GEOLOGIC STRUCTURE OF THE PUNXSUTAWNEY, CURWENSVILLE, HOUTZDALE, BARNESBORO, AND PATTON QUADRANGLES, CENTRAL PENNSYLVANIA.

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Based on work done in cooperation with the State of Pennsylvania.

INTRODUCTION.

The geologic structure of a region—that is, the lay of the rock strata—is important to the prospector for various mineral substances that occur in the crust of the earth. When searching for water the prospector should bore at the lowest point of a fold or trough, where the pressure is greatest, for there will be slender chance of success near the crest. When prospecting for gas and oil, he generally pursues the opposite course and drills his well on the highest part of the arch, unless experience has shown that the rocks are dry, and then he searches for oil on the flanks of the fold or even in the bottom of the trough. When coal is the substance which he is seeking his principal concern is its depth and the direction and amount of dip in order that he may place his mine so as to secure natural drainage and take advantage of gravity in handling his loaded cars.

In the region described in this report the geologic structure seems to have been little understood or entirely disregarded by those boring for gas or water. Most of the deep holes for gas have been drilled at or near the bottoms of the troughs (synclines), and too often water has been sought near the crests of the arches (anticlines). An exception is the test well on the axis (crest) of the Laurel Hill anticline, which developed the gas supply now used in Carrolltown.

Examination of a map of western Pennsylvania showing the oil and gas fields reveals the fact that oil is not nearly so widespread as gas. Although gas has been found in nearly all of the territory in which oil has been found, the converse is not true, for gas has been found over a large area in Jefferson, Indiana, Westmoreland, Clarion, Armstrong, and Fayette counties east of a line that appears to limit the oil

field in that direction. This line passes just east of Clarion, in Clarion County, thence west of south to Freeport, and continues in the same direction to the southwest corner of Fayette County, where Monongahela River enters the State. Between this line and the Allegheny Front gas has been found in greater or less abundance. It is true that most of this gas has been found within the first 20 miles east of the line mentioned, but it does not appear to have been demonstrated that gas may not be found farther southeast and in the quadrangles here considered, if searched for in the right place. That the chance of finding gas in these quadrangles is less than in the area to the west may be judged from the fact that whereas to the west, as in Armstrong County, gas has been found indifferently in the anticlines and synclines, several drillings in Clearfield County in synclines have failed to find gas. On the other hand, the fact that gas has been found on the Fayette anticline, in Westmoreland County; on a distinct structural bench on the northwest flank of the Chestnut Ridge anticline, south of Punxsutawney; and on an anticline near Carrolltown, suggests the possibility that the anticlines of the region here mapped may prove to be gas-bearing.

The demand for liquid and gaseous fuels becomes all the time more urgent, and the search for supplies must ultimately be pushed to the eastern margin of the coal field; thus the thorough testing of this supposedly less promising region seems inevitable. Sooner or later the question must be settled one way or the other. This paper and a preliminary sketch map (Pl. VII) showing the geologic structure of the five quadrangles mentioned in its title have been prepared and printed in advance of more detailed publications, in order that prospectors may sooner be able to utilize the general structural results of the work carried on by the Survey. It is hoped that the information here given will enable the driller more quickly and economically to determine the presence or absence of oil or gas by making better locations for his test wells, and that the fruitless waste of money by boring where the structure is distinctly unfavorable may be abated, if not entirely obviated.

The geologic field examinations which furnished the data here presented were carried on by the United States Geological Survey under a cooperative agreement with the State Topographic and Geologic Survey Commission of Pennsylvania, which defrayed one-half of the expense of the work and which has, further, the credit of initiating these studies. The field work in the Barnesboro and Patton quadrangles was done by M. R. Campbell and F. G. Clapp, supplementary observations being made by Charles Butts. A bulletin on the mineral resources and a folio describing in detail the geology of these two quadrangles have been prepared and the maps are now in process of engraving. The geology of the Punxsutawney and

Curwensville quadrangles was studied by G. H. Ashley, assisted by Frederick B. Peck in the former and F. G. Clapp in the latter. The Houtzdale quadrangle was examined by G. H. Ashley, assisted by F. G. Clapp and W. C. Phalen. A bulletin on the mineral resources of the Punxsutawney quadrangle is now nearly prepared, and the manuscripts for folio texts covering all these quadrangles are approximately complete.

The geology of the Indiana quadrangle, which lies west of the Barnesboro, is described in folio 102 of the Geologic Atlas; the Johnstown and Ebensburg quadrangles, south of the Barnesboro and Patton quadrangles, are described in folio 174 (also in Bulletin 447) and folio 133, respectively. The general relations of the structure of the northeastern quadrangles here treated to those farther west is partly indicated in the map published as Plate IV of Bulletin 454 of the United States Geological Survey.

GEOLOGIC STRUCTURE OF THE QUADRANGLES.

METHOD OF DETERMINATION AND REPRESENTATION.

The geologic structure of the quadrangles here described is relatively simple; the rocks lie nearly flat and in general descend gradually westward from the Allegheny Front. When examined in detail, however, the rocks are found to be not horizontal but to be affected by a number of parallel folds resembling strongly the long ground swells of the ocean. These great rock swells have had a decided influence on the development of the topography of the region and they also affect in a most important way the accumulation and development of its economic resources.

Therefore, in undertaking a study of this field with the object of aiding in its development it seemed best to pay particular attention to the size and shape of the folds and to represent them on the map in such a way that any prospector can clearly comprehend them. The geologic structure is represented on the map by contour lines based on the prominent and well-known Lower Freeport coal bed, whether it shows at the surface or is deeply covered. To do this, the elevation above sea level of the top of this bed has been determined at as many points as possible.

The structure contour lines on Plate VII are drawn at uniform distances above sea level, and hence all points on a given contour have the same altitude. In other words, a structure contour is the line of intersection of the datum surface with a plane all points of which have the same elevation above sea level. For instance, the Lower Freeport coal at all points along the 1,850-foot contour has an altitude of 1,850 feet; it descends in the direction of the 1,800-foot contour and rises toward the 1,900-foot contour. At points where the altitude of the surface is greater than that of the coal the

approximate depth of the coal below the surface can readily be determined by subtracting the one altitude from the other. Where the altitude of the surface is less than the corresponding altitude of the coal the coal has been removed by erosion and the contours simply show its hypothetical position. If positions of other beds than the Lower Freeport coal are desired, their distances above or below the datum surface must be added or subtracted accordingly.

In order to illustrate the use of structure contours, suppose that the depth of the Lower Freeport coal is desired at Plattsville, in the Patton quadrangle. The surface altitude at this place is about 1,830 feet, and the road corner at Plattsville is three-fifths of the distance between the 1,450 and 1,500 foot structure contours; therefore the Lower Freeport coal at this place is 1,830 − 1,480 feet, or about 350 feet, below the surface.

It should be borne in mind that it is impossible to determine accurately the positions of structure contours in all parts of the field, and allowances for possible errors should therefore be made in using them. In large areas the Lower Freeport coal is deeply buried beneath the surface, and no facts are at hand by which its distance below the outcropping beds can be determined. Even where the coal reaches the surface there is in places no visible outcrop, and only the approximate position of the bed is known. Such is likewise the case where the contoured bed has been removed by erosion. In all such localities the contours may be somewhat in error, but the error is probably nowhere very great. Throughout most of the southern half of the Barnesboro quadrangle and in some of the western and northern portions, also in large areas in the central and southern portions of the Patton quadrangle, the evidence is not satisfactory. It will be noticed that in these regions the contours are generalized and more regular in trend, lacking the details in deviation which they have in the better-known mining regions.

