containing Emlenton, Foxburg, and Parker, and extending eastward to Knox.

In the east-central part of the quadrangle a coal bed about 18 inches in thickness is found below the main Lower Kittanning, and separated from it by 4 to 17 feet of clay. The coal beds diverge to the north, and in the vicinity of Wentlings Corners and Knox there is a coal bed about midway between the Upper Clarion and the Lower Kittanning. Whether this bed should be considered a lower bench of the Lower Kittanning or a separate coal is somewhat uncertain.

Middle Kittanning coal.—Above the Lower Kittanning coal is 35 to 70 feet of shale, including in some places layers of sandstone and sandy shale. The upper strata especially tend to be sandy. The shale shows more or less strong olive tints and is prevailingly soft. Above this member is a coal bed, locally underlain with clay, but more generally it rests upon a nonfissile, sandy mudstone.

The older surveys have assigned three coal beds to the Kittanning, and have designated them Lower, Middle, and Upper Kittanning, named from the type locality at Kittanning, Pa. However, in the southeastern part of the quadrangle there seem to be two Middle Kittanning coal beds. The first is about 45 feet and the second about 70 feet above the Lower Kittanning. Both the Middle Kittanning coal beds are thin, and in many sections one or both are absent. This irregularity is shown on Plate VII (p. 16) by sections 13 to 18, in the vicinity of Rimersburg.

Throughout most of the Foxburg quadrangle the Middle Kittanning coal is about 18 inches thick, and is known as the "18-inch bed," and also as the "cannel," "chance," or "local" coal. The average distance of this bed above the Lower Kittanning is 51 feet. One and one-half miles east of Concord Church the distance is 53 feet; one-half mile west of Bela it is 51 feet; and at Bruin the distance is about 35 feet. In general, the Middle and the Lower Kittanning beds diverge to the east, and between the two the extra bed makes its appearance.

Upper Kittanning coal and clay.—The Upper Kittanning coal, commonly called "Pot vein," or "Stray vein," lies from 130 to 180 feet above the Vanport limestone member. The coal is very irregular in thickness, dip, and quality, and is absent over large areas. The underclay seems to be more persistent than the coal. One-half mile east of Petrolia this coal is from half a foot to 7 feet thick, and dips much more steeply than adjacent strata.

Lower Freeport limestone member, coal, and clay.—Between the Upper Kittanning and the Lower Freeport coal beds there are about 40 to 60 feet of rock, which varies from shale to conglomerate, but is predominantly sandy. This rock is widely known as the Freeport sandstone, but has sometimes been called the "Lower Freeport" sandstone. Northeast of Catfish and elsewhere the sandstone is conglomeratic, containing many pebbles one-fourth inch, and a few 1 inch in diameter.

On Myers Hill, southeast of Sligo, and on Squirrel Hill, fragments of limestone along the roadside indicate local developments of the Lower Freeport limestone member. It is not known to occur elsewhere.

A bed of clay is generally present between the sandstone and the coal. It is gray and averages about 5 feet thick.

The Lower Freeport coal lies from 175 to 220 feet above the Vanport limestone member, and is called "Lost vein" and "Pot vein." It is irregular, but less so than the Upper Kittanning. It is present to a limited extent near the tops of the hills in the southeastern part of the area, and is locally of minable thickness (2 feet or more). It is also mined to a small extent about midway between West Freedom and Rimersburg, where it is known as the "Wilcott vein." In this district it is separated into two benches by a parting of shale 1 to 2 feet thick.

Upper Freeport limestone member and clay.—Above the Lower Freeport coal there is from 30 to 50 feet of sandy shale and sandstone, grading locally into conglomerate. In the north edge of Rimersburg, there is an outcrop of flint clay at the horizon of the Upper Freeport clay. The flint clay, however, is probably of very local development.

Of much wider occurrence, though it is irregular, is the Upper Freeport limestone member, with which is more or less plastic clay. It is present at New Athens and Sandy Hollow and thence north to Concord Church, and locally from Petrolia north to Bear Creek.

Upper Freeport coal.—The Upper Freeport or "Summit" coal lies about 245 feet above the Vanport limestone member. It is a persistent bed, but variable in thickness. In perhaps half the area of its occurrence the overlying strata are of shale, and here the thickness is uniformly 3½ to 5 feet. Elsewhere the coal is overlain with sandstone, and the thickness in such districts varies greatly in short distances.

The stratigraphic position of the Upper Freeport coal is high, and consequently it is found only in those parts of the area where the higher rocks occur. It is almost uninterrupted in the southern half of Foxburg quadrangle, and is mined extensively in the vicinity of Rimersburg, at Petrolia, and in many other localities.

CONEMAUGH FORMATION.

The Conemaugh formation, widely known also as the "Lower Barren Measures," takes its name from Conemaugh River, along which it outcrops in typical form. It extends from the top of the Upper Freeport coal to the base of the Pittsburg coal. It is varied in character, and few of its strata are uniform over any considerable area. Considering the bulk of the formation, the proportionate mass of sandstone and shale is about the same as in the Allegheny, but there is less limestone and much less coal.

The entire thickness of the Conemaugh in this part of the State is over 500 feet. Of this, 230 feet, or nearly one-half, is exposed in the Foxburg quadrangle, the highest rocks being found 2 miles southeast of Petrolia. The formation caps the highest hills, and its distribution is very nearly that of the Upper Freeport coal, just described, for it lies immediately above that bed.

The strata above the Upper Freeport coal vary from olive shale to conglomeratic sandstone. Near Rimersburg the coal is overlain by 70 feet of uniform olive shale, with traces of black shale about 50 feet above the coal. Elsewhere, as at 1 mile east of Lower Hillville, the lowest stratum of the Conemaugh consists of massive sandstone. This is known as the Mahoning sandstone member, from its extensive outcrops along Mahoning Creek. In many places the sandstone is separated from the coal by a few feet of shale, and its upper limit is likewise irregular.

Mahoning coal.—One mile northwest of Queenstown there is a coal bed 1 to 3 feet thick about 45 feet above the Upper Freeport coal, and there is also a "Second Summit Vein" 2 miles southeast of Concord Church. In the last-named place the coal is nearly 3 feet thick, and lies 60 feet above the Upper Freeport. Elsewhere, there is clay and some indication of limestone at this position. The "Second Summit Vein" is correlated with the Mahoning coal, known locally in Pennsylvania, West Virginia, and Ohio, and is discussed in the Report of Progress under the Topographic and Geologic Survey Commission of Pennsylvania, Annual Report for 1907. The coal is generally found between two divisions of the Mahoning sandstone member.

Brush Creek coal.—About 75 to 110 feet above the Upper Freeport coal, or the base of the Conemaugh, is found the Brush Creek coal. The interval between this coal and the Mahoning sandstone is occupied by shale with a yellowish cast. The coal is of little economic importance and is not persistent. The horizon is commonly marked by a peculiar dark shale, and in some sections by a bed of dark blue limestone.

Bakerstown coal.—Above the Brush Creek coal, and separated from it by about 75 feet of sandy, gray shale and thin sandstone, is the Bakerstown coal, so called from Bakerstown, in Allegheny County, where it has been considerably mined. A limestone is found near this coal also.

The highest strata which outcrop in the Foxburg and Clarion quadrangles are sandy, greenish shale; they extend about 75 feet above the horizon of the Bakerstown coal.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

After the deposition of the Carboniferous rocks, just described, sediments continued to accumulate for an unknown length of time, but before the end of the Carboniferous period the region was elevated and has remained a land area until the present time. During this long period the surface has been subjected to processes of erosion, and, while the streams carried away much material, they also made local deposits. Of such deposits practically none remain except those made in Quaternary time. These consist of unconsolidated gravel, sand, clay, and silt, and are found along the river valleys at various altitudes up to a little over 300 feet above the streams.

STRUCTURE.

Definition.—By structure is meant the attitude or "lay" of the beds. When first formed, the strata were nearly horizontal, but since that time stresses developed within the earth have tilted, wrinkled, and broken the strata to a greater or less extent. In the eastern part of Pennsylvania this sort of deformation has gone so far that there are only small areas where the strata are horizontal, and faults or places where the rocks are broken and displaced are found in great numbers. But in western Pennsylvania, although the strata have been perceptibly tilted and uplifted hundreds of feet, they have been only slightly wrinkled or folded and very few faults have been discovered. In the Foxburg quadrangle in particular the layers of rock are approximately horizontal. They have a general slope to the south of a few feet to the mile, and this slope is interrupted by low domes, basins, anticlines, synclines, and minor irregularities throughout the area.

Method of representing structure.—Structure is commonly represented in two ways, by cross sections and by contour lines. The former method is better for a region in which the rocks are sharply folded and faulted and the latter for a region where the folds are very low and there is little or no faulting, for in such a case structural features are scarcely perceptible in a cross section.

In representing the structure by means of contours, a reference stratum is chosen which has extensive outcrops and is easily recognized. The altitude and amount and direction of the slope of its surface are determined at as many points as possible, and lines are then drawn on the map in the same manner that topographic contour lines are made, each of which connects points of equal elevation. In the Foxburg quadrangle the reference stratum used is the Vanport limestone member, and the contour interval 10 feet. Thus, on the map (Pl. I) the sinuous lines marked 1050, 1100, 1150, 1200, etc., are

contour lines connecting points on the top surface of the Vanport limestone, which lie at the indicated heights (in feet) above sea level. The unmarked lines between have a vertical interval of 10 feet, those between 1050 and 1100 being 1060, 1070, 1080, and 1090. The dip of the limestone is thus 10 feet in the horizontal distance embraced between the contours. In some cases the altitude of the reference stratum was obtained directly in outcrops, mines, or wells, and in other cases it was calculated from observations on other recognizable strata, for the layers of rock are approximately parallel. The average spacing of the rocks was obtained by measurements made at all places where two or more recognizable beds were found in outcrop or in a well or boring. Thus, where a stratum above the reference layer was found, its altitude was determined and the average distance, or the nearest measured distance to the reference layer, was subtracted; where the outcrop of a bed below was found, the average interval was added, thus giving the approximate altitude at which the reference stratum would lie if it were present. An intersection of a surface contour with a structure contour of the same elevation marks a point of outcrop of the Vanport limestone.

In the Foxburg quadrangle two sets of structural contours were drawn; one set on the top of the Vanport limestone, an outcropping bed, and another set on the top of the Third oil sand, which lies from 800 to 1,800 feet below the surface. These two sets of structural contours are of interest because they show the variations which are found to occur in the structure of different strata in the same area. This difference is due to lack of parallelism of the beds caused by uneven distribution of sediments on the sea floor when they were laid down and to unconformities as mentioned under "Stratigraphy."

Although the structure of the oil sands in the Foxburg quadrangle appears to have had little or no effect upon the shape of the oil pools and their places of accumulation, in other quadrangles of the Appalachian region it is one of the important factors of accumulation, and in such areas is therefore of very great economic value. For this reason a brief explanation may well be made of the methods used in constructing a contour map of the deeply buried oil sands.

Method of making a structural map of an oil sand.—In an area where numerous records of deep wells are available the construction of a contour map of the oil sand is quite simple. Elevations above sea level of the mouths of the wells are secured and the distance down to the top of the sand in each well is subtracted from the altitude of the well mouth, thus giving the elevation of the sand with reference to sea level. If the top of the oil sand should be below sea level in a given quadrangle a datum plane is assumed 1,000 or 2,000 feet below sea level, and the height in each well of the top of the sand above

this plane is platted on the base map and contour lines drawn connecting points of equal altitudes as described above.

In areas where deep wells are widely scattered or where few good records are available, the construction of an accurate map of an oil

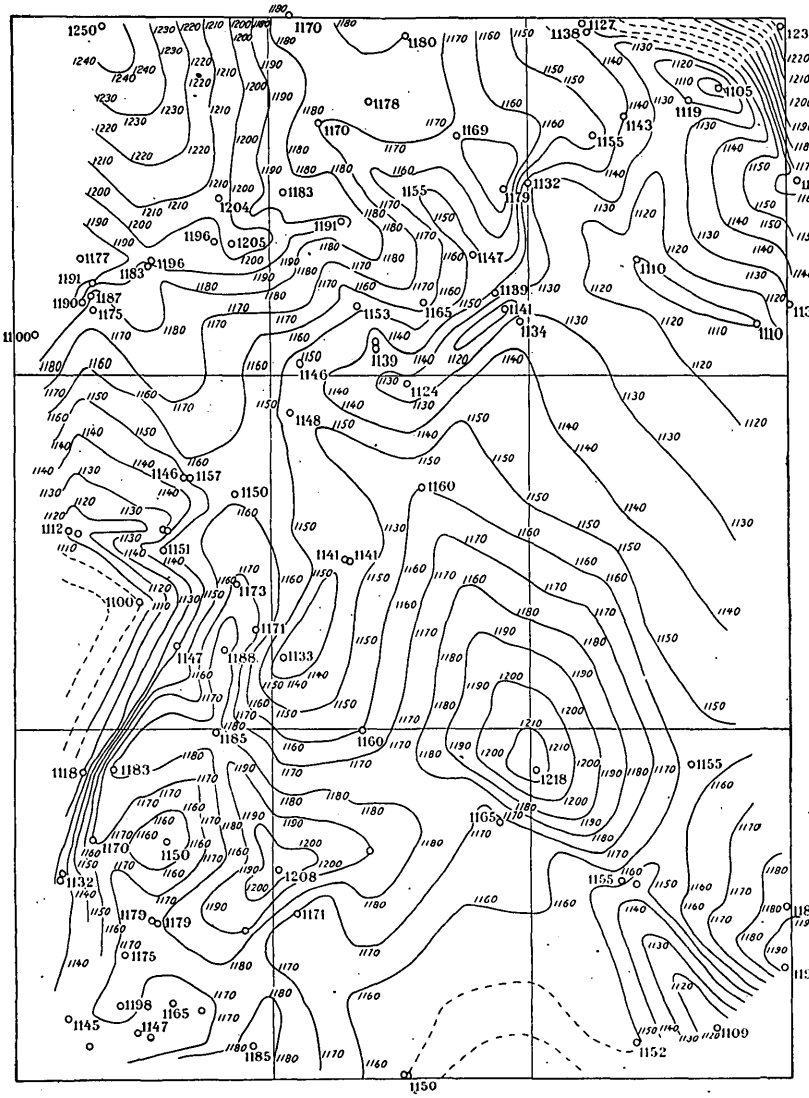


FIGURE 4.—Convergence map showing variation in distance between top of Vanport limestone member and top of Third or Gordon sand.

sand is much more difficult and requires a combination of the material for the two structural maps in such a way that altitudes on the outcropping bed are reduced to equivalent altitudes on the oil sand. This is done geographically by means of the convergence sheet, a brief description of which follows.

Convergence sheet.—The convergence sheet is a mechanical drawing on which are platted lines of equal distance (isochor lines) between the outcropping bed and the oil sand upon which structural contours are to be drawn. To make this drawing, all deep wells at which the distance between the tops of the two beds is known are platted in their proper positions on the base map. (See fig. 4, and note the wells marked by the numbers in larger type.) These wells are connected by straight lines, on which are laid off proportionately the difference in the distance between the tops of the beds as found in the wells thus connected. Points of equal distance are then connected by lines, thus forming the sinuous isochor lines of figure 4. Over this convergence sheet is then laid a transparent tracing of the structural contours of the outcropping stratum, and the altitudes thereon are reduced to equivalent altitudes of the lower bed by subtracting the vertical distance as shown by the lines of the convergence sheet.

In the Foxburg quadrangle an accurate structure map of the Vanport limestone was made by E. W. Shaw in connection with work for a folio of that region. By the use of this structural map and the well-record data obtained M. J. Munn has attempted to make a similar structure map of the Third sand by determining the variation of interval between this limestone and the Third sand and showing it on the convergence sheet, as described above. The difficulty of making an accurate structural map of the oil sands in this quadrangle is due to lack of accurate detailed records of many of the thousands of wells drilled therein and to the fact that in reconnaissance work of the nature done on this quadrangle the altitudes of comparatively few of the wells could be secured.