Notwithstanding the uncertainties in the structure contours, they are very accurate throughout large areas, particularly where more active mining and drilling has been done, as in the Barnesboro-Patton region, in the area north of Punxsutawney, and in and near Houtzdale. The contours in many parts of the area are determined directly from mining levels furnished by the coal companies and are very accurate. A few mine levels have also been obtained in the Delaney and Glenwhite regions and at Amsbry. In portions of the area where drilling has been done the contours have been drawn to correspond with the levels of the beds as found in records which have been furnished to the Survey by the operators. In regions where levels on the Lower Freeport coal are lacking it has been necessary to use other means of determining the altitude of the bed. This has been done by adding or subtracting its distance from some bed exposed on the surface. Moreover, nearly all the roads and some parts of the intervening

areas in the territory have been traversed and the positions of the different rocks noted. These data, taken in connection with drill records, give valuable information regarding the position of the coal beds. It is believed, therefore, that in general the geologic structure of the territory has been determined with a good degree of accuracy.

By grouping the five quadrangles on one map, attention is called to certain features of the structure not so apparent when the quadrangles are considered individually, especially the undulatory character of the folds in the direction of their axes. No such even-crested anticlines or even-bottomed troughs or synclines as have usually been pictured are found in the area represented by the map, and the same is true of the structure of most of the coal fields of western Pennsylvania. The syncline appears to consist of a series of elongated or oval (spoon-shaped) basins, separated along the axes by relatively high divides or buckles, and the anticline of elongated or oval domes or crests, separated along the axis by low "sags," as they may be called. A study of the relative positions of these strings of basins and crests in southwestern Pennsylvania brings out some interesting points. Thus in the Uniontown and Connellsville quadrangles the basins and crests are set in alternate arrangement, whereas in Cambria County they are generally opposite. That is, in the latter region a line normal to the strike drawn through a crest on an anticlinal axis generally cuts through a basin in the adjoining synclines. Though this is generally true there are many exceptions. Thus the high crest on the Laurel Hill anticline in the northeast quarter of the Patton quadrangle is almost on a normal through the center of the deep basins on the Wilmore and Mudlick synclines to the southeast. The highest point on the Nolo anticline, just northeast of the center of the Barnesboro quadrangle, is almost on a line between two low points on the Barnesboro and Brush Valley synclines on either side. The low area on the Clearfield syncline, in the northwest corner of the Houtzdale quadrangle, is almost on a normal with the high knob on the Laurel Hill anticline in the northeast part of the same quadrangle. This whole subject was discussed broadly and more at length in a paper by Mr. Ashley in the report of the Topographic and Geologic Survey Commission of Pennsylvania for 1906–1908, pages 213–217.

The particular object in calling attention to this feature of the structure is its bearing on the possible occurrence of gas. If gas will work its way up the sides of an anticline to the crest, it will also work its way up the crest of an anticline to the highest points of that crest. So that, if there is any gas in a given arch it is most likely to be found at the crest of the high "nodes" or "domes" along the summit of that arch.

PRINCIPAL FOLDS.

Nittany arch.—The most pronounced fold in the region is the Nittany arch, the northwest limb of which crosses the extreme southeastern corners of the Patton and Houtzdale quadrangles. This fold is a great structural feature and to its partial erosion the Allegheny Front owes its existence. As shown on the map, the fold begins on the west, 6 miles from the southeast corner of the Patton quadrangle, and continues with a fairly uniform rise on beyond the limits of that quadrangle. The altitude of the Lower Freeport coal increases from about 1,350 feet at the western base of the arch to 2,400 feet at the corner of the quadrangle. The same arch crosses the southeast corner of the Houtzdale quadrangle. In that quadrangle the Lower Freeport coal bed rises from about 1,450 feet in the Houtzdale syncline to 2,800 feet or more in the southeast corner of the quadrangle.

Wilmore syncline.—The name of the Wilmore syncline is taken from the town of Wilmore, through which it passes. The axis enters the Patton quadrangle a quarter of a mile east of Loretto and continues in a course averaging N. 30° E., passing a mile and a half east of St. Augustine, beyond which it dies out or connects with the Mudlick syncline. This basin is narrow and shallow in the Patton quadrangle, but farther south it is much more important. Between St. Lawrence and the Ebensburg quadrangle the altitude of the Lower Freeport coal along the axis is believed to average about 1,350 feet. This is merely estimated, however, as the only data available are on the surface 300 to 600 feet above the coal bed.

Ebensburg anticline.—The Ebensburg anticline is the Viaduct anticline of the Second Geological Survey, but the term Viaduct has been discarded as not being a geographic term, and the name Ebensburg substituted. The axis enters the territory at Ebensburg, just off the southwest corner of the Patton quadrangle, and appears to run for 5 miles in a course N. 65° E., though its form and extent are rather obscure on account of lack of traceable strata in that area. One and one-half miles north of Loretto the course turns rather abruptly to N. 20° E., in which direction it continues to Chest Springs, where it bears eastward and dies out in the vicinity of St. Augustine. Along its entire length in the Patton quadrangle it is a fold of minor importance, being at its best not more than 200 feet higher structurally than the bottom of the syncline on either side. In breadth it varies from 2 to 3½ miles. The altitude of the Lower Freeport coal along this axis descends from over 1,800 feet at Ebensburg to about 1,500 feet east of Driscoll and 1,200 feet at St. Augustine.

Mudlick and Houtzdale synclines.—The Mudlick syncline is named from Mudlick Creek, in White Township, where the basin is deepest.

It is continuous with the Johnstown syncline lying to the southwest, but as the two troughs are separated by a cross anticline in the vicinity of Ebensburg and are practically independent depressions, they are distinguished by different names. To the northeast it appears to fuse with the Houtzdale syncline in the quadrangle of that name. The two are separated on the map by the corner of the quadrangle east of the Patton quadrangle, the structure of which has not yet been determined and mapped. From Ebensburg the axis of the Mudlick syncline pitches steeply northeastward to a point a mile south of Bradley Junction, thence continues on about a N. 30° E. course to the head of Beaverdam Run. Along Mudlick Run the trough broadens and the position of the axis is less definitely determinable. Apparently a low structural hump lies in the course between Mudlick and Beaverdam runs and causes a westward deflection across the southeast corner of Chest Township into White Township. The hump just mentioned is probably a continuation of the Ebensburg anticline. South of Glendale the axis begins to rise to the northeast and continues to the boundary of the quadrangle. This trough is supposed to be continuous with the Houtzdale syncline of Clearfield County. The determination is based entirely on the Morgantown sandstone member of the Conemaugh formation, the identification of which is not everywhere beyond doubt. The structure as shown by the contours seems about the best that can be determined from existing knowledge. The continuation of this syncline beyond the corner of the unmapped quadrangle, in the Houtzdale quadrangle, will be described as the Houtzdale syncline. The axis enters that quadrangle through the valley of Muddy Run, follows that valley nearly north to a point a mile south of Smoke Run station, then turns to a course north of east directly through Houtzdale and Osceola, whence it turns more nearly north toward Philipsburg, off the eastern edge of the Houtzdale quadrangle. From the south line of the quadrangle to Houtzdale the Lower Freeport or "D" coal has an altitude of 1,400 to 1,450 feet. From Houtzdale eastward the altitude of that coal is irregular, being strongly affected by faults, so that its elevation may vary as much as 90 feet within a short distance. The known position and extent of some of these faults are shown on the map. Their character is discussed more in detail on a subsequent page.

In the Houtzdale quadrangle this syncline is broad and flat, having a width of 3 or 4 miles, but to the southeast the rocks rise abruptly to the Nittany arch. To the northwest the rise is gentle from the axis in Beccaria Township toward the Laurel Hill anticline, which in that region is low. To the northeast that anticline is higher and consequently the rise from the Houtzdale syncline is much steeper.

The positions of the contour lines in the faulted area of this syncline have been worked out from the information available with considerable care, but doubtless they will be subject to revision when fuller information is at hand. It is possible that some of the facts obtained have been misinterpreted.

Laurel Hill anticline.—The Laurel Hill anticline is one of the most pronounced folds in the region and corresponds for many miles in western Pennsylvania with a ridge known as Laurel Hill. This is not so marked a topographic feature here as farther south in the State, but nevertheless the ridge is one of the most extensive belts of highland west of the Allegheny Front. The axis enters the Barnesboro quadrangle just east of Pindleton and runs with a trend averaging N. 40° E., crossing the northern edge of the Patton quadrangle near the boundary between Chest and Beccaria townships. In the Curwensville quadrangle this anticline is nearly cut in two north of Irvona by a transverse fold or syncline. Beyond that place it rises gradually, passing through McCartney, across Clearfield Creek a mile or more north of Belsena Mills, then past Jeffries, near the center of the Houtzdale quadrangle, whence it turns northward, passing just east of Bigler, and leaves the quadrangle about 2 miles west of the northeast corner. The mine workings between Carrolltown and Thomas Mills show several minor deviations from this course, and it is probable that other irregularities exist which can not be correctly mapped until the coal has been more extensively mined and levels taken.

In general, the structure of this anticline seems from the data at hand to be fairly regular through the Barnesboro and Patton quadrangles, the dips being equal on both sides. The highest points of the fold are in Cambria Township, Cambria County, and in Boggs Township, Clearfield County, in both places the altitude of the Lower Freeport coal being nearly or quite 2,150 feet. Between the two points the crest of the anticline is undulating, as shown by numerous mine workings and drill holes. The Lower Freeport coal is about 1,950 feet above sea level east of Elmora, 2,030 feet northwest of Carrolltown, 2,050 feet east of Benedict, and 2,080 feet above Thomas Mills. Northeast of Thomas Mills no mines have been opened, but the correlations by means of sandstones exposed at the surface indicate a local development of the anticline in which the coal bed reaches a height of 2,100 feet. Toward the Curwensville quadrangle the axis plunges, and beyond the Clearfield County line the coal passes below the 1,800-foot contour. North of Irvona the "D" or Lower Freeport coal has descended almost to 1,650 feet. Thence it rises northeastward to 1,725 feet at McCartney, then holds a uniform altitude of about 1,750 feet to the crossing of Clearfield Creek, beyond which it rises steeply to 2,150 feet north of Burly or west of Blue

Ball. From that place it descends to a height of 1,900 feet at the point where it leaves the quadrangle.

In the Houtzdale quadrangle the anticline is broad and has an equal descent to the synclines on either side. The southeast flank of the anticline is made irregular by a number of faults, the displacement at some points amounting to 200 feet. The northwest side likewise may be faulted, but there has been no mining or quarrying on that side to reveal the fault structure, as there has been on the southeast side, except along the Pennsylvania Railroad in the Bigler-Woodland region. In that area faults have been abundantly revealed in the mining of the coal and clay, so it seems a fair assumption that future exploitation of the clay on the northwestern flank of the anticline may reveal a number of faults.

In the center of Cambria Township the Laurel Hill anticline sends off a spur toward the southeast, making a decided cross anticline between the Mudlick and Johnstown synclines.

Barnesboro syncline.—The Barnesboro syncline, best known for its coal workings, was named by W. G. Platt[1] in his Indiana County report (1878) the Centerville synclinal, the name being taken from the town of Centerville, located near the center of the syncline on Conemaugh River. This trough was originally known as the Second Basin, but in the report on Cambria County (1877) Franklin Platt designated it the Ligonier Basin, on the assumption that it is continuous with the syncline of that name occupying the Ligonier Valley. On the map of Cambria County, published in 1888, the trough was named the Westover Basin. There has thus been considerable confusion in the name. Recent work of the United States Geological Survey has shown that the basin is not nearly so prominent a structural feature at Westover as at Barnesboro. Indeed, at Sylvis the basin is nearly divided by a cross anticline. As the term Centerville seems likewise to have gone out of usage, it is necessary to adopt a new name, and for this purpose Barnesboro was selected, the name of the town where mining operations in the basin have been most extensive.

From Wehrum, south of the southwest corner of the Barnesboro quadrangle, the axis of the basin runs about N. 45° E., passing through Nipton and continuing in this direction to a point near the head of Elk Creek. From this point it swings to about N. 25° E., passing just west of Nicktown and thence to Barnesboro, where it makes a bend to the northeast; but between Barnesboro and Plattsville it turns directly north, passing through Shazen, then bends outward through Sylvis to Westover, on the edge of the Curwensville quadrangle. The axis is supposed to pass about one-half mile west of the town of Westover.

[1] Second Geol. Survey Pennsylvania, Rept. H4, 1878, pp. 33, 34.

The Barnesboro syncline is deepest at the southern edge of the Barnesboro quadrangle, where the Lower Freeport coal is supposed to be about 1,400 feet above sea level. The axis rises northward to the northern part of Black Lick Township. In the direction of Nicktown, however, it plunges, the Lower Freeport coal probably descending locally to about 1,400 feet, as indicated by the oval-shaped area near Nicktown.

South of Nicktown the only data available for correlation were furnished by the massive sandstones which outcrop extensively throughout that section. In the region to the north, however, are many extensive mines, and as the operators have kindly allowed the Survey to copy their level maps the contours have been drawn with considerable accuracy. A great number of diamond-drill records furnished by the operators have also been valuable in determining depths of coal beds.

The facts at hand indicate a rather peculiar structure in this region. At Nicktown the basin seems to broaden out and its flat bottom covers an area as much as 2 miles in width. The exact shape of this flat is unknown, for the reason that only along the center of the basin has any mining been done, but from surface exposures and drill records the area included within the 1,500-foot contour appears to be roughly heart-shaped. That there is a small secondary trough about a mile west of the main axis is proved by the levels of Stirling No. 11 mine, which show the 1,540-foot contour to have a decided infolding toward the north.

Although but one mine is located in the center of the basin, the numerous mine and drill holes on the east and west sides have revealed the structure in the vicinity of Barnesboro to such a degree that it has been possible to draw some of the contours with exceptional accuracy. At Barnesboro the horizon of the coal, which has here been removed by erosion, is at an altitude of about 1,500 feet, but as the axis veers to the north it plunges abruptly, and north of Shazen descends below 1,400 feet. From this place it rises gently to nearly 1,500 feet at Westover. Between Shazen and Sylvis, owing to a plunge in the Nolo anticline to the west, this basin nearly connects with the Brush Valley syncline.