Variation in the structure of the Vanport limestone member and the Third sand.—From the structure maps it will be noted that if the beds were originally deposited in horizontal layers on the old sea bottom, they have since been slightly tilted to the southeast and wrinkled into a number of very shallow irregular anticlines and synclines. The anticlines or arches are broad and flat, from the axes of which the rocks dip very gently. The synclines or troughs are also flat and very irregular, with a tendency to grow shallower and to disappear toward the north. It will also be seen that the folds appear to be steeper and more pronounced in the Third sand than in the Vanport limestone. This condition is found in all portions of the Appalachian region over which structural work of this character has been done. As may be seen by a comparison of the contours of Plates I and X, the local variations of structure of these two beds are of considerable magnitude, though the general structural features are essentially the same in both.

Use of structure contours.—The structure map is of value not only for the study of broad structural problems and for an abstract knowledge of the structure of the region, but it has a practical value which lies in the aid it may give in locating and recognizing beds of value and in the data it gives concerning the "lay" of such beds. Since the strata of rock are approximately parallel and the average spacing of the valuable beds is given (see sections on pp. 26 and 27), it is not a difficult problem to calculate the approximate position of any bed at any point by adding or subtracting, according as the bed is above or below the key rock, or reference stratum, the average distance between the two to the elevation of the reference stratum as indicated on the map. The map may be used in this way not only for locating coal, clay, and limestone, but for the oil and gas bearing rocks.

In all mining exploitation in stratified rocks it is essential to know the strike and dip of the beds. The importance of this knowledge is well brought out by the hundreds of coal prospects which have been abandoned because the bed was found to dip away from the outcrop. The expense of draining and hauling up the slope to the opening was considered too great to allow of profitable work. In some cases deep ditches have been dug to drain the mine, whereas if the dip of the bed had been known it would have been opened in a more favorable location.

Accuracy of structure contours.—The accuracy of the structure contours depends upon three factors: First, the accuracy of the altitudes obtained directly; second, the difference between the actual and the assumed distance to the key rock as calculated; third, the number and distribution of the points whose altitudes are known. In the Foxburg quadrangle the altitudes were determined with a hand level, and the possible error is thought to average less than 3 feet. The second factor is more likely to cause error, because the different strata are not parallel. The effect of the third factor varies in different areas, but generally in the Foxburg quadrangle points at which the altitudes of well-marked beds have been determined are numerous and well distributed. When all the possibilities of error are allowed for, it is assumed that the structure contours are, for the most part, correct within a contour interval. It is thought that the extreme error is not more than 15 feet and that the average error is less than 5 feet. Certain districts are known to be mapped more nearly correctly than others in which the data are meager and scarcely sufficient to warrant 10-foot contour lines.

Former ideas of structure.—In the report of the Second Geological Survey of Pennsylvania on Clarion and Butler counties[a] Chance

[a] Second Geol. Survey Pennsylvania, Rept. VV, pp. 23-30.

describes four anticlines and four synclines crossing the Foxburg quadrangle. They are represented by straight lines drawn approximately N. 35° E. and bear the following names and positions, beginning at the southeast:

Bradys Bend anticline, in the southeast corner of the quadrangle.

Bradys Bend syncline, just east of Catfish and Callensburg.

Millerstown anticline, passing about 2 miles east of West Monterey, and through Callensburg.

Millerstown syncline, about one-half mile northwest of the anticline.

Martinsburg anticline and syncline, about one-half mile apart, near Fairview and Parker.

Harrisburg anticline and syncline, about one-half mile apart, and passing through Scrubgrass Bend between Wood Hill and Rockland stations.

The present survey, instead of finding numerous straight and narrow parallel folds, worked out a few irregular, broad folds, which are shown in detail on the map (Pl. I). These structural features are the product (1) of irregularities of the surface upon which each layer was deposited; (2) differential settling; (3) warping at various times since deposit. Some features suggest slight folding. Such features are the depression west of Knox, the one between Parker and Emlenton, and the one running north from Petrolia, but the structure as a whole is that of gently sloping surface, with slight irregularities throughout. The general dip is probably the result of deformation since the rocks were laid down, but the irregularities of the northwestern part of the quadrangle are somewhat similar to those represented on coastal charts of such regions as that off Cape Henry or the central part of Chesapeake Bay. It is therefore considered probable that the irregularities of structure are due in part to the shape of the floor upon which each successive stratum was laid down.

COAL BEDS OF THE FOXBURG QUADRANGLE.

By E. W. Shaw.

INTRODUCTION.

Bituminous coal and petroleum are and will for many years continue to be the most important mineral resources of the Foxburg quadrangle. Of these two it is difficult to say which is more valuable, particularly since in 1909 and 1910 the price of oil has been falling, while the price of coal has been gradually rising. In 1908 the production of coal at the ten active shipping mines in this quadrangle amounted to 386,263 short tons.

Although none of the coal beds is everywhere workable on its own merits and many are unworkable throughout extensive areas, it may

be that in years to come a considerable part of the coal which is unworkable at present will be mined not only on account of the probable increase in the price of coal, but by reason of the fact that considerable iron ore exists in these rocks, and it may be that a part of the thin coal will sometime be taken out incidentally in iron mining. The iron ore was worked 50 years ago, and with the exhaustion of richer deposits it may be worked again.

Most of the coal beds belong to the Allegheny formation. An estimate of the average total thickness of coal in this region, based on many measurements, indicates that no less than one-fourteenth of the total volume of the formation is made up of this valuable mineral. Four beds are known to be workable over considerable areas. These are the Lower Clarion, Lower Kittanning, Lower Freeport, and Upper Freeport. Openings have also been made on the Mercer, Brookville, Craigsville, Upper Clarion, Middle and Upper Kittanning beds, and also on the Mahoning coal of the Conemaugh formation and the Mercer coal of the Pottsville formation. All of these strata outcrop in the quadrangle, and the coal has been mined almost exclusively by drifting. A small part of the area—that occupied by the river gorges—is not coal bearing. Below the level of the rivers it is all but certain that no coal will ever be found.

On the whole the coals are of good quality, but partly on account of sulphur and other impurities they are of little value for coke. About 1870, however, considerable coke was made from the Upper Freeport coal at Sarah Furnace and Redbank Furnace, near the southern boundary of the quadrangle. The lower coal beds, particularly the Clarion, run high in sulphur, generally containing 3 or 4 per cent or more.

In the field work on the general geology and coals every mile of public highway and every ravine was traversed, and the outcrops were studied and described. It was the aim also to visit every mine, prospect, and quarry in the area. Hundreds of hand level lines were run from benchmarks to recognizable strata, and the topography, both in the field and on the map, was carefully studied in order to gather all the preserved record of past events. Such deformation as has taken place has left the rocks in slightly tilted positions, and an idea of the approximate amount and direction of the dip at any place can generally be gleaned from a study of the present surface, for in a series of alternating hard and soft strata the surface features produced by erosion are closely controlled by the arrangement and altitude of the various beds.

GENERAL DESCRIPTION OF COALS.

Pocono coal.—At a few places thin lenses of shaly coal were found near the top of the Burgoon sandstone. One of these lenses was seen in the river bluff opposite Emlenton. Here the coal is 5 inches thick

and has a lateral extent of more than 20 feet. It lies between beds of sandstone and appears to be of very poor quality. The other lenses of Pocono coal seen are less than 3 inches in thickness, and some of them are underlain with clay.

Mercer coal.—The Mercer coal beds are thin and shaly, and consequently of little value. At several places drillers report a bed of black, carbonaceous material, 4 to 8 feet thick, at the position of the Mercer, but no such thickness of coal was seen in outcrop, and it seems probable that the carbonaceous bed is black shale or shaly coal, and not good coal. The Mercer seems to be best developed and the coal beds thickest in a belt extending from Callensburg to Parker, where the coal beds are 2 to 4 in number and range up to 20 inches or more in thickness.

Brookville coal.—The Brookville coal is somewhat thicker than any of the Mercer coal beds, but it is generally too thin to be workable. In many places it is broken up by thick partings, and in some places its sulphur content is large.

At many places the Brookville is divided into several members or benches. The most noteworthy case of this kind is found in the vicinity of Knox, for apparently it is 18 feet from the top of the highest bench to the bottom of the lowest. Other sections to the south show a similar division of the bed, but the partings decrease in thickness and disappear as they are followed south.

Craigsville coal.—With the exception of one or two small areas, the Craigsville coal is of no economic value in this quadrangle. Where seen and recognized it generally ranges from 3 inches to 20 inches in thickness, but southeast of Knox there are several abandoned prospects on this bed in which the coal is reported to have been 3 feet thick. The greatest thickness observed was in the weathered outcrop 1 mile east of Callensburg, where the coal measured 20 inches.

Clarion coal.—The Clarion coal is sulphurous and carries one or more binders, but it is 2 to 7 feet thick, persistent, and the most extensive and valuable bed in the Foxburg quadrangle. It is probable that it underlies the whole quadrangle, except in those places from which it has been removed by erosion, and throughout much of the area it is divided into two benches, the lower of which is generally thicker. The amount of iron pyrite or sulphur which is found in the bed is so large that it serves as an identification character, and the coal is known as the "Sulphur vein."

Lower Kittanning coal.—In the southern half of the quadrangle the most important coal is the Lower Kittanning. It is persistent, uniform in thickness, and widely distributed. No regular partings occur in the coal, and the irregular ones are thin, in few places being over

one-half inch thick. In about one-half of the sections measured no partings were noted. In the others, from 6 to 12 inches below the top of the coal occurs a binder of splinty character, from one-half to 2½ inches in thickness, that is readily distinguished on fresh surfaces of the coal. In mining, no attention is paid to this binder. The average thickness of the Lower Kittanning is about 3 feet, but the upper portion generally consists of 2 to 12 inches of bony coal, thus making the average thickness of clean coal 1 or 2 inches under 3 feet. In the northern part of the quadrangle the coal is broken up by partings and over considerable areas is thin or absent. In the vicinity of Emlenton there is scarcely a trace of it.

Wherever seen, the bed has a shale roof and a clay floor. Analysis of the coal generally shows that it is high in sulphur and moderately high in ash, but it contains less sulphur and is known as a more valuable coal than the Clarion. In the vicinity of Wentlings Corners it is unusually free from sulphur and has been used as a blacksmith coal.

The position of this coal bed, like that of others, is such that over the greater part of the region it can be mined by drifting. In the northern third of the area the coal is found in only a few isolated patches and these are now practically worked out, but south of a line drawn through Clarion and Parker the coal is present in nearly all the hills.

In the northeast corner of the Foxburg quadrangle there are two coal beds near the position of the Lower Kittanning, separated by shale and sandstone. The upper one is the more valuable, and it shows very unusual local dips. Near Wentlings Corners there is said to be a drop of 30 feet in a distance of 40 rods.

Much of the coal that is shipped from this quadrangle is taken from the Lower Kittanning bed. It is used as a domestic and steam coal in northwestern Pennsylvania and western New York and a small amount goes to Canada.

Middle Kittanning coal.—In the eastern part of the Foxburg quadrangle there are two coal beds between the Upper and Lower Kittanning. Both of them are thin and not of great value. In the central and southwestern part, the Middle Kittanning is 12 to 30 inches thick, averaging about 16 inches. It is commonly held as a reserve supply by farmers when they sell the Lower Kittanning. There are several small country banks on this coal.

Upper Kittanning coal.—The Upper Kittanning coal is variable in thickness and quality and is worthy of its name "Pot vein." With one or two exceptions, this coal is found only in the southern half of the quadrangle, and in most of the few openings it is thin and dirty. Near Petrolia it is minable, but in one place the thickness in 200 yards decreases from 66 inches to 7 inches.

Lower Freeport coal.—The Lower Freeport coal has been opened in a number of country banks, but it is absent over large areas and where present it is generally too thin to be workable.

About 3 miles southeast of West Freedom the Lower Freeport coal is known as the "Wilcott vein." It is mined here in several country banks and the quality is as usual very good, but there is a parting of shale about 2 feet thick which separates the coal into two benches, each about 2 feet thick.

Upper Freeport coal.—Next to the Lower Kittanning and Clarion coal beds the Upper Freeport is the most valuable in the Foxburg quadrangle. It is quite persistent and is of minable thickness in perhaps half the area in which it occurs. There are no shipping mines on the coal, but in the vicinity of Redbank Furnace, just south of the area, it has been mined extensively for the last fifty years, and much of it has been coked. The coke was not of superior quality but was used in iron smelting. The Upper Freeport is found near the tops of the hills, consequently it occurs in many isolated areas, and its outcrop is long and irregular. It is extensively worked in the vicinity of Rimersburg and also near Fairview.

Coal beds above the Upper Freeport coal.—The Mahoning coal is found in a few small areas in this quadrangle. It has been prospected near Queenstown and also 3 miles southeast of West Freedom, where it is known as the "Second Summit vein." The coal lies under slight cover and scarcely reaches workable thickness. It is, however, reported to be of very good quality.

The Brush Creek and Bakerstown coals occur in only a few small areas, and are less than 12 inches thick.

COAL ANALYSES.

No samples of coal were collected in the Foxburg quadrangle, but the following analyses of coal from the adjoining quadrangle to the east indicate the general character of the coal:

Analyses of coal samples from Clarion quadrangle, Pennsylvania.[a]

	Upper Freeport.		Lower Freeport.	Upper Kittanning.		Lower Kittanning.				Clarion.	Craigsville.
Laboratory No.	4111.	4171.	4172.	4176.	4177.	4116.	4170.	4055.	3951.	4173.	3953.
Analysis of sample as received:											
Moisture	3.98	5.56	3.30	5.89	4.09	2.87	2.73	4.09	3.36	4.84	2.35
Volatile matter	33.70	30.72	33.79	30.46	30.24	34.51	34.77	34.79	35.94	37.86	37.47
Fixed carbon	54.50	57.14	56.83	48.66	57.37	54.31	52.20	55.32	52.05	50.28	49.01
Ash	7.82	6.58	6.08	14.99	8.30	8.31	10.30	5.80	8.65	7.02	11.17
Sulphur	2.18	1.10	2.73	1.60	1.01	1.36	3.66	2.39	2.30	3.98	4.04
Loss of moisture on air drying	2.30	3.30	1.80	3.90	2.10	1.00	1.30	2.60	1.70	3.20	1.10
Analysis of air-dried sample:											
Moisture	1.72	2.34	1.53	2.07	2.03	1.89	1.45	1.53	1.69	1.69	1.26
Volatile matter	34.49	31.76	34.41	31.70	30.89	34.86	35.23	35.72	36.56	39.11	37.89
Fixed carbon	55.79	59.09	57.87	50.63	58.60	54.86	52.89	56.80	52.95	51.95	49.56
Ash	8.00	6.81	6.19	15.60	8.48	8.39	10.43	5.95	8.80	7.25	11.29
Sulphur	2.23	1.13	2.78	1.66	1.03	1.37	3.71	2.45	2.43	4.11	4.08

[a] Lines, E. F., Coals of the Clarion quadrangle, Pennsylvania: Bull. U. S. Geol. Survey No. 316, 1907, pp. 13–19.

4111. Saylor country bank, 2 miles south of Sligo.
4171. Fairmount No. 11 mine, 3 miles northeast of New Bethlehem.
4172. Fairmount No. 12 mine, 3 miles northeast of New Bethlehem.
4176. John Mohney country bank, 5 miles southeast of Sligo.
4177. Sam Shankle country bank, 1 mile northwest of New Bethlehem.
4116. Baldorf No. 1 mine, 2 miles southeast of Strattonville.
4170. Mine No. 1, 1 mile north of Oak Ridge.
4055. Acme Mine, 1 mile south of Rimersburg station.
3951. Lyon Shorb country bank, at Sligo.
4173. George Cook country bank, 1½ miles northwest of Clarion.
3953. Sligo Mine, at Sligo.

DETAILED DESCRIPTION OF COALS.

In order to facilitate the detailed description of the coals, the quadrangle will be divided into three districts—(1) that lying east of the Allegheny and north of the Clarion, (2) that lying east of the Allegheny and south of the Clarion, and (3) that lying west of the Allegheny.

COAL BEDS IN DISTRICT EAST OF ALLEGHENY RIVER AND NORTH OF CLARION RIVER.