Nolo anticline.—The Nolo anticline was named by W. G. Platt from the village of Nolo, 1¾ miles west of the axis, in Indiana County. The crest of the anticline enters the Barnesboro quadrangle at its southwest corner and maintains a course N. 40° E. as far as Grip, passing directly through Pineton and just west of Martintown. At Grip the direction of the axis is a little more to the east, crossing the West Branch of Susquehanna River at Garmans Mills; then it curves to the north and at the Clearfield County line corresponds with the hilltops at this point. Its direction is toward the corner of the quadrangle, but it dies out before reaching Beaver Run.

In the southwest corner of the Barnesboro quadrangle the observations indicate that the altitude of the Lower Freeport coal is just above 1,700 feet. Between this point and Grip lie two conspicuous structural knobs, one at Pineton and the other at Martintown, on both of which the coal rises to the 1,800-foot contour. Northeast from Grip the anticline plunges steeply, the coal descending to 1,600 feet at Garmans Mills and to 1,400 feet at the edge of the quadrangle.

The only place where the exact position of the axis is open to question is just north of Grip, where there is some difficulty in distinguishing between the Upper and Lower Freeport coal beds. At Garmans Mills the axis as represented on the map may possibly be a couple of thousand feet from its correct position. North of this point the data are still less sufficient; nevertheless the sandstones in this region are believed to mark the position of the axis quite accurately.

The Nolo anticline is comparatively a sharp fold, throughout extensive areas having dips up to 3° and in at least one locality as steep as 5°. Throughout the length of the anticline in the Barnesboro quadrangle the dip is steeper on the western than on the eastern side of the axis.

Brush Valley syncline.—The basin west of the Nolo anticline is known as the Brush Valley syncline, from the village of Brush Valley, formerly Mechanicburg. This axis crosses the western edge of the Barnesboro quadrangle about a mile northwest of Kellers Mill and follows a wavy course averaging N. 40° E., passing through Kenwood just west of Pine Flats, east of Cookport, and 1½ miles northwest of Cherrytree.

This basin consists of two canoe-shaped troughs. In the southernmost of these, at the edge of the quadrangle, the coal lies at a minimum altitude of 1,200 feet. Near the junction of Laurel Run with Yellow Creek is a structural "col," where the coal rises to about 1,250 feet, but to the north it plunges and northeast of Cookport is at 1,200 feet or less. The part of the basin lying between Kenwood and the northern edge of the quadrangle is a typical canoe-shaped basin. The bottom of this basin, covering a maximum breadth of over 3 miles, is unusually flat, with dips not exceeding 1°. Southeast of an imaginary line drawn from Pine Flats to Uniontown, however, the dips increase to 3° or 4°. The same is true northwest of a line from Mitchells Mills to the center of the north edge of the quadrangle. The exact shape of the Hazlett Run trough is rather indefinite, but it is believed to be long and narrow, with slight indication of a subbasin in the vicinity of Painters Run. On the eastern side of the Brush Valley syncline the rise of the strata is unusually steep.

In the Punxsutawney quadrangle this syncline continues east of north, passing just east of Burnside and west of Mahaffey in the Curwensville quadrangle. On the west of this syncline the rocks rise sharply to the Chestnut Ridge anticline, but on the east they rise

gradually and indefinitely around the end of the Nolo anticline, joining with the Barnesboro syncline, so that in the middle of the Curwensville quadrangle these two synclines and the intermediate anticline are represented by broad flat areas of slightly rolling structure, the "D" or Lower Freeport coal having an average elevation there of about 1,500 feet above sea level.

Clearfield syncline.—Northeastward from the broad area in the center of the Curwensville quadrangle the basin between the Laurel Hill and Chestnut Ridge anticlines narrows toward Lumber City, from which point it has the structure of a simple syncline, herein called the Clearfield syncline, deepening to the northeast. The axis follows the valley of the West Branch of Susquehanna River, passing east of Curwensville, across the northwest corner of the Houtzdale quadrangle and through the town of Clearfield, to the north of the Houtzdale quadrangle.

In the northeast corner of the Curwensville quadrangle and the northwest corner of the Houtzdale quadrangle the "D" coal has an altitude of about 1,350 feet in the center of the syncline.

Chestnut Ridge anticline.—This is one of the strongest and most persistent folds of the Appalachian Plateau, extending continuously from a point near the southern boundary of the State through Fayette, Westmoreland, Indiana, and Clearfield counties, and beyond to an unknown distance. In the Barnesboro quadrangle this anticline has a length of 8 miles, extending in a fairly direct course from the point where it crosses Two Lick Creek, 1¼ miles west of Diamondville, to the Punxsutawney quadrangle north of Purchase Line. The highest point on the axis in the Barnesboro quadrangle occurs on the northern edge of the quadrangle, where the Lower Freeport coal is about 1,650 feet above sea level. The axis here rises steeply. Two knobs occur on the axis in this quadrangle, bringing the coal up to a maximum of about 1,600 feet east of Taylorville and 1,550 feet south of Two Lick Creek.

In the Punxsutawney quadrangle the Chestnut Ridge anticline passes through East Run and continues northward with a nearly level top almost to Smithport. In this area the top is narrow but flat along the axis, the "D" coal having an altitude of about 1,700 feet. Near Smithport the axis rises and widens by uniting with the Kinter Hill axis from the west, so that in the middle of the Punxsutawney quadrangle the "D" coal has an altitude of about 1,850 feet for a width of nearly or quite 3 miles. Near the northeast corner of Indiana County the anticline rises still higher, so that where the axis crosses, just west of the northeast corner of Indiana County, the "D" coal has an altitude of about 2,050 feet. This altitude is maintained with some regularity along the axis, passing to the north of Newtonburg and on to the Curwensville quadrangle, but it decreases somewhat in crossing the northwest corner of that quadrangle. After

leaving the north edge of the Curwensville quadrangle the axis apparently turns and swings east to a point northwest of Curwensville, where it turns to the northeast. In Grant Township, Indiana County, the total descent of the strata on the east side of this anticline to the Brush Valley syncline is about 500 feet in the space of 5 miles, the greatest dip being 200 feet or more to the mile near the center of the slope. Near Glen Campbell the dip is very steep, the "D" coal descending from 1,800 feet in the divide northwest of Glen Campbell to 1,400 feet or less at Cush Creek. This slope to the southeast continues past McGees Mills and across the northwest corner of the Curwensville quadrangle. There the dip changes from southeast to south or even southwest, in the area north of Lumber City, but changes again to the southeast in the vicinity of Curwensville. Near Curwensville the "D" coal descends from an altitude of 2,000 feet to 1,350 feet in the Clearfield syncline in a space of 3 miles. On the west side of the anticline, in the Punxsutawney quadrangle, north of Smithport, the dip is about the same as that on the east side, decreasing toward the Punxsutawney syncline, but the total descent is greater, as the "D" coal in the center of the syncline around Punxsutawney has an altitude of about 1,100 feet.