General conditions.—In the northern part of the quadrangle, the base of the Allegheny formation lies well up in the hills and the upper part has been removed by erosion. Consequently the number of coals found here are few, those which anywhere exceed 1 foot in thickness being the Mercer, Brookville, Craigsville, Lower and Upper Clarion, and Lower and Upper Kittanning. From that part of the district occupied by the deeper valleys, an area amounting altogether to several square miles, all of these coal beds have been removed by erosion. Moreover, as they are followed north the coal beds generally show a tendency to split and become shaly. The sections given in Plate VI (p. 16) were measured and drawn from roadside and ravine exposures and illustrate the stratigraphy of this district.

The general southward dip of the rocks is modified by a broad depression between Lamartine and Knox, another at Allegheny River, and numerous small irregularities throughout the district.

Figure 5 shows representative sections of the Mercer, Brookville, and Craigsville coals.

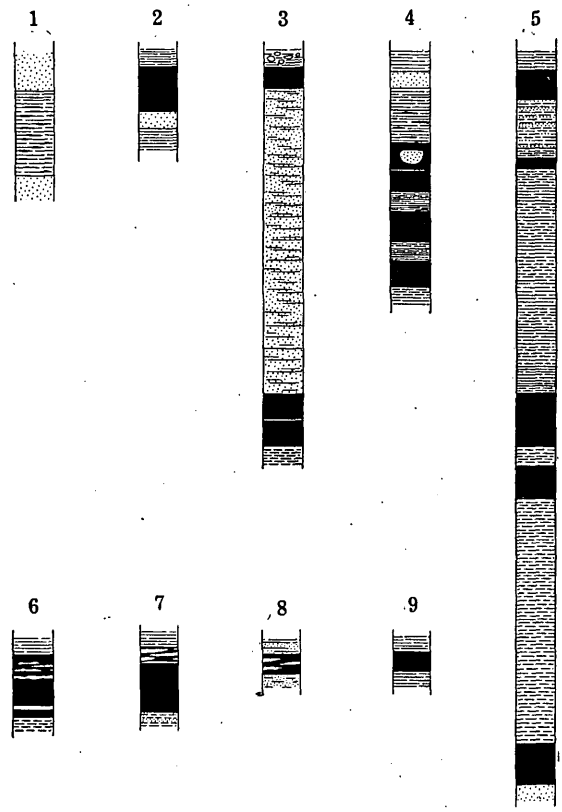


FIGURE 5.—Sections of Mercer, Brookville, and Craigsville coals in the northern part of the Foxburg quadrangle. Scale, 1 inch=5 feet.

Mercer coal: (1) 2 miles southeast of Emlenton.

Brookville coal: (2) 3 miles north of Callensburg. (3) Blairs Corners. (4) 1 mile southeast of Blairs Corners. (5) One-half mile east of Knox. (6) 1 mile southeast of Emlenton. (7) 1 mile west of St. Petersburg.

Craigsville coal: (8) 1 mile southwest of Lamartine. (9) 1½ miles southeast of Emlenton.

Mercer coal.—One or more Mercer coal beds outcrop here and there in this part of the quadrangle, but they are nowhere workable. The thickest coal seems to lie about 2 miles southeast of Emlenton, where about 16 inches of shaly coal were seen in the river bluff. In one place this coal lies between heavy beds of sandstone, but a short distance away what appears to be the same bed is overlain with shale and underlain with clay. Elsewhere in the district the Mercer coal beds seem to be only a few inches thick.

The structural geology map (Pl. I) shows that north of Clarion River the top of the Vanport limestone member lies for the most part

over 1,300 feet above sea. Since the Mercer coal beds lie less than 200 feet below the Vanport limestone, their altitude ranging from 1,100 feet up, or fairly high in the hills, and since these beds are the lowest which may contain workable coal, it follows that coal prospecting in the valleys, either at the surface or by deep drilling, would be time and energy wasted. Only very thin seams of coal have ever been found in this region below the Mercer.

Brookville coal.—The Brookville coal seems to be the most persistent coal in the district, but, except for places where it is broken up by thick partings, it does not attain a thickness of more than 2 feet. In the vicinity of Emlenton the coal ranges from 10 to 22 inches in thickness, and has been opened for mining in the river bluff, 2 miles southeast of Emlenton. Eastward the bed separates into 2 or more benches, which diverge toward Knox, where there are no less than 5 benches of Brookville coal, separated by layers of sandy to shaly clay. The total thickness of these benches is over 4 feet.

Generally the Brookville coal is of excellent quality and is very low in sulphur. In many places it has been stripped and mined in very small quantities for use as a blacksmith coal. A part of the stratum is locally a more or less pure cannel coal, which varies to a shale, with a cannel-like appearance. Another characteristic of the coal is that lenses of sandstone are commonly included in it or interbedded with its benches. Most of these lenses are only a few feet in horizontal extent, and are cemented with iron and calcium carbonates into a very hard rock.

With few exceptions the coal is overlain by soft shale several feet thick and containing "ore balls" of iron. In a mine this shale would break and fall very easily. The floor of the coal varies from soft clay to a hard white sandy clay, which because of its resemblance to both fire clay and sandstone has sometimes been spoken of as a "fire sandstone."

Craigsville coal.—The Craigsville coal is not a very persistent bed and is not minable at present anywhere in the northern part of the Foxburg quadrangle. The coal bed is thin and broken up by partings of carbonaceous shale. It is doubtful whether it will ever be mined. Not more than 6 inches of good coal were found in any outcrop of this bed. One peculiarity of the Craigsville is that in only a few places is it underlain with clay. Generally, it lies between layers of iron-bearing shale.

Clarion coal.—Throughout the district lying north of Clarion River the Clarion coal is separated into two persistent beds, the interval being filled with shale or clay and in a few places sandstone. Both coal beds are generally workable, though they have a high sulphur content, the lower one in particular containing throughout its extent a large amount of iron sulphide, generally in the form of marcasite and

being for this reason known as the "Sulphur vein." Coal from the lower bed is said also to leave more ashes and clinkers than that from the upper.

But, notwithstanding their impurities, the Clarion coals are by far the most valuable in the district; indeed, they are the only coal beds that have been worked to any extent. The lower bed is commonly spoken of as the "Four-foot vein," and the upper as the "Three-foot vein," though the average thickness is slightly less than these figures would indicate. The lower bed ranges from 20 inches to 50 inches and the upper generally from 8 inches to 38 inches, but at St. Petersburg the upper bed is thicker, reaching 58 inches in the Richland Coal Company's mine. Figure 6 shows typical sections of both branches of the Clarion coal.

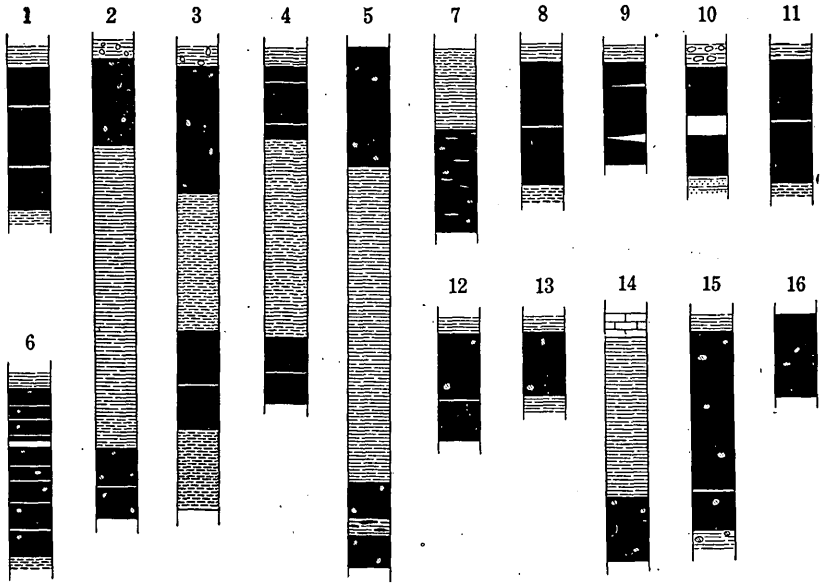


FIGURE 6.—Sections of Clarion coal. Scale, 1 inch=5 feet.

Upper and Lower Clarion coal: (1) 1 mile northeast of Emlenton. (2) 3 miles east of Emlenton. (3) Eastern part of St. Petersburg. (4) One-half mile east of Richmond. (5) 2 miles southeast of Knox.

Lower Clarion coal: (6) Russell's mine, 2½ miles southeast of Emlenton. (7) 1 mile northeast of Emlenton. (8) 3½ miles northeast of Emlenton. (9) 1 mile west of Lamartine. (10) 3 miles west of Knox. (11) 2½ miles southwest of Knox. (12) 1½ miles southeast of Wentlings Corners. (13) 1 mile northeast of Emlenton. (14) 2 miles north of Dotter's station. (15) Richland Coal Co.'s mine, St. Petersburg. (16) 1 mile northwest of Turnip Hole.

The Lower Clarion coal has a persistent binder one-fourth inch to 6 inches thick near the middle of the bed, and in many places contains one or more additional binders. It lies upon a thick bed of soft clay, which in many places at least is worth working. The coal is overlain by a shale, which is more or less carbonaceous and makes a fairly strong roof. At present, there are no shipping mines on the Lower Clarion, but there are scores of country banks from which coal is taken for local domestic and steam use.

The Upper Clarion coal has no regular partings, but contains local thin lenses of bone and shale. Sulphur balls are numerous, both in the coal and in the roof and floor. Throughout much of its extent the coal lies between beds of shale. The floor, however, is inclined to be clayey, and in one or two places a bed of soft white clay was seen underneath the coal.

The only shipping mine on this bed is at St. Petersburg, where the coal ranges from 40 to 58 inches in thickness. Here the roof and floor are both hard but brittle, the material being a compact mudstone with concretions and nodules of marcasite and very uneven stratifications. The coal has been opened at many other places, but has not been worked extensively because of the proximity of the lower thicker and more attractive bench of the Clarion.

The Clarion coals underlie about 50 square miles, or two-thirds of the district, and have been mined out from perhaps 10 square miles.

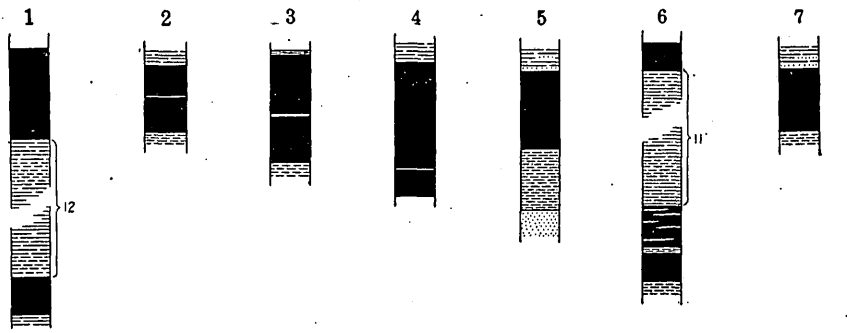


FIGURE 7.—Sections of Lower Kittanning coal. Scale, 1 inch=5 feet.

(1) One-half mile south of Keefer Mill. (2) One-half mile east of Richmond. (3) 1½ miles northeast of Turnip Hole. (4) One-half mile north of Wentlings Corners. (5) One-half mile south of Wentlings Corners. (6) 3 miles north of Callensburg.

Lower division of Lower Kittanning coal: (7) One-half mile northwest of Lamartine.

A considerable part of the mining has been wasteful, not more than a third of the coal being taken out. Thus, the coal has been "hogged out," as the miners say, and many small bodies of good coal are lost among the old workings.

Lower Kittanning coal.—The Lower Kittanning coal, which is so valuable over an area extending south and southwest for hundreds of miles, is almost worthless in this district. In many localities it could not be found, and only here and there is it workable. Throughout the northern two-thirds of the district its horizon is found only in the tops of the hills, and it is absent from the broad valleys which occupy much of this area. Where seen and recognized it is probably somewhat thicker than elsewhere, so that the sections given in figure 7 probably indicate a better coal than the average. The strata overlying the coal are of gray shale or sandy shale, making an excellent

roof, though commonly separated from the coal by a few inches of black "draw slate." The underlying stratum or floor is a firm gray clay.

The coal is present in the hill south of Keefer Mill and locally in the vicinity of Lamartine. It seems to be absent from much territory about Emlenton, Mariasville, and St. Petersburg. Near Richmond several prospects have been opened on it, but, on account of its thinness, the coal was not worked. It has also been opened in a few places near Turnip Hole. In the vicinity of Monroe the coal is broken up by partings of clay. Here the aggregate thickness of the Lower Kittanning coal reaches a maximum of 4 feet or more, but the bed is split into several benches, the highest being 10 to 15 feet from the lowest.

The most valuable coal is found at Wentlings Corners. Here the bed is thick and persistent throughout the broad flat-topped ridge which lies between Beaver and Canoe Creeks. The coal is of excellent quality and has a good roof and floor. It has been mined to a considerable extent and much has been used as blacksmith coal, some for this purpose having been hauled by wagon to places 50 miles away. Considerable difficulty is experienced in mining this coal at Wentlings Corners owing to strong local dips—an unusual feature for the Lower Kittanning coal, which elsewhere lies nearly flat.

Coal beds above the Lower Kittanning.—Coal blooms at or near the horizon of the Middle Kittanning were found here and there, but nowhere were there indications of more than 1 foot of coal. At several good exposures of associated beds, including clay, no coal could be found, and it seems probable that the Middle Kittanning is not at all persistent.

The Upper Kittanning coal is well developed in the hill 1 to 2 miles north of St. Petersburg, where it lies at an altitude of about 1,500 feet. Several years ago it was prospected at one or two places, but not much coal was taken out. Elsewhere in the district the Upper Kittanning seems to be thin or absent.

The Lower Freeport coal was not seen north of Clarion River, though a few of the hills are high enough to contain it. The hills which extend highest in the stratigraphic column are the one about midway between Emlenton and Turkey City, which extends 230 feet above the Vanport limestone member, and the one just north of Monroe, which extends 215 feet above the limestone.

COAL BEDS IN DISTRICT EAST OF ALLEGHENY RIVER AND SOUTH OF CLARION RIVER.

General conditions.—In the southeastern part of the quadrangle, the rocks which outcrop comprise a section extending from the lower part of the Burgoon sandstone to 100 feet above the top of the Allegheny formation. The lowest strata are exposed in the bottom of the

Allegheny Valley at the mouth of the Clarion and the highest form the top of the hill 1 mile east of Catfish. Thus, all of the Pottsville and the Allegheny and the lower part of the Conemaugh are included—a series of strata as richly coal-bearing as any other of similar thickness in western Pennsylvania. The road sections given on Plate VII illustrate the stratigraphy of this district.

In the northern part of the district the rocks dip south at the rate of 20 to 40 feet per mile. Southeast of Freedom and northwest of Rimersburg are areas comprising several square miles each where the rocks have almost no dip. Extending southward from Perryville is a depression of peculiar form, being 8 or 10 miles long and only a mile or two wide. The Rimersburg anticline, which is a well-defined feature of the area to the east, fades out west of Rimersburg and at the river it is imperceptible. With one exception, near Bruin, the steepest dips in the quadrangle are along the southern border east of Allegheny River. Here the strata descend to the south at the rate of nearly 100 feet per mile into a depression known as the Bradys Bend syncline, which lies just off the southern boundary of the quadrangle.

Coal beds below the Clarion coal.—The Mercer coal beds underlie almost the whole district, and outcrop along the bluffs of both Clarion and Allegheny rivers. However, coal is found in but few places, and where seen is thin and dirty. Back from the narrow river valleys not much is known concerning the Mercer coal, for there are no exposures and little careful drilling has been done. In several oil-well records drillers report beds of coal 2 to 6 feet thick at the position of the Mercer; but in ordinary methods of drilling for oil it is not easy to distinguish between coal and black shale. Near Callensburg in particular, beds of black carbonaceous material probably belonging to the Mercer were encountered in several oil wells. It may be, therefore, that lenses of Mercer coal of good quality underlie a part of the area, but, since no good coal measuring more than 9 inches in thickness was seen in outcrop, it seems improbable that any considerable body of minable Mercer coal will ever be found here.

The Brookville coal also is believed to be unminable in this district. Signs of coal were seen at almost every place where the lower part of the Allegheny formation was exposed, but in most places the coal is less than 1 foot thick and in many exposures the coal is broken up by partings of clay, shale, and sandstone.

The Craigsville coal is worthless throughout much of the district, but in the southeastern and northeastern parts it is thick and of good quality. It may be that it will be found to be minable in other parts also, where it is deeply buried under higher strata. In a small country bank in the extreme southeast corner of the area the Craigsville is 28 inches to 36 inches thick, but in a near-by outcrop it was found to be only 9 inches thick. Hence, it is probable that the thick-

ness is irregular and that the coal only locally attains such a thickness and quality as to be valuable. At Sligo, just outside the district on the east side, there is a shipping mine on a coal bed which seems to be the Craigsville, though the correlation is somewhat doubtful. A short distance to the west the Craigsville appears in outcrops in the road, where it ranges up to 20 inches in thickness and appears to be of good quality, containing less sulphur than the Clarion coal.

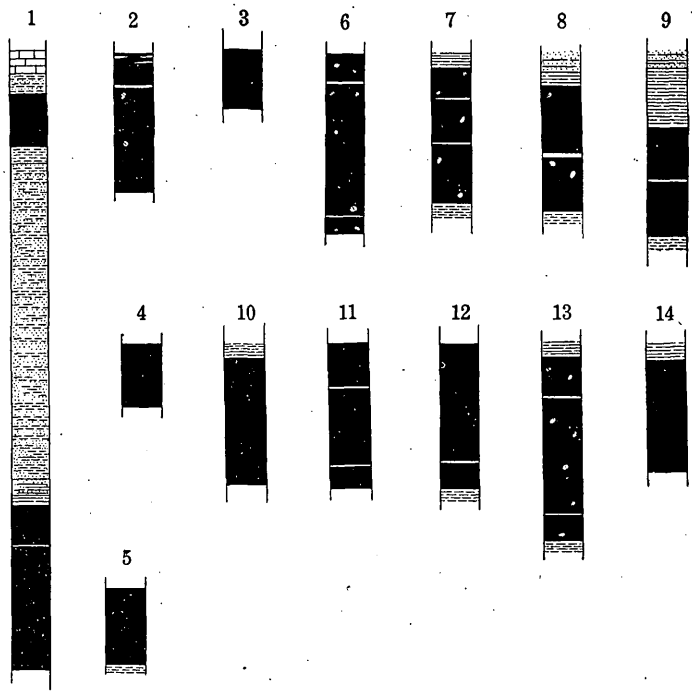


FIGURE 8.—Sections of Clarion and Craigsville coals in southeast part of the Foxburg quadrangle. Scale, 1 inch=5 feet.

Clarion coals: (1) 2 miles north of West Freedom.

Upper Clarion coal: (2) 1 mile north of Parker station. (3) 2 miles east of West Freedom. (4) One-half mile southeast of Callensburg. (5) 1¼ miles east of Callensburg.

Lower Clarion coal: (6) 1 mile north of Parker station. (7) 1½ miles southeast of Perryville. (8) Preston Coal Co.'s mine, at West Monterey. (9) Hicks Coal Co.'s mine, 1 mile southeast of West Monterey. (10) 1 mile west of West Freedom. (11) 2 miles east of West Freedom. (12) 1¼ miles east of Callensburg. (13) 2½ miles southeast of Callensburg.

Craigsville coal: (14) Southeast corner of the quadrangle.

Clarion coal.—The Clarion coal—one of the most valuable in the area—outcrops along the Allegheny River bluffs, and for a mile or two up the tributary streams. It is found also along the side of the valley of the Clarion and up its tributaries for 3 or 4 miles. The outcrop is thus not very long or devious.

As in the northern districts, the coal is separated into three divisions each of which is minable throughout most of the area. The sections (fig. 8) illustrate the thickness of the bed, its partings, and its relations to other strata.

The Lower Clarion coal is persistent and minable throughout its extent. With the exception of a small area from which it has been removed by erosion, it underlies the whole district and is not known to fall below 20 inches in thickness. Generally, it ranges from 30 to 50 inches, but falls below 30 inches along the southern border. The coal lies about 1,250 feet above sea along Clarion River and slopes from this down to about 1,100 feet at the south side of the district. The amount of cover varies from place to place, the greatest depth of the coal below the surface being 340 feet at certain points near Catfish and Rimersburg.

This coal has much sulphur and one or more partings of soft clay, shale, or bone, but, aside from these, the coal is of excellent quality. The bed rests upon a stratum of clay, which appears to be worth working. The clay makes a good floor, but shows a slight tendency to heave. The roof of the coal is, for the most part, a good tough shale, though in a few places the overlying bed is sandstone. There are two shipping mines near West Monterey and the coal has been worked also in many country banks and prospects.

The Upper Clarion coal is fairly persistent and is found throughout most of the territory underlain by the Lower Clarion coal. Its outcrop is not long or complicated, but follows along the sides of the river valleys slightly above the lower division. Generally the coals are so near each other and the hillsides so steep that they could not be mapped separately, though in few if any places are they near enough to each other to be mined together. Along the Allegheny the distance between them ranges up to 30 feet, but along the Clarion the coals are only 5 to 15 feet apart. The intervening stratum is clay shale for the most part, and not rich in iron. Between West Freedom and St. Petersburg a heavy sandstone seems to rise up through and take the place of the Clarion and Craigsville coals and the Vanport limestone member.

The Upper Clarion coal contains less sulphur than the Lower Clarion and has fewer partings and other impurities, but, notwithstanding its superior quality, it is not mined extensively because of its thinness. Generally it does not measure over 24 inches, though locally it thickens up to 40 or 45 inches. For a time there was a shipping mine on this coal, the Pollock Lime and Coal Co. mine, about a mile north of Perryville, but this mine has not been in operation recently. In the vicinity of this mine the Upper Clarion coal is nearly 40 inches thick and apparently of very good quality. Here the overlying stratum is a tough, sandy mudstone, which should make an excellent roof. The material under the coal is a thick bed of soft fire clay. Elsewhere the roof is of shale and the floor of clay or shale.

Lower Kittanning coal.—The Lower Kittanning coal is more widely developed and thicker in this district than in any other part of the Foxburg quadrangle. Its outcrop is roughly parallel to that of the lower coal beds, but slightly longer, for it lies higher and hence extends farther up the tributary streams. It extends up Catfish Run to Kissingers Mill, up Black Fox Run to the Eagle mine, recedes from the river near Church Hill, and follows the wall of the old valley of the Allegheny around Perryville; thence the outcrop swings south to West Freedom, where it crosses a small stream, and from this

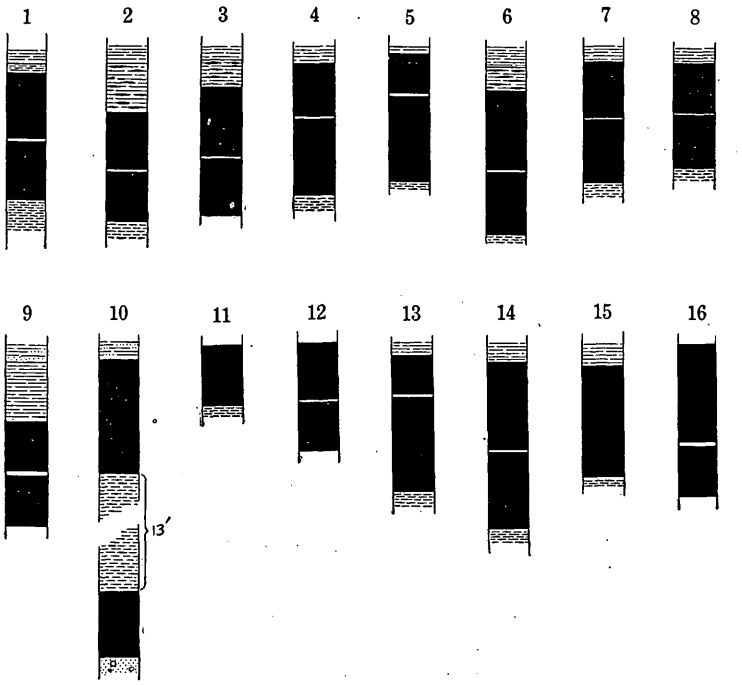


FIGURE 9.—Sections of Lower Kittanning coal. Scale, 1 inch=5 feet.

(1) Dutch Hill mine. (2) Hillville ("Blue Goose") mine. (3) Eagle mine. (4) One-half mile east of Upper Hillville station. (5) 1 mile north of Catfish. (6) Catfish mine. (7) One-half mile southeast of Catfish. (8) 2 miles east of West Freedom. (9) 1½ miles southeast of West Freedom. (10) One-half mile north of Zion Hill. (11) 1½ miles southeast of Callensburg. (12) 1 mile southwest of Zion Hill. (13) Clarion mine, near Huey. (14) Cherry mine, near Huey. (15) 1 mile northwest of Mount Airy. (16) Southeast corner of quadrangle.

place runs north and east, winding around the hills toward Callensburg. It is found above drainage along Cherry Run as far as Huey and up Licking Creek to the east boundary of the area. From Licking Creek the outcrop passes northeast through Zion Hill and leaves the quadrangle not quite in the place where Clarion River enters.

The character of this coal and that of the overlying and underlying strata as well are nearly uniform throughout the district. (See fig. 9.)

The coal is about 3 feet thick in the southern part of the area and thins to 2 feet along Clarion River. One fairly persistent binder lies about a foot below the top of the bed and there are in some places other impurities. The coal has less sulphur than either of the Clarion coals and is known locally as one of the best coals in the region. The overlying strata are of tough gray shale, which in mines makes an excellent roof. The underclay is rather soft, and in wide rooms is likely to heave, but with ordinary care it makes no trouble. Generally this clay is valuable and may be mined to advantage in connection with the coal. In the district there are eight shipping mines on the Lower Kittanning coal, one of which has, however, not been in operation recently. The active mines are the Cherry Run and the Clarion near Huey; the Dutch Hill, Eagle, and Hillville mines, not far from West Monterey; and the Sarah Furnace and Catfish mines, near Catfish.

Two and a half miles northeast of Callensburg there is a local lens of flint clay below the Lower Kittanning coal, which is here separated into two divisions 16 feet apart. The interval is filled with fire clay and a small amount of shale and iron ore. The ore was formerly worked, the clay appears to be valuable, and the coal benches measure 17 inches and 5 inches, so that here the Lower Kittanning and associated beds seem to be of unusual value.

Middle Kittanning coal.—The Middle Kittanning coal is of little value in this district, in few places exceeding 16 inches in thickness, though it is commonly known as the 18-inch bed. It is not a persistent coal, and where present it is commonly only a few inches thick. The average distance between this coal and the Lower Kittanning is about 50 feet, but in this district the distance increases from about 55 feet in the southwestern corner to about 90 feet at Rimersburg, and a short distance north of Rimersburg another coal bed is found about 50 feet above the Lower Kittanning. In the area to the east also there are two coal beds between the Upper and the Lower Kittanning, so there seems to be good evidence of two Middle Kittanning coal beds. The thickest coal seen was at Mount Airy, where there are two benches separated by 18 inches of shale. The lower bench is 4½ inches and the upper 21 inches thick. At this point the strata above the coal consist of 4½ feet of shale overlain by heavy sandstone. Under the coal there is a bed of fire clay 6 feet 9 inches thick, followed by shale and sandstone.

Upper Kittanning coal.—The Upper Kittanning coal or "Pot vein" is present in only a few localities and is very irregular in thickness and quality. Even where best developed the thickness is variable, dropping in a few yards from 4 feet to a few inches. It may be minable in an area of 2 or 3 square miles east of West Freedom and in another

area of about the same size north of New Athens. Sections of the coal bed in these localities are shown in figure 10.

Lower Freeport coal.—The Lower Freeport coal is somewhat more extensive and regular than the Upper Freeport, but on account of its thinness and large partings its minable area is no greater. About midway between Rimersburg and Parkers Landing, or one-half to 3 miles northeast of the Eagle mine, the Lower Freeport coal is separated by a shale parting, 1 to 2 feet thick, into two benches, ranging from 12 to 36 inches thick. (See sections 7 and 8 of fig. 10.) In this area it has been mined to a small extent. The roof here is of shale, the floor of soft clay, and the coal seems to be of very good quality. Elsewhere the coal is for the most part not over 1 foot thick.

Upper Freeport coal.—The Upper Freeport coal lies so high that, except on hilltops in the southern part of the district, it has been

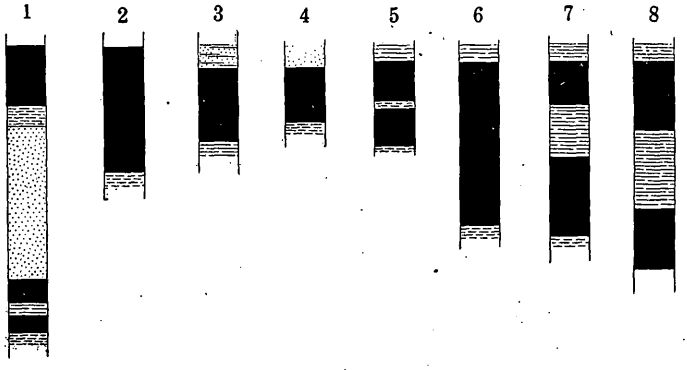


FIGURE 10.—Sections of Middle and Upper Kittanning and Lower Freeport coals. Scale, 1 inch = 5 feet.

Middle Kittanning coal: (1) 1 mile south of West Freedom. (2) One-half mile west of Sligo. (3) 3½ miles north of Rimersburg. (4) 1 mile north of Rimersburg.

Upper Kittanning coal: (5) 1 mile east of West Freedom. (6) 1 mile northeast of New Athens.

Lower Freeport coal: (7) 1 mile north of Eagle mine. (8) 2½ miles northeast of Eagle mine.

completely eroded away. Three hills near West Freedom are high enough to contain it; it is found in several hills near Concord Church; and it underlies a considerable part of the country between Rimersburg and the river. Thus there are many isolated areas of Upper Freeport coal, the largest of which is but little over 1 square mile in extent. The total area underlain by the coal is about 12 square miles, or less than one-sixth of the area of the district.

The Upper Freeport coal contains less sulphur and other impurities than any other minable coal in the region. Near Catfish it was coked extensively between 1850 and 1870. The coke was of fair quality and was used in the iron furnaces. There are no shipping mines on this coal, but there are many country banks, particularly near Rimersburg, where the coal is thick (see fig. 10) and of a uniform and excellent quality.

Throughout its extent the coal bed rests upon a stratum of fire clay, which overlies or is interbedded with limestone. The strata overlying the coal are more variable, ranging from coarse sandstone to a shale having almost no grit. In mines where the roof is of sandstone the coal is extremely variable in thickness, and the maximum is less than that of the coal where it lies under shale. Thus at Rimersburg, where the overlying stratum is shale, the coal has a comparatively uniform thickness of 4 to 5 feet and has also a bench of bony coal above and below, which grades locally into pure coal; but between

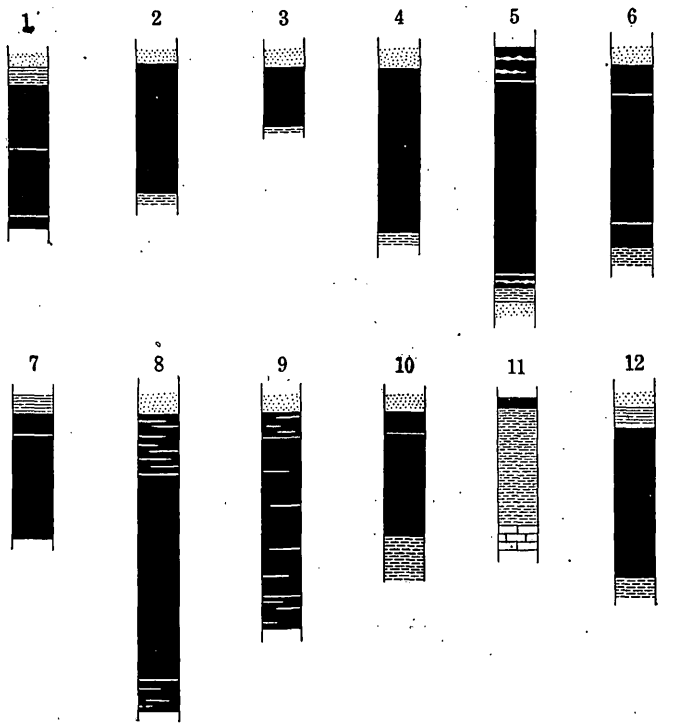


FIGURE 11.—Sections of Upper Freeport coal. Scale, 1 inch = 5 feet.