Dixonville syncline.—The Dixonville syncline is a relatively unimportant syncline which crosses the northwest corner of the Barnesboro quadrangle. It is broad, has gentle dips, and along its axis the Lower Freeport coal rises from 1,350 feet on the western border of the quadrangle to 1,450 feet on the northern border. After crossing into the Punxsutawney quadrangle the Dixonville syncline follows down Little Mahoning Creek to Robertsville, where it disappears by the blending of the Kinter Hill and Chestnut Ridge anticlines. After entering the Punxsutawney quadrangle from the south the axis rises steeply, so that in the vicinity of Nashville or Ord post office the "D" coal is hardly more than 50 to 100 feet below the position of that coal on the Chestnut Ridge anticline.

Kinter Hill anticline.—The Kinter Hill anticline crosses the west line of the Punxsutawney quadrangle 1¼ miles north of the southwest corner, extends northeastward through Kinter Hill, past the Doty Roundtop, and disappears near the center of the quadrangle by blending with the Chestnut Ridge anticline. The dip of the rocks from this anticline toward the Dixonville syncline on the southeast amounts to 100 to 150 feet. On the northwest the dip toward the Punxsutawney syncline is similar to that from the Chestnut Ridge anticline toward the Punxsutawney syncline in the region farther to the northeast. Between Kinter Hill and Doty Roundtop the Lower Freeport coal has an altitude of 1,800 feet.

Punxsutawney syncline.—The axis of the Punxsutawney syncline enters the quadrangle from the north near the Eleanora shaft, passes

west of south and then south of west through Punxsutawney, following down Mahoning Creek valley. In the center of the syncline, which appears to be quite flat, the "D" coal has an elevation of less than 1,100 feet above sea level. From the center of the syncline the coal bed rises abruptly to the southeast toward the Chestnut Ridge anticline and also toward the northwest corner of the quadrangle.

A broad structural bench appears on the slope between the Chestnut Ridge anticline and the Punxsutawney syncline in the region north and west of Juneau. The shape of this bench was not determined very exactly, but is about as shown. It is believed that the accumulation of gas found in the drillings in this vicinity is due to the presence of this bench.

FAULTS.

A detailed description of the faults in the Houtzdale quadrangle will be given in the economic bulletin on the geology of that quadrangle, to be published by the Survey, and they will be described here only briefly to show their general features. The directions of the larger faults are shown on the map. It may be noted that nearly all run northwest and southeast, or nearly at right angles to the strike, but tend to bear to the west of the northwest-southeast line. An apparent exception exists between Blue Ball and Wallaceton. It is of interest to compare the direction of the faults in this district with the direction of faults elsewhere along the Allegheny Front, as at Cumberland Gap, Fork Mountain, and in the Birmingham region of Alabama, where the cross faults have an almost identical direction with reference to the strike of the rocks. The fact that these faults appear to be confined to a belt a few miles wide, extending back from the Allegheny Front, has led Mr. Ashley to suggest that they may be the result of yielding to the great forces of compression to which these rocks were subjected at the time of their folding, the faults seeming to have directions relative to the assumed direction of the pressure similar to the direction of the cracks in blocks of building or other stone when being tested for strength in the testing machine. Another possible explanation is that these cracks or faults are due to torsional stresses developed where there is a pronounced change in direction of the main structures of the Appalachian region.

The faults appear to be of the type known as "normal"—that is, faults in which the hanging face has gone down (fig. 2), the dip of the face usually approaching the vertical. Faults of this type have usually been assumed to be in a direction parallel to the strike and to be due to tension rather than pressure. It is believed that these faults can be accounted for on the basis of differential yielding under pressure, in which the rocks on one side of the fault yielded more than those on the other and thus "buckled up," with horizontal movement.

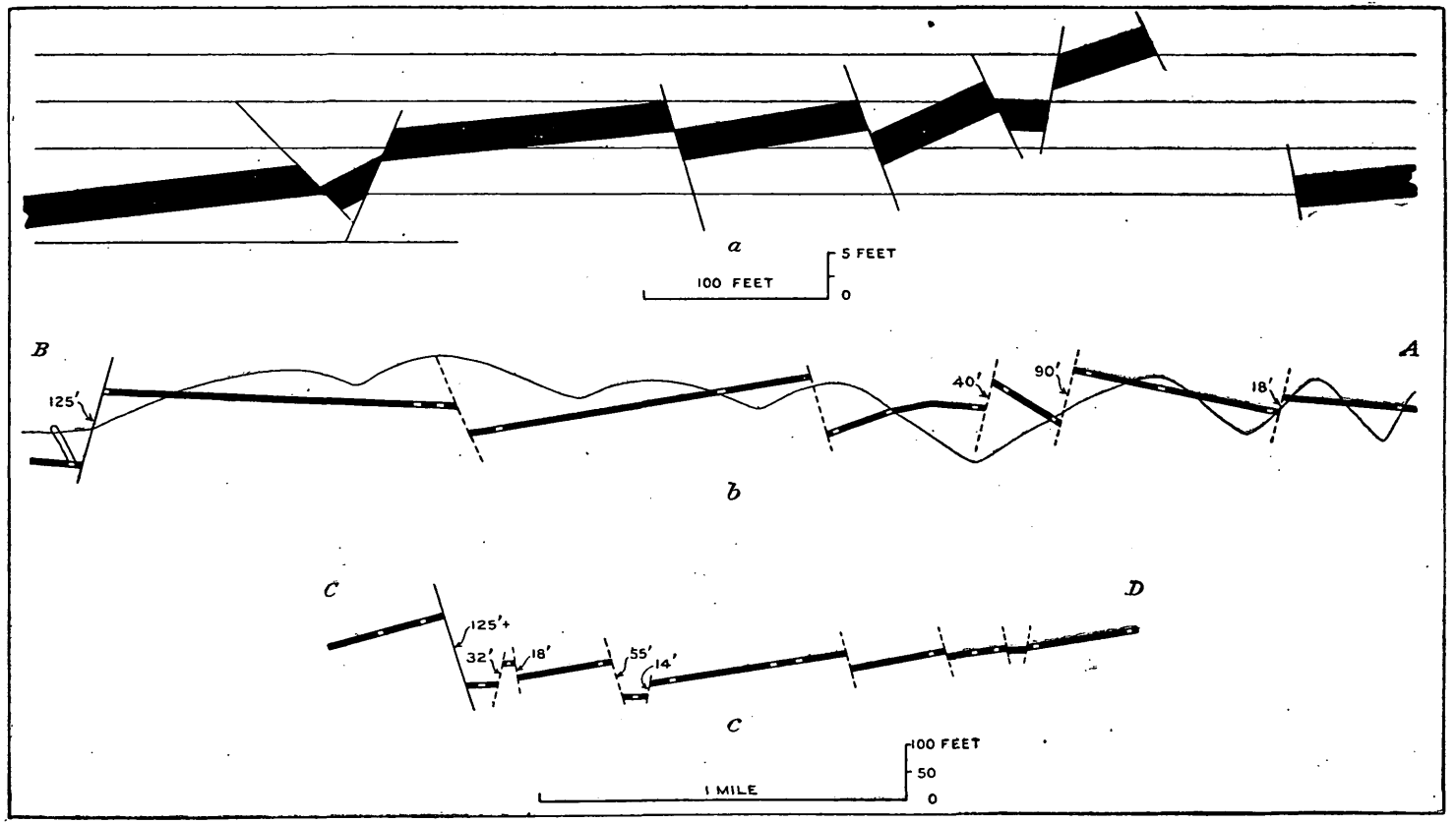


FIGURE 2.—Faults in the Houtzdale quadrangle, Pa. *a*, Series of faults in Plané mine, near Mineral Spring; *b*, series of faults between Houtzdale and Osceola on a line running northeast and southwest through Moshannon; *c*, series of faults along Whiteside Run.