(1) 1 mile northeast of Dutch Hill. (2) 2½ miles northeast of Eagle mine. (3) 1 mile northwest of Kissingers Mill. (4) 1 mile northwest of Kissingers Mill, 20 feet from section 3. (5) 1½ miles northwest of Rimersburg. (6) 2 miles west of Rimersburg. (7) One-half mile south of Rimersburg. (8) 1 mile southwest of Maple Grove. (9) One-half mile northeast of New Athens. (10) New Athens. (11) Three-fourths of a mile north of New Athens. (12) Sandy Hollow.

Kissingers Mill and Fredell post office the Upper Freeport lies under a heavy sandstone and the thickness ranges in short distances from a few inches to about 4 feet. In one country bank, where sections 3 and 4, figure 11, were measured, the thickness of the coal increases from 18 inches to 49 inches within a horizontal distance of 20 feet. In the local "kitchens," as they are called by the miners, where the coal is thick, the roof, floor, and other features to be considered in mining are almost ideal, but the sandstone is very resistant, and where the coal is thin the necessary rock blasting makes the expense of mining almost prohibitive.

Mahoning coal.—The Mahoning coal or "Second Summit vein" is found in the tops of one or two hills 2 miles southeast of Concord Church, but it lies so near the surface that it has been deeply weathered and is not minable. Two or three prospects have been opened on this coal, and it is reported to be about 3 feet thick.

COAL BEDS IN DISTRICT WEST OF ALLEGHENY RIVER.

General conditions.—The highest and the lowest strata of the Foxburg quadrangle outcrop on the west side of Allegheny River. The Meadville shale member of the Cuyahoga formation appears in the bank of the river in the north end of Scrubgrass Township, Venango County, and rocks belonging near the middle of the Conemaugh form the top of a hill a mile and a half southeast of Petroleum. The stratigraphic column for this district thus includes all the coal beds found in the quadrangle. The succession and character of the strata are shown in the road sections given on Plate VIII.

At the north end of the district the rocks dip southeast at the rate of 30 or 40 feet to the mile; between Emlenton and Parkers Landing this dip is modified by a north-south depression, 50 to 100 feet deep; and in the southern half of the district the rocks have an irregular attitude. A slight syncline lies under Petrolia and Bruin; another runs from a mile east of Fredericksburg to West Monterey, and a third underlies Queenstown and Fredell.

Coal beds below the Clarion coal.—The strata below the Clarion coals underlie all but a small fraction of the district and outcrop along the gorge of the Allegheny, and for short distances up each side of the tributary streams. But none of the beds of coal are at present workable. A shaly Mercer coal measures 17 inches at Parker, but elsewhere the Mercer, Brookville, and Craigsville are less than 1 foot thick wherever seen. However, exposures of these coals are not abundant, and it may be that each of them attains local thicknesses of 20 inches or more.

Clarion coal.—Throughout most of the district the Clarion coal is separated into two divisions, but in the southwest corner there is a single bed with a parting of clay shale which seems to be equivalent to the strata which lie between the Upper and the Lower Clarion coals in other parts of the Foxburg quadrangle.

The Lower Clarion coal outcrops extensively and underlies a large part of the district. Its most northern exposure is in the hills 2½ miles northwest of Emlenton and 1 mile south of Wood Hill station. From this point the line of outcrop winds around the hills running up one side of each valley and back along the other side. For a considerable distance in Sugar Valley the coal is not exposed and is doubtfully present. From Sugar Valley south the line of outcrop is

somewhat devious but lies within a mile or so of the river, to a point opposite the mouth of Clarion River. Here it inclines to the west and follows the western side of an old valley of the Allegheny as far as Bear Creek. The coal lies above drainage along both sides of north and west branches of Bear Creek and passes below South Branch one-half mile south of Bruin. Southeast of Bear Creek the tributaries of

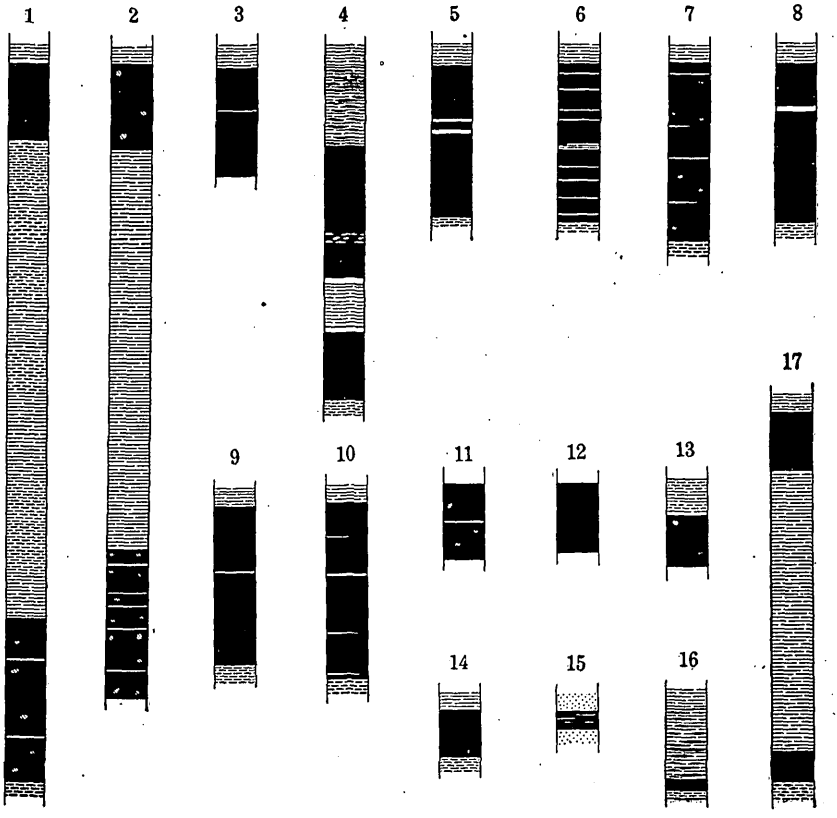


FIGURE 12.—Sections of Clarion and Mercer coals. Scale, 1 inch=5 feet.

Clarion coal: (1) 1½ miles west of Foxburg. (2) 1 mile south of Foxburg. (3) 1 mile southwest of West Monterey. (4) One-half mile south of Bruin.

Lower Clarion coal: (5) 1 mile west of mouth of Clarion River. (6) One-half mile southwest of Parkers Landing. (7) One-half mile northwest of Parkers Landing. (8) 1½ miles southwest of Bonus. (9) One-half mile northeast of Stonehouse. (10) 2 miles southwest of Parkers Landing. (11) 2 miles southwest of Parkers Landing, 100 yards from section 10.

Upper Clarion coal: (12) Parkers Landing. (13) 1¾ miles west of Parkers Landing. (14) Stonehouse.

Mercer coal: (15) River bluff opposite Emlenton. (16) 1½ miles southwest of Parkers Landing. (17) 1 mile south of Parkers Landing.

the Allegheny are small, the valley side is steep, and the position of the coal is low. The outcrop therefore lies close to the river, extending less than a mile up the tributaries.

The Upper Clarion coal is not so persistent as the Lower Clarion coal, but it underlies a large area and its outcrop is parallel to that of the Lower Clarion. Throughout much of their extent the coals

are so close to each other that they can not be mapped separately on the scale used in this report. Where the coals are far enough apart and the Upper Clarion is workable, it is mapped separately. Thus, the outcrop of the Clarion coal is represented on the map by a line, which, in many places, is double.

On account of its great extent and desirable thickness, the Lower Clarion coal is the most valuable coal in the district. It contains many masses of marcasite ("sulphur balls") and several thin partings, but it is possible to remove much of the impurities by washing, and it may be that the iron sulphide might be turned into a source of profit, for iron sulphate or copperas and sulphuric acid are readily made from the sulphide.

The thickness of the coal bed varies from 20 inches to 60 inches, and averages perhaps 45 inches. The overlying stratum is shale, commonly somewhat clayey and overlain by the under clay of the Upper Clarion coal. The Lower Clarion coal rests upon a fire clay which is several feet thick and appears to be of good quality. It is firm enough to make a good floor in coal mines.

In this district the Upper Clarion coal is somewhat variable in quality. In many places it is excellent and contains few impurities, but elsewhere it is bony and shaly and in a few places contains considerable pyrite. Where present its thickness ranges from 1 inch or less to 20 inches. It is overlain by shale, which, in turn, is overlain by sandstone, clay, or limestone. The stratum under the coal is clay or shale. In some places the shale above and below the Upper Clarion is nonfissile and might more properly be classed as a mudstone. The sections given in figure 12 illustrate the character of the Clarion and Mercer coals.

Lower Kittanning coal.—North of Bear Creek the Lower Kittanning coal is not persistent and where present is thin and contains much clay and shale, so that it is practically worthless. However, it is well developed in the vicinity of Petrolia and eastward to the river. It outcrops along Pine, Cove, and Whisky runs and along Allegheny River, and its tributaries, which are small, and extends nearly 2 miles up Binker Valley.

In the southern part of the district the Lower Kittanning coal ranges from 18 inches to 38 inches in thickness and is of very good quality. The coal is overlain generally by shale, but in some places by sandstone, either rock making a very good roof. The underclay is thick and soft where weathered, but unweathered parts are fairly firm. The sections shown in figure 13 are typical.

Middle and Upper Kittanning coals.—These coals are not persistent and where present are generally worthless, but each in one or two places attains minable thickness and quality. The Middle Kittanning coal is seen and recognized at an outcrop in the road 2 miles

west of Emlenton. From this point south to Bear Creek the outcrop is very devious, and the coal is of little or no value. At Bruin a coal which seems to be Middle Kittanning has been opened at several places, though none of the mines are now in operation. The bed is said to be about 30 inches thick and to have a hard shale roof and clay floor. Elsewhere the Middle Kittanning is not known to be minable and in many places is probably absent.

The Upper Kittanning coal was not seen north of Bear Creek, though a considerable territory near Bonus is high enough to contain it. This coal is very irregular in thickness, but is of fair quality. One-half mile southeast of Petrolia the coal is in a few places nearly 6 feet thick, though the upper 10 or 12 inches is bony; but within a few hundred feet the coal thins down to such an extent that it is worthless. The underclay of this coal seems to be of very good quality and more persistent than the coal. The coal is overlain by shale varying from 2 to 40 feet or more in thickness.

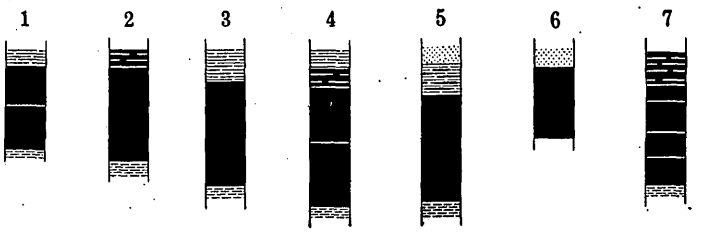


FIGURE 13.—Sections of Lower Kittanning coal. Scale, 1 inch=5 feet.

(1) One-half mile west of Parkers Landing. (2) 2¼ miles south of Parkers Landing. (3) Ravine across river from West Monterey. (4) 1¾ miles south of West Monterey. (5) Queenstown. (6) Queenstown, 100 yards from section 5. (7) Cove Run, three-fourths mile southwest of Queenstown.

Lower Freeport coal.—The Lower Freeport is a fairly persistent bed in this part of the quadrangle, though it lies so high that it has been eroded from a large part of the area, its northernmost extension being found in a few isolated areas near Bonus. In this vicinity the coal is about 40 inches thick, and there are excellent outcrops, particularly on the road running northwest from Bonus. South of North Branch of Bear Creek it underlies the broad flat-topped hill upon which Glenora is situated and much of the territory between this hill and the south boundary of the area. It underlies the same area which contains the Upper Freeport but is slightly more extensive.

Throughout most of this territory the Lower Freeport is not thick enough to be worked and is commonly separated into two benches by a parting of shale. On Pine Run it is 36 to 45 inches thick and of very good quality. Elsewhere the thickness of this coal ranges from a fraction of an inch to 30 inches but is generally under 1 foot. The coal lies between layers of shale and clay, both of which are rather soft. Near West Monterey and elsewhere the shale is thin and is overlain by sandstone.

Upper Freeport coal.—The Upper Freeport coal underlies 10 or 12 square miles in this district, mostly in the southern part. There are a few small bodies of the coal in the tops of hills near Glenora, but most of it lies near the surface of the uplands south of Bear Creek. As shown by the geologic map (Pl. I, in pocket), the outcrop is extremely irregular and long. With the exception of about 2 square miles near the mouth of Bear Creek, there is scarcely an area a mile square in this part of the district that does not contain some Upper Freeport coal.

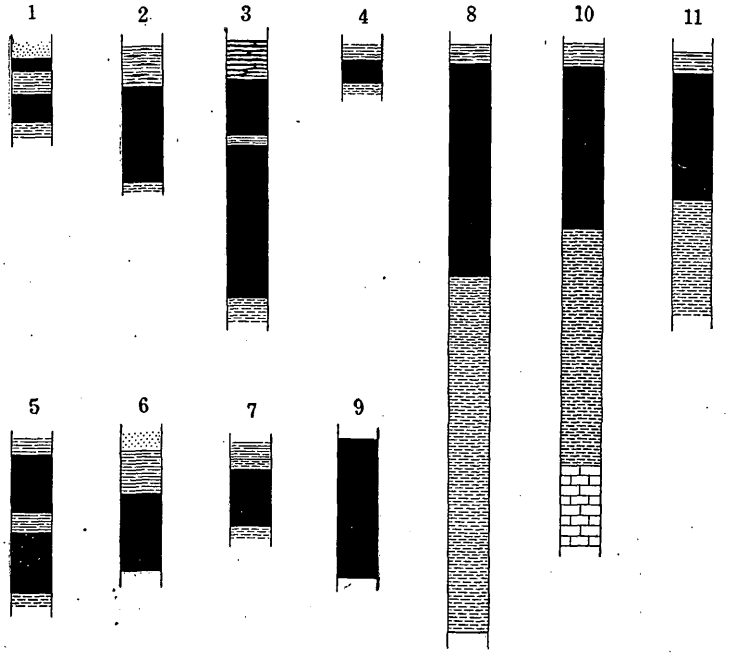


FIGURE 14.—Sections of Middle and Upper Kittanning and Lower and Upper Freeport coals. Scale, 1 inch=5 feet.

Middle Kittanning coal: (1) 2 miles west of Emlenton. (2) One-half mile southwest of Bruin.
Upper Kittanning coal: (3) One-half mile southeast of Petrolia. (4) One-half mile southeast of Petrolia, 200 yards from section 3.
Lower Freeport coal: (5) Near Bonus. (6) 1½ miles west of West Monterey. (7) 1½ miles southwest of Bruin. (8) 2 miles northeast of Petrolia. (9) On Pine Run, 3 miles east of Petrolia.
Upper Freeport coal: (10) 1½ miles southwest of West Monterey. (11) At Fairview.

The most valuable coal is found in a belt extending from Fairview and Karns City to West Monterey. Here the Upper Freeport ranges from 36 inches to 60 inches in thickness and is of excellent quality. At Karns City, just off the south boundary of the quadrangle, there are a shipping mine and several country banks. Northwest and southeast of this belt the coal generally measures under 36 inches in thickness.

West of Allegheny River the Upper Freeport coal wherever seen has a shale roof and clay floor. The bed contains very little sulphur and few bedded impurities, and it yields a better quality of coal than any other in the area. The value of the bed as a whole has been lowered by erosive processes, which have cut away much of the coal and left only irregular, more or less isolated bodies. On account of erosion also the parts of the bed that remain lie under such slight cover that they are more or less weathered, and much of the coal has so little cover that it is minable with difficulty.

The sections given in figure 14 illustrate the character of the coals in the upper part of the Allegheny formation.

STATISTICS OF COAL RESOURCES.

The following table gives the areas of each of the most valuable coal beds, and also gives rough estimates as to the territory which has been worked out and as to that which is still underlain with valuable coal:

Estimated coal resources in Foxburg quadrangle, Pennsylvania.

Coal.	Quantity before mining began.		Worked out, including waste and coal not recovered.		Minable, but not yet worked.		Not minable at present.		
							1 to 2 feet thick.		Less than 1 foot thick.
	Square miles.	*Short tons.*	*Square miles.*	*Short tons.*	*Square miles.*	*Short tons.*	*Square miles.*	*Short tons.*	*Square miles.*
Mahoning...	5.00	5,000,000	0.01	10,000	0.50	1,400,000	1.00	1,600,000	3.50
Upper Freeport.....	20.40	59,000,000	.30	2,400,000	16.90	54,200,000	1.50	2,500,000	1.50
Lower Freeport.....	25.00	48,000,000	.01	10,000	8.00	27,000,000	11.00	18,000,000	6.00
Upper Kittanning....	48.00	58,000,000	.01	10,000	5.00	13,000,000	18.00	31,000,000	25.00
Middle Kittanning....	120.00	169,800,000	.05	200,000	7.95	19,000,000	85.00	135,000,000	27.00
Lower Kittanning....	138.10	393,300,000	2.90	10,800,000	98.10	337,500,000	21.40	36,000,000	15.70
Upper Clarion.....	144.80	338,000,000	.20	65,000	100.00	260,000,000	35.00	72,000,000	10.00
Lower Clarion.....	168.10	689,200,000	1.10	5,200,000	145.00	650,000,000	15.00	29,000,000	7.00
Craigsville...	80.00	75,000,000	.02	70,000	10.00	25,000,000	15.00	22,500,000	55.00
Brookville...	164.10	182,500,000	.01	10,000	6.50	16,000,000	96.00	144,000,000	61.60
Mercer.....	170.00	70,000,000	.01	10,000	.01	10,000	12.00	17,000,000	158.00

It should be borne in mind that in the areas which have been mined out a large part, probably half or more, of the coal still remains in the ground, having been left as pillars, waste, etc.

Figure 15 shows diagrammatically the amount of territory formerly underlain by each of the eleven coal beds which were anywhere of workable thickness and also their positions in the stratigraphic column.

The sides of the diagram are so drawn as to indicate the area underlain by each of the strata above the base of the Pennsylvanian series. The upper point represents the highest stratum present within the quadrangle.

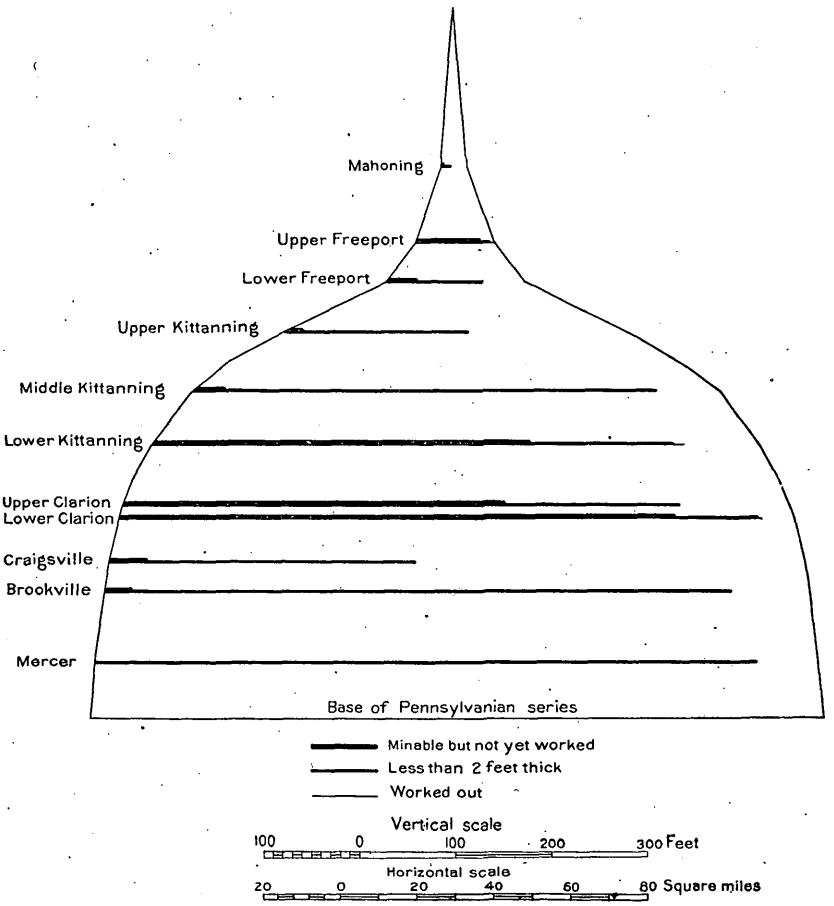


FIGURE 15.—Diagram showing areas underlain by and stratigraphic positions of the coals in the Foxburg quadrangle.

From this figure it will be seen that only a small area—only a few square miles—is not underlain by any coal.

TECHNOLOGY.

SHIPPING MINES.

In the Foxburg quadrangle there are ten active shipping mines, the individual output of which in 1908, according to the Pennsylvania Department of Mines, ranged from 6,768 short tons to 105,030 short tons, the total output being 400,263 tons.

The average individual production of the bituminous coal mines of western Pennsylvania in 1908 was 88,413 tons. The mines of the

Foxburg quadrangle have, therefore, about half as large an average production as that of the mines of western Pennsylvania as a whole.

Since the coal beds lie well up in the hills and the principal railroad lines are in the bottom of the deeper valleys, most of the shipping mines are high above the railway track level. The coal must be let down by inclines, the descent in many cases being 200 or 300 feet. All of the mines along Allegheny River are of this type. At St. Petersburg, near Clarion River, there is a mine which is just at tipple height, so that the mine can be operated without incline or hoist, and near Sligo there are two mines, one having a drift and the other a slope opening, in which the coal lies considerably below the level of the tipple.

All of the mines are above drainage, and no difficulty is experienced with either gas or dust. Most of the mines use fans exclusively for ventilation, the fans being 8 to 12 feet in diameter and having blades about 3 by 4 feet. The number of revolutions of each fan per minute varies from 55 to 110, and the amount of air driven into the mine from 4,000 to 18,000 cubic feet per minute. Two of the mines have furnaces for ventilation. One of the furnaces has 12 square feet of furnace bars and the other 24 square feet. Undercutting machines are generally used, the number in each mine varying from 2 to 14, and the coal is shot down with black powder. A small quantity of dynamite is used for brushing the entries. Compressed air is used exclusively for operating the machines and for drilling. Sulphur balls and partings are discarded by the loaders and the coal is brought to the surface by mule, cable, or motor power. The room-and-pillar system is used in all the mines. In most mines the pillars are drawn soon after working out the rooms, but in others the pillars are not drawn. The rooms average about 21 feet wide, the gangways about 9 feet, and the pillars are about 16 feet thick. The underclay is generally soft and thick, and it is necessary for the mine operators to exercise considerable care to avoid "squeezes."

The number of men employed, both inside and outside, at each mine varies from 40 to 150, the total for the 10 mines being 806, and the average number of days which each mine worked in 1908 was 188. Thus the average production per man per day was a little over 2½ short tons. The average production for each man inside the mines would be somewhat higher, for only 689 of the 806 employees worked inside.

COUNTRY BANKS.

Much coal is mined in country banks and sold at 4 to 6 cents a bushel, or $1 to $1.50 per ton, for local domestic and steam purposes, a considerable quantity being used in connection with drilling for oil and gas. However, much natural gas also is used for house

heating and power and the local demand for coal is thus not so great as it would otherwise be. Not more than 2 or 3 men work in each mine. The coal is generally hand picked, forked into 1-ton or 1½-ton cars and pushed by hand out to the tipple. There seems to be a growing demand for the slack or fine coal, which was formerly wasted. Aside from taking out the slack, the coal is not screened.

OIL AND GAS POOLS OF THE FOXBURG QUADRANGLE.

By M. J. Munn.

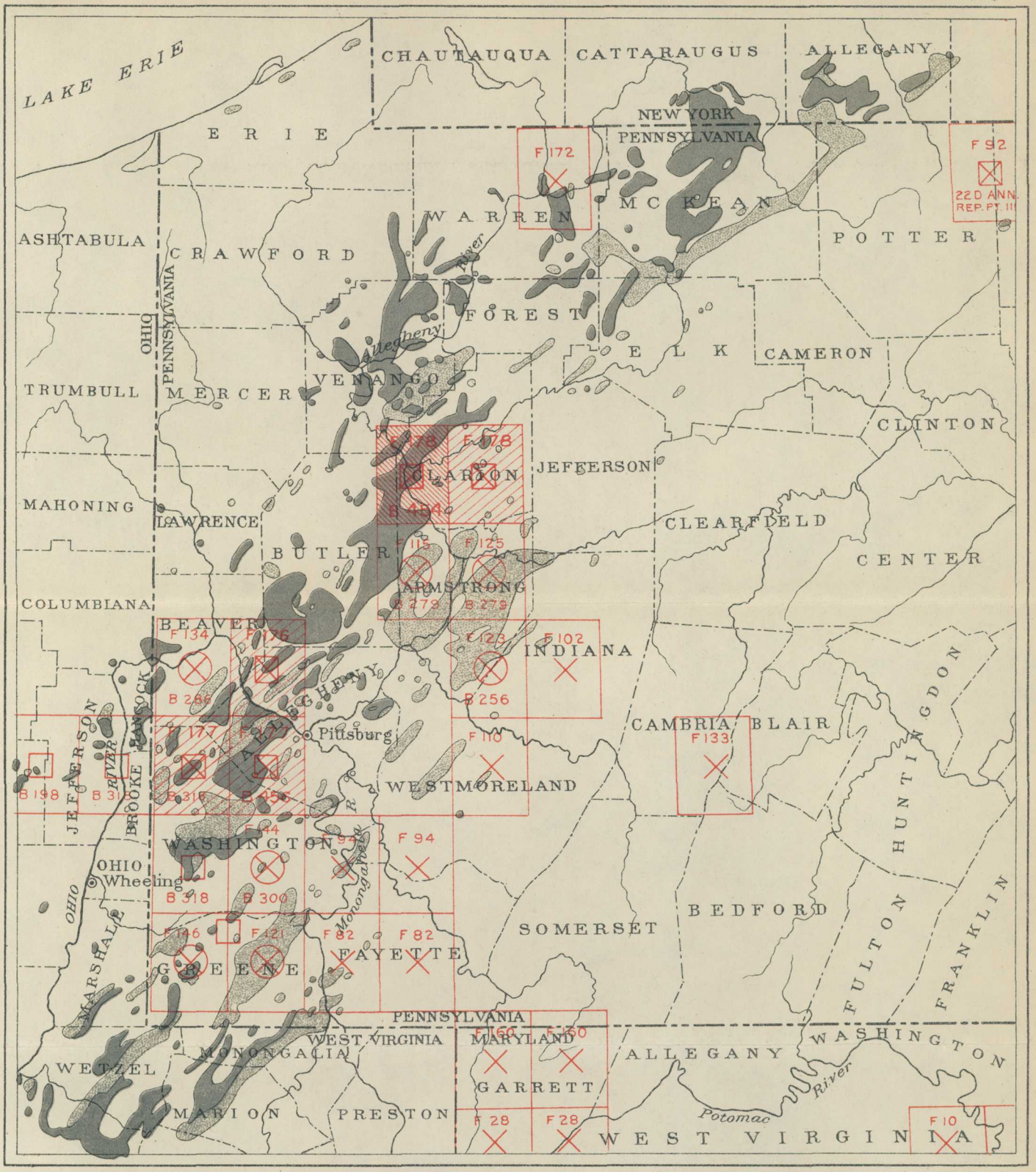
INTRODUCTION.

From the accompanying map (Pl. X) it will be seen that most of the Foxburg quadrangle has been thoroughly tested by deep wells for oil and gas. These have developed a large number of pools, more or less completely cut off from each other by unproductive or untested areas. Taken collectively, however, these pools cover a large portion of the northwest half of the quadrangle, forming two broad and fairly distinct belts trending from northeast to southwest across that area and making up one of the large and prolific oil fields of the Appalachian region. (See Pl. IX.)

The greater number of wells of this field have been producing for twenty to thirty years and much of the geologic data available when they were drilled has since been scattered and lost. At the present time, therefore, it is very difficult to secure material sufficiently accurate to justify an attempt to work out in detail the geologic history of these remarkable accumulations.

In former studies of oil and gas pools it has been found that several determinable factors have materially affected the size and position of each. Among the more important of these factors are variations in porosity of oil sands, the degree of their saturation by salt water, and their geologic structure. In areas where much drilling has been done and where accurate records of the wells have been preserved, together with data relative to the initial conditions of flow, pressure, and capacity, the geologist is well provided with facts that when properly grouped and studied furnish reasonable explanations of some of the important phases of oil and gas accumulation, and furnish also a valuable guide to the producer in his search for undiscovered pools. The difficulty of collecting sufficient information of this kind throughout much of the Foxburg quadrangle has rendered it advisable not to attempt more than a preliminary examination of this region and to confine special studies of oil and gas phenomena to more favorable fields.

In the Foxburg quadrangle no less than six distinct sandstones produce oil in commercial quantities. Named in decreasing order of their productiveness these are the Third, Fourth, Hundred-foot



SKETCH MAP OF WESTERN PENNSYLVANIA AND PARTS OF OHIO, WEST VIRGINIA, MARYLAND, AND NEW YORK

Showing oil and gas fields, location of quadrangles, and nature of geologic reports published on each

10 0 10 20 30 40 50 Miles

1910

Gas — Oil — F 133 Geologic folio with number — B 300 Economic bulletin with number — Geologic folio and economic bulletin — Oil and gas bulletin — Geologic folio and oil and gas bulletin — Reports in course of publication

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House Doc. 1425; 61st Cong., 3d Sess.

(Second), Nineveh Thirty-foot, Bowlder, and Fifth sands. All of these have furnished more or less gas, and in addition gas has been found in the First, Big Injun, Tiona, Speechley, and Bradford (?) sands. By far the greatest amount of oil has come from the Third, Fourth, and Hundred-foot (Second) sands, and to these are accredited most of the enormous supply produced by the Petrolia-Bruin field in the southwest part of the quadrangle and the Foxburg-Elk City and the Emlenton-Richey Run fields.

In the following brief discussion of the pools by townships some of the salient geologic features of these pools will be pointed out.

DESCRIPTION BY TOWNSHIPS.

ELK TOWNSHIP, CLARION COUNTY.

In the northeast corner of the Foxburg quadrangle is included a small part of Elk Township. This area is all within the productive belt of the Third sand which, in this vicinity, is known as the Elk City pool. Oil was first discovered here in 1874 or 1875, and the greatest development work occurred in the following three years. The production came mainly from the Third sand, which furnished many wells having a capacity ranging from 100 to 500 and, rarely, 1,000 barrels per day. The average initial production for the entire pool in the early stages of its development was perhaps not more than 60 barrels per day. The Third sand has a thickness of from 10 to 40 feet, with relatively thin streaks of pay sand. It is usually separated from the Fourth sand below by from 5 to 20 feet of shale, but in a number of places the two sands appear to be united with a thin streak of dark, hard sandstone, marking the division.

In general the Third sand furnished no salt water with the oil in the early stages of pumping, the Fourth being the salt-water sand. In a number of places, however, the Third sand produced salt water with the oil from the beginning, the water decreasing in volume with pumping; in these wells the quantity of the oil depended apparently upon the quantity of salt water produced, as the oil became exhausted with the salt water. This fact is in marked contrast with the salt-water conditions in the Third sand farther to the south in Allegheny and Washington counties. In those areas no salt water is pumped from new wells, and in many places the yield of oil is checked and eventually completely cut off by an invasion of salt water.[a] Only a few of the large number of wells drilled in this portion of Elk Township are now producing. Some of them, however, still furnish from 1 to 2 barrels per day after more than a third of a century of constant pumping.

[a] Munn, M. J., Bull. U. S. Geol. Survey No. 318, 1907; oil and gas bulletin of Sewickley quadrangle (in preparation); and Rept. Pennsylvania Top. and Geol. Survey Comm., 1906-1908.

BEAVER TOWNSHIP, CLARION COUNTY.