The faults vary in the amount of vertical displacement from zero to 200 feet or more. Some have been found to lie entirely within the confines of a single mine, so that their exact forms are easily determined. In tracing these faults the displacement starts at zero and increases to 20 or 30 feet, then decreases again to zero at a distance from end to end of 1,000 to 3,000 feet. In a number of places a single fault divides. In one place a 50-foot fault separates along a horizontal plane into two faults of 20 feet and 30 feet throw. In some localities the positions of two faults suggest that there has been a separation of the rocks between them so as to allow the intermediate block to drop. Some idea of the general character of the faults is given by figure 2.

Some of the faults do not appear to have affected the coal beds and rocks on either side of the break for more than a few inches or a foot. Along one fault, with a throw of 125 feet, in the Eureka No. 5 mine, the coal runs in places within 2 feet of the fault face without showing any bending toward it. At other places along the same fault the strata bend for a distance of 5 or 6 feet back, so that the roof of the coal descends nearly or quite to the level of the floor a few feet back. In nearly all such places a stringer of coal extends down the fault plane, usually mixed with clay below the level of the underclay of the coal. In some places it has been possible to detect the presence of faults at distances of 50 or 60 feet by the slickensiding in the coal and also by certain slight changes in it, as if it had been somewhat affected by heating, though analysis of this coal does not appear to indicate a higher percentage of fixed carbon or a smaller percentage of volatile matter. The fault faces, as a rule, do not show scratches indicating the direction of movement, but in a few localities such scratches were clearly evident and they are inclined less than 45° from the horizontal, indicating that the movement has been more nearly in a horizontal than in a vertical direction.

RESULTS OF DEEP BORING.

GAS.

As stated below, there is no reasonable hope of finding oil in commercial quantities in the quadrangles here described. Some gas, however, has been found, and, although much of the boring already done has been misguided, the exploration is sufficient to show that gas pools of commercial importance may be present.

In the Punxsutawney quadrangle, which lies near the developed gas and oil fields, between 30 and 40 deep wells have been drilled. These wells have located northwest of Juneau a field yielding sufficient gas for piping to Punxsutawney. The wells of this field (see Pl. VIII) start at the surface in the Conemaugh formation and

obtain gas in part from one of the Devonian sands corresponding closely in position to either the Tiona or the First Bradford sand. The Fifth sand yielded small flows of gas in some of the wells. The upper productive or "Gas" sand, which is thought to be at about the horizon of the Berea or the Hundred-foot sand, is reached at a depth of 1,100 to 1,300+ feet. The pay streaks have thicknesses of 2 to 50 feet, the gas seeming in some wells to come largely from the upper part of the sand, though in others it increased in volume in drilling through the sand. In some wells no gas sand was found, though in others 50 feet of gas-yielding rock was penetrated. However, the "Gas" sand appears usually to be 15 to 30 feet thick.

The gas in the wells varies widely as to pressure and as to duration of flow. In some of the wells barely enough gas was found to light, but in the better ones pressures of 40 to 300 pounds per square inch were observed, and the maximum initial pressure in any well was 425 pounds. The gas in the well last mentioned blew itself out in a couple of months. Those wells which struck but little gas were abandoned at once; others flowed for a year or two, and others were still flowing in 1905. Several wells drilled as early as 1887 were still producing.

A few feet above the "Gas" sand occurs the "Salt" sand that yielded a little gas in a few wells. If the "Gas" sand represents the Hundred-foot sand, the "Salt" sand may represent the Murrysville sand, though it appears likely that the productive or "Gas" sand does not come at the base of the Carboniferous.

A number of the wells were drilled to depths ranging from 2,700 to 2,900 feet, finding a productive sand 10 to 30 feet thick at 2,620 to 2,850 feet. This sand is 1,500 to 1,600 feet below the upper productive sand and is thought to be near the position of the Tiona sand. It is usually a hard white sand, and the gas from it has initial pressures varying from 15 to 140 pounds per square inch.

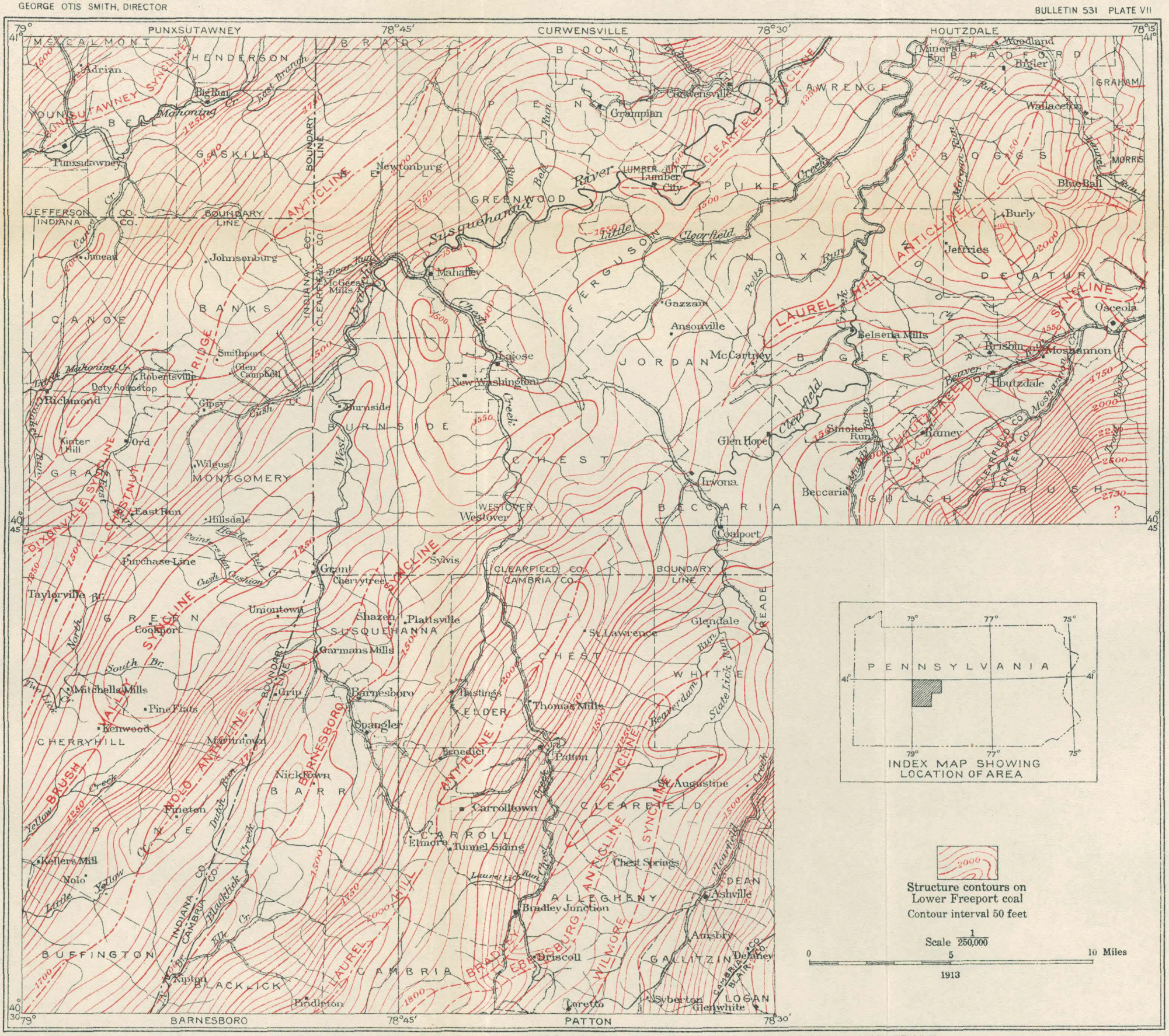
Examination of the structure map (Pl. VII) shows that the gas field northwest of Juneau is on a slightly domed bench on the northwest side of the principal anticline in the quadrangle. The fact that gas occurs on this bench makes it seem likely that drilling on the crest of the anticline may also develop gas. It is therefore suggested that if further drilling is to be done a well be located on the broad crest of the anticline that runs from a point a few miles south of the northeast corner of the Punxsutawney quadrangle along the crest of the ridge north of Newtonburg, past the northeast corner of Indiana County, south of Johnsonburg, through Smithport, west of Gipsy, and west of Wilgus, leaving the quadrangle near East Run. At the same time it might be worth while to try the Kinter Hill anticline, running from a mile or so north of the southwest corner of the quadrangle northward through the center of Kinter Hill and across

Mahoning Creek a little west of the point where the creek turns from a northward to a westward course. The ground on either side of the broad anticline that follows about the direction first given is not likely to be so favorable for striking gas. It should be understood that this area appears to be outside of the oil region, the easternmost oil wells lying west of the northeast-southwest line which crosses the Clarion and Kittanning quadrangles, so that, judging by past experience, no oil need be anticipated in this region.

The following table is a summary, furnished by the T. W. Phillips Gas & Oil Co. (formerly Mahoning Gas & Heat Co.), of the results of 30 borings in the Juneau field in the Punxsutawney quadrangle.

Gas wells in the Punxsutawney quadrangle.

No. of well.	Year drilled.	Year abandoned.	Casing.	No. of sand.	Depth to top of sand.	Thickness of sand.	Depth to bottom of well.	Initial pressure.		Notes.
								Pounds per square inch.	Time.	
			Feet.		*Feet.*	*Feet.*	*Feet.*			
1	.....	.....	.....	Third...	2,620	.....	2,680	.....	.....	
2	1887	1892	.....	Third...	2,710	10	2,720	.....	.....	
3	1889	1890	750	Third...	2,802	15	2,828	.....	.....	Not good; sand hard and close.
4	1889	1892	1,250	.....	.....	.....	2,814	.....	.....	
5	1890	.....	.....	.....	.....	.....	2,777	.....	.....	No gas; no gas sand.
6	.....	1903	1,165	Third...	2,755	18	2,790	15	.....	Very hard white sand.
7	.....	.....	1,277	.....	.....	.....	2,907	.....	.....	Dry sand, hard, close, black.
8	1891	.....	1,118	First....	1,166	24	1,200	.....	.....	
	1894	.....	.....	Third...	2,715	30	2,757	.....	.....	
9	1892	.....	.....	First....	1,203½	.....	.....	.....	.....	Cased to about 700 feet.
	1894	.....	.....	Second..	1,975	.....	2,000	.....	.....	No gas.
10	.....	.....	.....	First....	1,242	49	1,297½	.....	.....	Small amount of gas.
11	1893	.....	.....	First....	1,122	26½	1,154	40	30 min..	Gas at 675 and 800 feet.
12	1894	.....	.....	First....	1,153	37	1,190	.....	.....	
13	1894	.....	.....	First....	1,231	2	1,311	.....	.....	Gas at top of "Salt" sand threw water over top of derrick at intervals for 3 or 4 days.
14	1894	.....	.....	First....	1,102	20	1,243½	.....	.....	Just gas enough to light.
15	1895	.....	1,239	Third...	2,833⅔	22	2,858	140	2 days...	
16	.....	.....	750	Third...	2,864	10+	2,877	.....	.....	Gas increased from 2,864 to 2,874 feet, the gas being on top of sand, as in Nos. 4, 6, and 15.
17	1895	1895	757	Third...	.....	.....	2,933	.....	.....	No gas sand; no gas.
18	1896	1897	1,125⅓	Third...	2,858	17	2,885	115	5 min...	
19	1897	1897	1,114	First....	.....	.....	1,242	.....	.....	No gas sand or gas.
20	1897	1897	1,035	First....	1,120	.....	1,220	.....	.....	No gas or sand.
21	1897	1897	1,050	First....	1,150	.....	1,170	310	24 hrs...	Good well.
22	1898	.....	1,218	First....	1,316	6	1,333	145	24 hrs...	
23	1898	.....	1,152	First....	1,227	29+	1,272	.....	.....	Most gas at 1,256 feet.
24	1899	1899	.....	.....	.....	.....	1,301	.....	.....	Dry.
25	1899	.....	842 574	First....	1,164	15	1,188	.....	.....	Small well, better than Nos. 22 or 23; not equal to No. 21.
26	.....	.....	969	First....	.....	.....	1,409	.....	.....	Very little gas.
27	.....	.....	844	.....	.....	.....	2,000	.....	.....	
28	1900	.....	776	First....	1,220	.....	.....	425	.....	Gas blew out in 2 months.
29	1900	.....	776	First....	1,300	.....	1,341	.....	.....	
30	.....	.....	1,263	First....	1,368	.....	.....	.....	.....	



2000

Structure contours on
Lower Freeport coal
Contour interval 50 feet

Scale 1/250,000

0 5 10 Miles

1913

Base from Punxsutawney, Curwensville, Houtzdale, Barnesboro, and Patton topographic sheets, U. S. Geological Survey

MAP SHOWING THE GEOLOGIC STRUCTURE OF THE PUNXSUTAWNEY, CURWENSVILLE, HOUTZDALE, BARNESBORO, AND PATTON QUADRANGLES OF CENTRAL PENNSYLVANIA

In Clearfield County no well-directed testing seems to have been done. A well drilled many years ago about 2 miles southwest of Clearfield is said to have struck gas at two horizons, supposed to be 300 and 600 feet below the top of the Pottsville formation. A section of this well is shown in Plate VIII. The gas-bearing sands appear to be approximately the same as those in the Juneau field, though the stratigraphic intervals vary.

In the Barnesboro and Patton quadrangles there are several wells in which small quantities of natural gas have been found. Five wells of very light production are located on the Laurel Hill anticline, between Carrolltown and Elmora. It should be remarked that these wells, which are located on or near the axes of anticlines, are the only producing wells in this entire region. The gas from these wells is enough to supply in part the town of Carrolltown. One of them, drilled 23 years ago to a depth of 3,300 feet, is reported to furnish gas at about 2,200 feet. At present very few data are obtainable as to the logs of these wells.