Most of the northwest half of Beaver Township lies in the Third sand field, which stretches in a broad belt from Petrolia to Elk City. In Beaver Township hundreds of wells formerly producing from this sand have since been exhausted and abandoned. At the present time it is impossible to find the locations of a large number of these wells, and for this reason there are many small unproductive areas within the limits of the field, as indicated on the map, that can not now be outlined with even a fair degree of certainty. During the early days of the development of this immense field hundreds of wells were drilled which furnished a few barrels of oil per day, but owing to the low price of oil and the frantic endeavor of producers to make big strikes these holes were abandoned. At that time no reliable maps of the pools were available and little or no attempt was made by the producers to preserve detailed logs of the wells. The data thus lost materially added to the cost of later development, since in many cases unproductive wells have been drilled where it was later discovered that previous holes had been of no value. Doubtless, in other cases, the report of a dry well has prevented the complete development of that portion of the pool in which it was located. Much of this area has been drilled the second time, the higher price of oil and the use of the gas engine for pumping rendering it possible to pump wells at a profit which produce from half a barrel to 2 barrels of oil per day.

Although most of the oil produced in this township has come from the Third sand, the Fourth, and Third stray sands have also furnished considerable quantities.

All of the oil-producing area has furnished more or less gas, varying from only a show in some wells to several million cubic feet per day in a few of the best. As a rule the gas wells were small producers, ranging from 25,000 to 50,000 cubic feet. Southeast from the oil pools in this township the Third sand is said to pinch out within a short distance and the Fourth to become hard and close with few porous streaks of pay sand.

The exact outline of the area in which the Third sand is wanting is not known, but from the available data it seems to be little more than a hard, close sandstone "shell" in most, if not all, of the southeastern part of Beaver Township.

The Speechley sand has been found to be gas bearing at a number of places in Beaver Township. With a few exceptions, however, the wells are light producers, though the closed pressure of the gas ranges from 500 to more than 900 pounds to the square inch. In the George Hanst No. 1 well at Wentlings Corners this sand is 30 feet thick, and was reached at a depth of 2,060 feet. Some oil was found in the

Third sand in this well, but the production was small; and the well is believed to be at or near the southeast edge of the pool. The distance from the top of the Third sand to the top of the Speechley, as given by the record of this well, is 865 feet. This distance seems to be too small for that between the Speechley and the Third sands, but there are not sufficient data available to determine the exact stratigraphic position of the gas-bearing bed. In the Thomas Wentling No. 1 well in the same vicinity the gas-bearing bed said to be Speechley is 14 feet thick and lies at a depth of 2,111 feet. A well on the D. V. Kline farm, northwest of Ritt station, in Beaver Township, found gas in the Speechley sand at a depth of 2,036 feet, the sand being 13 feet thick. In this well the Third sand is 40 feet thick and has produced some oil. The interval between the tops of these two sands is 946 feet. The Fourth sand is 14 feet thick and separated from the Third sand above by 6 feet of shale. A well was drilled in 1908 on the G. A. Hahn farm, about 1 mile southeast of Canoe Furnace and just off the eastern edge of the quadrangle, which found a light flow of gas in the Red Valley sand, which is a local name for a division of the Hundred-foot sand, at a depth of 870 feet and a small amount in the Bowlder sand at 992 feet, and also in the Speechley at 1,904 feet, the thickness of the latter sand being given as 66 feet. The gas from the shallow sands in this well has a closed pressure of about 150 pounds per square inch and is used in the residence of Mr. Hahn. That from the Speechley has a pressure of 800 or 900 pounds and hence can not be used in the same line. The volume is too small to justify piping to a commercial line, and at the time of the writer's visit this gas was blowing off into the air unchecked.

About 1 mile south of Wentlings Corners is a group of four wells which produce gas. No data are available relative to the horizon from which this gas comes. It is said that a good show of oil was found in the Third sand here and that some of the wells still flow a few barrels per month. This seems to be the most southeasterly producing area in the Third sand in Beaver Township. Other wells in this vicinity report little or no Third sand.

SALEM TOWNSHIP, CLARION COUNTY.

A portion of the Petrolia-Elk City oil belt crosses the southeast corner of Salem Township, in which it is known as the Triangle Pool. This is in reality a field composed of oil pools in the Third and the Fourth sands and a gas pool in the First sand. The Third sand produces over the entire area, the Fourth only over the northwestern portion. The First sand carries more or less gas in all parts of the field.

One of the first wells driven in this vicinity was the D. M. Delo No. 1, in 1872 or 1873. It is said that this well was a light producer

from the Third sand. The field was mostly developed between 1873 and 1880, the best wells starting off at 100 to 200 barrels. Many of these old wells still produce from half a barrel to 3 barrels per day after more than 30 years of constant pumping. Others equally as good at first have long since been abandoned. Some portions of the field were abandoned before the wells were exhausted because of low price of oil at the time or of greater attractions in other pools. Later, when prices were better, some of these old holes were cleaned out and pumped again, and other wells were drilled between the locations of old wells. Some of the new wells began at 15 to 30 barrels per day; most of them, however, produced less than 10 barrels, running as low as 1 to 2 barrels per day. Taken as a whole, redrilling has been sufficiently profitable in this section to justify in places a third set of holes being put down. On the map but a small per cent of the entire number of wells are shown, most of these being wells that are now producing.

Northwest of the Triangle oil field is a continuous belt of unproductive territory, separating it from the northeastern extension of the Richey Run field, which in Salem Township is usually designated as the Salem and the Mariasville pools, both of which produce from the Third and Bowlder sands. Within this unproductive belt a few pools of oil have been found in the Third sand, but the total production from these pools has been very small. The gas wells located in this belt generally produce from the Second sand, though more or less gas has been found in the First, Bowlder, Speechley, and Third sands.

In the extreme northeast corner of Salem Township a small oil pool on the Exley and Snyder farms is said to produce from the Fifth sand, but no records of wells from this pool could be secured and therefore no definite correlation can be made. The pool was small, but furnished several good wells, a few of which flowed. After 20 years not more than five or six wells are now being pumped, and the total production is probably less than 10 barrels per day.

The gas from the group of wells to the north and northeast of Lamartine and the scattering wells in that vicinity comes from the First, the Second, the Stray, or the Bowlder sand, the principal gas horizon being the Second sand.

Most of the oil in the Salem and Mariasville pools comes from the Third sand, but the Bowlder sand carries oil at several places, the largest pool probably being at Lamartine.

Little or no salt water appears to be present in the oil-bearing sands of Salem Township. The Third sand seems to carry no water, though data on this point are not sufficient to justify a definite statement. In a few places outside the producing areas a small amount of water is reported in this sand.

The Second sand, usually a water-bearing bed in the oil region, is reported to be dry over much of the Foxburg quadrangle. From the

data in hand it is not possible to outline carefully the salt-water areas in these sands, but it seems safe to say that none of them are uniformly saturated with salt water over large areas. Only a small per cent of the wells are cased below the Big Injun or Mountain sand.

RICHLAND TOWNSHIP, CLARION COUNTY.

The Petrolia-Elk City oil belt passes diagonally across Richland Township from northeast to southwest. This productive area is about 1½ miles in width and contains a large number of small pools, most of which are in the Third sand, though the Fourth and Bowlder are also oil bearing, and there are also a few wells in the Second sand. As in the townships already described, these pools also have been developed for a long time. The wells are now almost exhausted and comparatively little drilling is being done. In a few places an occasional well is put down as a cautious extension of some favorable area, but most of the development work is that of redrilling old pools that have been abandoned as exhausted. It is found that many of these pools really contained an enormous amount of oil when the former wells were abandoned. New wells in this territory that start at from 3 to 6 barrels per day are not uncommon, and they are found to run down very slowly in production, due to the small gas pressure behind the oil.

It is not possible with the data in hand to outline each of the pools in the Bowlder, Hundred-foot, and Third sands. Considerable areas of the Bowlder and Hundred-foot sands in the vicinity of Alum Rock and northwest from that place were oil bearing. Between this portion of the field and St. Petersburg is a comparatively barren strip in which the wells were small or unproductive. From St. Petersburg to the edge of the township at Foxburg the Third and the Hundred-foot sands have been prolific along a narrow belt lying between the Foxburg-Petersburg pike and Clarion River.

Through the central portion of Richland Township extends an unproductive belt from 1 to 2 miles wide in which a few scattering wells have produced a little oil and gas. Along the northwest margin of the township is a narrow line of productive territory belonging to the Richey Run field, in which the oil comes from the Third sand. In the extreme northeastern part of the township in the vicinity of Martin's mill a number of fair gas wells have been secured in the Speechley sand. Some of these wells have shown oil in the Second sand and some gas in the Third sand.

RICHLAND TOWNSHIP, VENANGO COUNTY.

The Richey Run oil field in the Third and the Bowlder sands extends across the entire southern border of Richland Township, Venango County. This field has been a very prolific one in the Third

sand, having furnished many wells ranging from 100 to 500 barrels per day. Along the northern edge of the field several small pools occur in the Bowlder sand, the exact outlines of which could not be determined. It is said that the Fourth sand has also produced some oil in this field, but the amount was relatively small. Over most of the Richey Run pool the Third sand is less than 25 feet in thickness; the average is probably not more than 15 feet. The total production, however, has been great, and many wells continue to produce after twenty to thirty years of constant pumping. The Bowlder sand ranges from 5 to 20 feet, with an average thickness of about 12 feet. While wells in this sand have not, as a rule, been large, they hold up well.

On Plate X a considerable area to the northwest of the Richey Run oil field is shown to contain a number of scattering gas wells. Most of them are light producers from the Second sand. The Speechley, Third, Bowlder, and First sands also produce considerable gas in this area. The closed pressure varies from less than 100 pounds in the First sand to more than 800 pounds in the Speechley. This pressure seems to vary greatly from well to well in the same sand, and in the Speechley the range is from about 300 to more than 800 pounds. This is due to some extent, undoubtedly, to the partial exhaustion of gas in some areas, and the consequent reduction of the closed pressure, but in a few places recent wells showing a high closed pressure are surrounded by previous wells of a lower initial pressure; this seems to indicate strongly that the original closed pressure of the gas at various points in the sand was not the same. Unfortunately, sufficient data on this point could not be secured to enable the writer to arrive at any definite conclusion regarding this phenomenon.

Within this gas belt a number of wells have shown more or less oil in the Bowlder and Third sands, but only in a few places in commercial quantities. One of these pools in the Third sand occurs on the farms of J. L. Beals and J. A. Creswell, near the northeast boundary of the township. Several of these wells flowed from the Third sand. Gas was also found in the First, Second, and Speechley sands. A small pool of oil was found in the Bowlder sand south of Keefers Mill on the Bly farm. The oil came from five or six wells, and the total production was very small. Some of these wells are still producing. Gas is here found in the Second and the Speechley sands.

ROCKLAND TOWNSHIP, VENANGO COUNTY.

Only a small portion of Rockland Township is included in the northwest corner of the quadrangle. Within this area the Black Hill oil pool has been developed in what is locally known as the Red Valley oil sand. This pool is about 2 miles long by three-fourths mile maximum width. The major axis extends in a northeast-southwest

direction, with Black Hill near the southwest margin. The first wells in this pool were drilled in about 1873 on the Samuel Batton farm, but they were small producers and attracted little attention. The greatest development took place ten or twelve years later, when a well on the Jolly farm came in at about 200 barrels per day. From this time forward the development was rapid. Many wells had an initial production of more than 100 barrels per day. These wells are now exhausted and abandoned. A few of the less-productive wells are still being pumped after 25 years, but they probably average less than one-half barrel per day each. Redrilling has developed a few producers of 1 to 3 barrels each, which show remarkable steadiness of production; the field as a whole, however, is practically exhausted, though there is some reason to believe that a few wells will continue to be pumped for years. These can be profitably operated because of the high price of oil and the low cost of pumping. This is achieved by shackling a number of wells to a single gas engine, which in turn is run by gas drawn from the wells. This pool has been encircled by holes, but no other oil has been found in that portion of the township lying within the quadrangle.

SCRUBGRASS TOWNSHIP, VENANGO COUNTY.

The Emlenton-Richey Run oil field, producing from the Third and the Bowlder sands, crosses the southeastern corner of Scrubgrass Township in the vicinity of Emlenton. At this point it is about 2 miles wide from north to south and contains a number of small barren areas in both the sands. The Third sand is productive at various points over the entire area, but most of the oil in the Bowlder sand is confined to the northern half of the belt. Northwest from this oil belt the Third sand is reported thin or absent. The Bowlder is present here in normal thickness, and has been found to contain some gas, but no oil. Most of the gas is derived from the Second and the Speechley sands. The gas wells, however, are few in number and of small capacity, though they usually produce for a long time.

ALLEGHENY TOWNSHIP, BUTLER COUNTY.

The Emlenton-Richey Run oil field occupies considerable territory in the northern part of Allegheny Township. In this area the production is mostly, if not all, from the Third sand. South of this field stretches the broad belt of unproductive territory from northeast to southwest across the quadrangle, separating it from the Petrolia-Elk City oil belt. At the southern edge of this unproductive belt is the Rosenberry pool, the largest oil-bearing area yet discovered in the Hundred-foot (Second) sand within the quadrangle.

From the incomplete records at hand the Second sand seems to range from 20 to 100 feet in thickness within the limits of this pool.

The oil is apparently always accompanied by more or less salt water, which decreases with pumping, the oil becoming exhausted with the water. In this pool some wells have found oil in the Third sand, but this sand is barren over much of the pool, especially in the northern part. Toward the south in this pool the Third sand is more commonly productive.

Southeast of the Rosenberry pool is the "Sucker-rod pool," in the Hundred-foot (Second) sand, a very narrow pool having an almost north-south trend for more than 1½ miles, its average width being less than 800 feet. The remainder of the oil produced in these townships comes from the Third sand, with the possible exception of that from a few scattering wells in the Bowlder sand.

HOVEY TOWNSHIP, ARMSTRONG COUNTY.

Hovey Township embraces a narrow strip of country lying between the Butler County line and Allegheny River, north of Bear Creek. In this township were drilled in 1869 the first wells of the Petrolia-Elk City pool. Some of these wells, located on the Reddick farm, had an initial production from the Third sand of more than 100 barrels per day. Of these wells Reddick No. 3, known as the "Buckhorn" well, drilled in 1869, is still producing about one-half barrel per day, after forty years. The Third sand in this vicinity is from 15 to 35 feet thick, with 2 to 10 feet of porous pay streak. The entire township lies within the productive areas of the Third and Second sands with the exception of the extreme northern end, which seems to be in the barren belt. The conditions of the oil sands in this area are similar to those described for Allegheny County, and need not be repeated.

PERRY TOWNSHIP, CLARION COUNTY.

Perry Township embraces a considerable area of the Third sand oil pool along the northwestern border. In this vicinity the Bowlder sand also produces oil in a few wells. A sand, about 300 feet above the Third, which is locally known as the Red Valley oil sand, and which is a part of the Hundred-foot sand, is also oil bearing in a small pool east of the mouth of Clarion River.

Many of the Third sand pools in the township have been developed for a long time, and a large per cent of the first wells have been exhausted and abandoned. These are not shown on the map, and were not located in the field, so that it is not possible to distinguish originally barren areas from abandoned pools within the productive belt. Without that belt, and especially in the eastern and southern portions of the township, considerable care was taken in the field to locate all the holes that have been drilled.

From the map (Pl. X) it will be seen that the Second sand furnishes a few small pools along Allegheny River from the extreme southern

edge of the township to half a mile below the mouth of Bear Creek. Data relative to these pools are meager. Many of the wells have been exhausted and abandoned, and the border of the productive area can not now be exactly determined.

In the remainder of the township no oil pools of consequence have been found, though small shows of oil were secured in a number of gas wells shown on the map. Most of the gas in this township, outside of the Third sand oil field, comes from the Speechley sand. In well No. 17, drilled in 1908, on the Terwilleger farm, it should be noted that gas was found in the Third sand at a point where it is 34 feet lower than the nearest oil pool in that sand. As a rule, the gas wells of this township have not been large producers, though the closed pressure ranges from less than 100 pounds in some of the shallow sands to as much as 800 or 900 pounds in the Speechley. As a rule, however, the gas wells continue to produce for relatively long periods, and the closed pressure decreases slowly.

LICKING TOWNSHIP, CLARION COUNTY.

Licking Township shows a remarkable contrast with the townships lying to the north and west as regards oil pools. Structurally this area seems to be as favorably situated for accumulations of oil as that of Beaver, Richland, or Perry townships, but from what could be learned the Third and the Fourth sands, from which so much of the oil comes, seem to be absent from a considerable portion of Licking Township, and are thin and of poor quality over all or nearly all the remainder. Within this township not more than 40 wells have been drilled. Of these probably less than 10 have shown indications of oil. One of the best indications was found on the Jessie Best farm near Turnip Hole, from which were pumped a few barrels of oil per day for several months from the Third sand. The John Black No. 1 well in this vicinity is said to have had a good show of oil in the Hundred-foot sand. Gas comes principally from the Hundred-foot and the Speechley sands, neither of which are large producers. In the limited time devoted to field work on this township considerable attention was given to locating on the map as many of the test wells drilled therein as could be found, and it is believed that at most only a few were overlooked. The map shows comparatively large areas yet untested, but on the whole the chance of finding a good quality of oil-bearing rock in either the Third or the Fourth sand in these areas is not encouraging, for sandstones of this type are very changeable as regards porosity. It is possible, however, that good porous pay streaks exist here which contain pools of oil and gas. If such pay streaks exist within this township the western portion will very probably be found to carry most of the oil.

PINEY TOWNSHIP, CLARION COUNTY.

In the small portion of Piney Township included in the quadrangle no oil or gas pools have been discovered and no wells are known to have been drilled. A short distance farther to the east, in the vicinity of Sligo, considerable quantities of gas have been found in the Second sand, and it is possible that future development will show a portion of this pool extending into the quadrangle along Licking Creek.

TOBY TOWNSHIP, CLARION COUNTY.

With the exception of a small pool in the extreme western end along Allegheny River, Toby Township has produced no oil in the Foxburg quadrangle. This pool contained only a few wells, none of which were large producers. All of the oil comes, it is said, from the Hundred-foot sand. The pool is now exhausted and all the wells are abandoned.

A number of fair gas wells have been brought in along the southwest border of this township, though none of them were very large. The gas is found principally in what is variously called Hundred-foot, Thirty-foot, and Second sand, but its correct name can not be determined from the few records available. In several of the wells the Bowlder and the Speechley sands are said to furnish gas.

Several wells drilled along Cherry Run have produced some gas from what is called First and Second sands. The wells northwest of Toby were small and of little value. Near the camp ground 1 mile west of Huey a well was drilled about 27 years ago which produced an enormous flow of gas from what is called Second sand. This well, it is said, caught fire and blew into the air for a year or more before it was put under control, the flame reaching to a height of 100 feet or more. Later a number of other wells were drilled around it and a considerable gas pool was developed. Some of these wells are still producing.

The map (Pl. X) shows most of the wells drilled in Toby Township, if not all of them. It will be seen that this area is by no means fully tested. Poor sands rather than unfavorable structural conditions have discouraged drilling. Of these, the Third sand is absent in some places and is but a thin, hard "shell" in other places. It is not known that the Third sand carries a porous pay streak at any point in the township, though there are, very probably, small areas where it is open and porous. So far as could be learned, the other sands have about their usual thickness and texture, except that the Bowlder and the Fourth sand are thinner and less porous than they are in the quadrangle farther to the northwest.

MADISON TOWNSHIP, CLARION COUNTY.

Only the northwestern portion of Madison Township lies in the Foxburg quadrangle. This part has produced but little oil or gas. In the extreme western end of the township, on Allegheny River, a number of wells produce oil from the Fourth sand. This is the western edge of the great "Cross Belt" from Petrolia to Allegheny River, described under Perry Township, Armstrong County.

Eastward from this field the Fourth sand is frequently gas bearing. In a few wells a small quantity of oil also has been found. The Fourth sand here contains most of the gas pools yet discovered in this area, but a number of wells produce gas from the Fifth, Bowlder, First, and Hundred-foot sands. The Third sand is thin or wanting over most of the area, especially toward the eastern edge of the quadrangle. The gas wells, as a rule, are of medium capacity, but they usually hold up well, both in capacity and closed pressure. Owing to the limited time at his disposal, the writer was unable to secure much data relative to initial closed pressures. As a rule, the sands above the Fourth carry an initial pressure between 50 and 400 pounds. In one well the initial closed pressure in the Fourth sand is reported at 500 pounds. No data relative to conditions of the Speechley, Tiona, and so-called Bradford sands were obtained.

BRADYS BEND TOWNSHIP, ARMSTRONG COUNTY.

Only a narrow strip along the northern edge of Bradys Bend Township is included in the quadrangle. A portion of this area in the vicinity of Allegheny River and as far west as Cove Run produced a large amount of oil during the "Cross Belt" oil excitement of 1874–75. Some of the wells in the vicinity of Queenstown are said to have had initial productions of 500 to 2,000 barrels per day from the Fourth sand. These wells were comparatively short lived and have long since been exhausted and abandoned. The Fourth sand is reported to be from 10 to 40 feet thick, averaging about 20 feet, over most of the area. At the present time a few wells drilled in later years are being pumped and an occasional well is being put down as a test of the old territory.

PERRY TOWNSHIP, ARMSTRONG COUNTY.

The accompanying map (Pl. X) shows scattering oil wells around almost the entire border of Perry Township. These wells are only a small portion of the number that have been drilled within the area, nor do they adequately cover the territory from which oil has been taken. Probably the first oil wells in the township were drilled in the vicinity of Parkers Landing in 1870. On April 20, 1870, a well was completed on the J. L. Mildren farm, at the head of Armstrong

Run, northeast of Queenstown. This well began flowing from the Fourth sand at the rate of 2,000 barrels per day. It was the first well in the "Cross Belt" pool and created great excitement throughout the oil region. A frantic development of the pool followed and it was rapidly extended westward across the southern part of Perry and the northern part of Bradys Bend townships to the vicinity of Petrolia and Karns City. So far as known, the best well in this pool was on the Parker farm, on Pine Creek, in Perry Township, near the southern border. This well began flowing at the rate of 3,000 barrels per day from the Fourth sand. Other wells in this vicinity produced from 1,000 to 2,000 barrels per day.

In the meantime during 1870 and 1871 the Third sand pool in the northwest corner of the township was being rapidly developed. The average daily production from the township during the period from 1871 to 1879 is not known, but it greatly exceeded that of any other time. The following figures from Stowell's Petroleum Reporter, published by Carll,[a] gives the approximate production of the Petrolia-Elk City oil belt from 1875 to 1879, inclusive:

Approximate production Petrolia-Elk City oil field, 1875–1879.

Date.	Number wells producing.	Average daily production.	Average daily production per well.
		Barrels.	*Barrels.*
1875	1,696	20,060	11.3
1876	2,346	14,490	8.3
1877	3,889	22,787	5.9
1878	4,650	18.730	4.0
1879	4,315	11,840	2.7

It seems very probable that a large portion of the oil from this region in the year 1874 came from Perry Township. The Fourth sand wells decreased rapidly in output, however, and many of them were down to a daily production of only a few barrels per day within two or three years. With the cheap price of oil at that time these small wells were not profitable and were abandoned. Few, if any, of the early Fourth sand wells in this pool were pumped after 20 years. The pool has been redrilled one or more times in many places for initial productions of from 2 to 20 barrels per day. A few of these later wells are still being pumped and have been noted on the map (Pl. X). Desultory redrilling is still going on with fair success.

Over the area embraced by the "Cross Belt" the Third sand is absent or unproductive. This sand thickens toward the northwest, however, and has furnished many fine wells in the vicinity of Fredericksburg and northward along the western border of the township.

[a] Second Geol. Survey, Pennsylvania, Vol. III, p. 147.

Gas and some oil have been found in what is called Second sand at a number of places within Perry Township. Probably the largest and most profitable pool in this sand is the Rattlesnake Pool lying along Allegheny River from West Monterey to near the mouth of Bear Creek. This pool has been developed on both sides of the river, but in Perry Township the best portion of the pool was practically embraced by W. H. Harrison's farm. The best well in this portion of the pool produced about 25 barrels per day. The pool has been developed for several years and the production is now quite small. The oil from the so-called Second sand in this pool, as in those previously described in the Foxburg quadrangle, is accompanied by more or less salt water, both oil and water decreasing with pumping and both being exhausted together. This phenomenon appears to be peculiar to the Second sand in this region, little or no salt water being found with the oil in the other sands with the exception of that mentioned above in the Third and Fourth sands in Elk and Beaver townships.

PARKER TOWNSHIP, BUTLER COUNTY.

Only the eastern half of Parker Township is embraced by this quadrangle. This area is nearly all in the producing territory of the Third, Hundred-foot, Bowlder, and Thirty-foot sands. To the east of Bruin and northward along Bear Creek to the vicinity of Parkers Landing the oil is all, or nearly all, from the Third sand, though small pools in the other above-mentioned sands occur.

West of Bruin and northward along the western edge of the field the Thirty-foot and the Bowlder sands are more frequently productive in small pools, though the Third sand furnishes the greatest amount. North of Bear Creek the Rosenberry pool in what is called Second sand has furnished a large quantity of oil, where the Third sand is barren. Over much of the area west and southwest of Parkers Landing the Third sand has produced oil since 1870, and much of the territory has been exhausted and abandoned. Many of the wells now being pumped in this portion of the pool are later wells put down in retesting. Only a small portion of these wells are located on the map. The thickness of oil-bearing sands of this township is discussed under the heading Stratigraphy.

FAIRVIEW TOWNSHIP, BUTLER COUNTY.

The northeast corner of Fairview Township is included in the southwest corner of the Foxburg quadrangle. The Third and Fourth sands of this area have furnished an immense quantity of oil. The Third sand is productive in the northern portion, the Fourth sand furnishing most of the wells in the southern part. It is said that some areas in the vicinity have been redrilled two and even three times for oil left when previous wells were abandoned.

In this township the rocks below the Mountain sand carry little or no water, and in order to increase the flow of oil vacuum pumps are used to exhaust the gas and air from the hole. These pumps have been used over a large area to the east, south, and west in this township where oil is derived from the Fourth sand. The continued use of such pumps has so developed a vacuum in the Fourth sand that a new well put down 1,000 feet from wells using pumps develops considerable "suction" when the drill reaches that sand. Drillers say that this is so strong in some wells that the water used in drilling immediately disappears and in some wells, it is claimed, the bailings composed of the powdered sandstone also go with the water. When such a well is drilled in and the pumping machinery is installed it is said that frequently several barrels of oil are dumped into the hole for "priming" before the well can be made to furnish a drop of oil, after which it will continue to furnish oil for years at a rate of from one-half to 4 barrels per day. These wells are pumped with gas engines which use the gas from the wells. One of these engines is frequently geared or "shackled" to six to ten wells. In areas where vacuum pumps are used one pump supplies suction for one to three wells, depending upon the leakage, etc., and these are also operated by the gas engine. All pumps on a lease are connected by pipes so that a relatively equal suction is maintained. The machinery is run day and night and shut downs are avoided as much as possible since they are accompanied by a loss of head.

APPARENT EFFECT OF STRUCTURE ON THE ACCUMULATION OF OIL AND GAS IN THE FOXBURG QUADRANGLE.

The oil pools of the Foxburg quadrangle show no marked relation to the structure of the rocks. Individual pools appear in places to be somewhat affected by the structure, as in the Second sand of the Rosenberry pool; but these instances of apparent conformity are so rare and insignificant in comparison to the total productive territory in the quadrangle that the position and extent of such pools seem probably only slightly, if at all, the result of structural influence.

Salt water is present with the oil in the Rosenberry field, and, according to the generally accepted anticlinal theory of accumulation, the oil, under such conditions, should be found on the side or crest of an anticline, which is true of this pool. But this rule will not hold good for other pools in the Hundred-foot sand. The Rattlesnake pool on Allegheny River, north of West Monterey, is an example where the oil occurs with salt water almost exactly in the bottom of a shallow syncline. There is little or no doubt that the Hundred-foot sand is continuous between the Rattlesnake and the Rosenberry pools, though it is not oil bearing.

The great oil pools in the Third and the Fourth sands, which furnish by far the larger part of the oil in the quadrangle, signally fail to conform to the structure lines. From Plate X it will be seen that the position of the pools in the Third sand is determined to a very great extent by the thickness of the sand, which in general serves also as an index of its porosity. These pools in the Third sand can not be explained by the generally accepted anticlinal or structural theory of oil and gas. This theory, in brief, provides that, having given an open porous sandstone slightly folded and filled with a mixture of oil, gas, and salt water, the ultimate condition will be that the oil and the gas, being lighter than the salt water, will become arranged through difference in weight along the arches of the folds in the order of their gravity, the gas at the top above the oil and the salt water below the oil. In these pools no such arrangement can be detected. The oil seems to occupy all open, porous areas of the Third sand in the broad producing belts regardless of the position of the folds. This is a marked exception to the condition found over broad areas in the Hundred-foot sand farther south, where the oil pools lie remarkably parallel to the trend of the structure.[a] To add to the difficulty of providing an explanation of the Third sand pools of this quadrangle by the anticlinal theory, it appears from the data in hand that the Third sand is comparatively free from salt water throughout the entire quadrangle, except a small area in the extreme northeast corner of the quadrangle, where salt water is pumped with the oil. The salt water area in this instance is the highest structural point in the producing belt of the Third sand. This fact is in direct opposition to the idea of accumulation by difference in gravity of oil, gas, and salt water.

Most of this oil territory was developed 25 to 35 years ago and it is now impossible to collect facts that will give a clear understanding of the minor geologic details of the field, but such details are of the utmost importance in the formation of correct conclusions relative to the geologic factors that have influenced the accumulation of oil. One fact may be pointed out, however, to which some significance is attached. In this field, as in almost every other field in the Appalachian region that has been examined, a bed saturated with water, usually saline, lies at a considerable distance above the oil sand. It is believed by the writer that this persistent and almost universal feature of the stratigraphy of producing territory may be found to be an important factor in the accumulation of oil and gas.

An extended discussion of the significance of this feature need not be given here, but it may be pointed out in passing that in such a

[a] Oil and gas bulletin of Sewickley quadrangle, published by Top. and Geol. Survey Comm. Pennsylvania; Bull. U. S. Geol. Survey No. 318, 1907.

stratum as the Third sand, shown on Plate X, the oil could hardly have traveled horizontally through the sandstone so far as would be necessary to furnish an accumulation so enormous, since the dip of the rocks is so slight that if we assume that the sand once contained salt water, the maximum pressure that could have been exerted by a globule of oil toward movement up the rise in the sands must have been a very small fraction of its weight. Under these conditions it seems that this pressure would have been totally inadequate to overcome the relatively great opposing forces to be encountered by globules of oil in their passage through the water-logged pores of the sand.

If, however, we consider the force exerted by a body of water slowly soaking downward through drier, close-grained shale and sandstone from a water-bearing stratum above, it does not require a great stretch of the imagination to see that the oil and gas scattered throughout the shale mass (from which the oil of the pools has doubtless been derived) might easily have been driven ahead of the water by a combination of hydraulic and capillary pressure. Such a movement might have come as easily from below as from above, provided there was a porous water-bearing bed in that direction. In either case the body of water would continue to move from its source until the supply was disseminated, or until the hydraulic pressure was reduced to zero by friction and the capillary power was also exhausted by coming in contact with open, porous sandstones. The moving water would tend to drive ahead of it a body of oil, which would be collected from and forced out of the fine-grained rocks into the coarser more porous ones. Except where hydraulic pressure predominated no water would be visible, since the rocks would yield no capillary water to a hole drilled into them. The capillary force exerted by water in porous sandstones is much weaker than it is in the finer-grained shale. It seems possible, therefore, that oil and gas pools may occur in zones where the surface water soaking downward through practically horizontal strata loses its active or hydraulic head through friction and its capillary pressure by the change from fine to coarse pores in the rocks. The oil thus forced from the fine-grained rock may be collected into pools in the porous bed by the action of this body of water, or, after being disseminated in the porous bed, it may at some subsequent time be collected into pools by currents of water moving through the porous bed in the direction of the bedding.

This idea of accumulation of oil and gas by the movement of bodies of water under both hydraulic and capillary pressure appears to be easily applicable to all types of oil and gas pools, but the facts to substantiate it can not be readily ascertained in old producing areas like those of the Foxburg quadrangle.

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