Forty years or more ago a well on the east bank of Susquehanna River, at Cherrytree, was drilled to a depth of 652 feet. In this well, the detailed log of which is quoted from a report by Platt,[1] a heavy flow of gas was struck at 250 feet below the surface, at the base of a tough sandstone 75 feet thick. The stratigraphic position of this sand is not certainly known, though it is supposed to occur between the Lower and Upper Kittanning coal beds. The stratigraphic position of the gas-bearing sand is not clearly determinable because the location of the well is not definitely known, but it is hardly possible that the sand belongs, as supposed by Platt, to the Pottsville formation. The log of the well is as follows:

Log of well at Cherrytree.

	Ft.	in.
Surface, soil, and gravel	33	
Coal	2	
Soapstone (fire-clay shale?)	10	
Sandstone, conglomeratic	40	
Coal	5	
White slate (fire clay?)	8	
Slate, ultimately changing to black carbonated slate	21	
Coal	5	
Fire clay	4	
Sandstone	19	
Coal (thin).		
Slate, changing in color to black	20	
Coal	5	
Fire clay	7	
Massive hard sandstone, heavy flow of gas	75	
Shale	20	

[1] Second Geol. Survey Pennsylvania, Rept. H2, 1877, pp. 178–180.

	Ft.	in.
Sandstone	40	
Hard boring (sandstone ?)	68	
Very hard flint	1	6
Massive sandstone	20	
Black slate	15	
Coal	4	6
Fire clay	5	
Massive sandstone	35	
Shale	5	
Massive sandstone (?)	165	
Shale	2	
Sandstone	18	
Total depth	653	

It will be observed that the location of this well is more than halfway from the axis of the Nolo anticline down into the Brush Valley syncline.

Another well is reported to have been drilled to a depth of 1,000 feet on Clearfield Creek, a few miles northwest of Gallitzin, but nothing is known as to the strata penetrated.

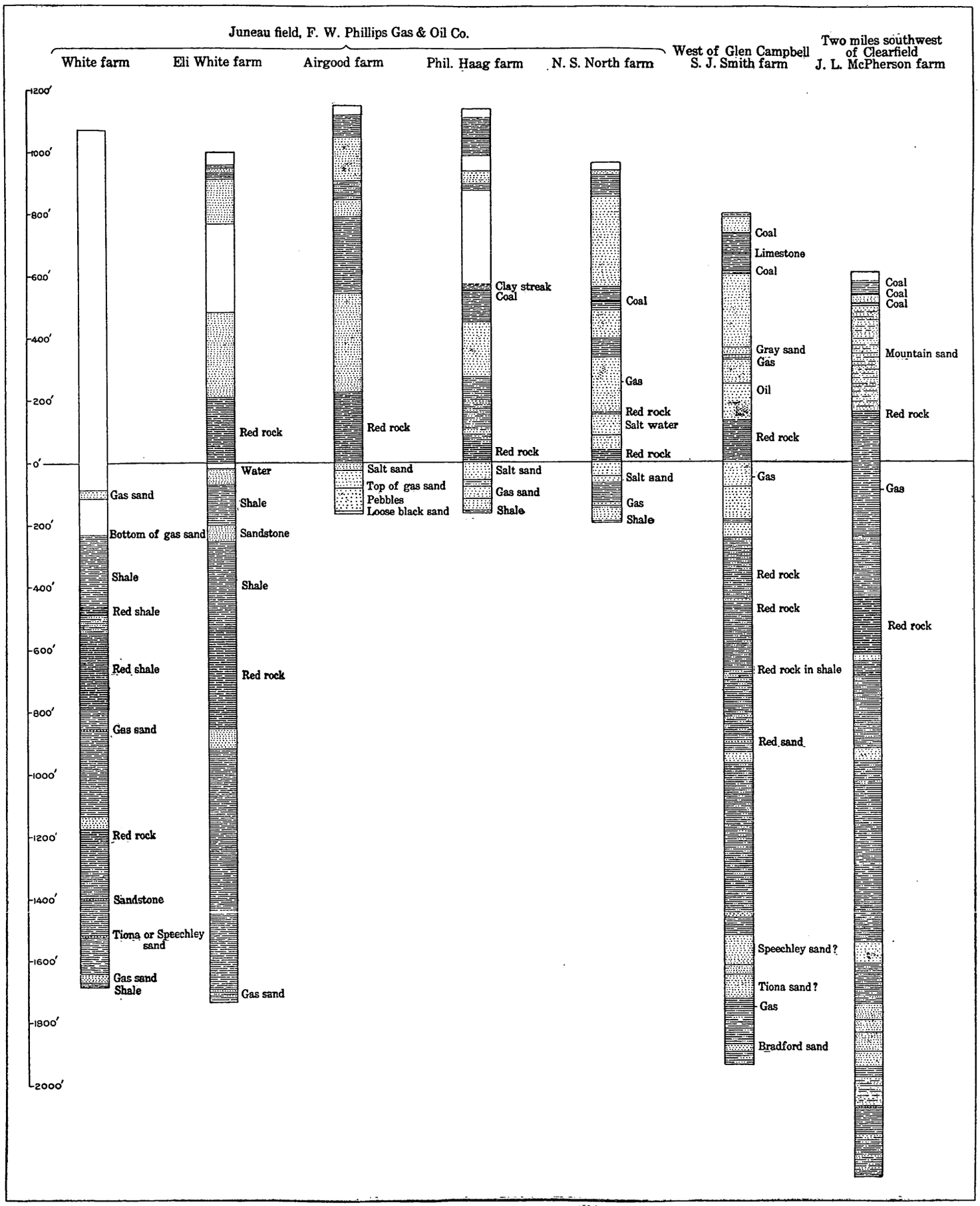
A well was drilled a mile west of Osceola, at the mouth of Beaver Run. It obtained a good flow of water but no gas. As it is directly in the center of the Houtzdale syncline, these results are just what might have been anticipated.

In the region west of the quadrangles here described exploration has been more active and the results in general are more promising. Thus, in the western half of the Indiana quadrangle a number of deep wells were drilled, but gas was found in paying quantities in only two localities, near Creekside, on Crooked Creek, and in the vicinity of Willet, on the South Branch of Plum Creek. The source of the gas in that region is a sandstone lying about 1,100 feet below the Upper Freeport coal and about 400 feet above the top of the red shale which constitutes the upper part of the Devonian system.

WATER.

Throughout much of this region the abundance of good springs has rendered the sinking of deep wells unnecessary, although there are many shallow wells. The deep wells at Ebensburg, Coalport, and Barnesboro, at the tannery at Westover, and on the hills east of Chest Springs are said to yield water of excellent quality.

There are several flowing wells in the territory. Near the town of Wilmore, in the Wilmore basin, 7 miles south of the southwest corner of the Patton quadrangle, there is a well with a strong flow. At Syberton, in the Patton quadrangle, water flows from a deep well. These flows are due to a head of 1,000 feet, caused by the anticlinal structure of the Allegheny Mountain on the east. It is



SECTIONS OF SEVEN DEEP WELLS IN CENTRAL PENNSYLVANIA BORED FOR OIL AND GAS.

probable that when the surface supply becomes contaminated water in abundance may be obtained by deep drilling along the Wilmore syncline. Water is said to flow from a diamond-drill hole on Laurel Lick Run, 1¼ miles southeast of Tunnel Siding, on the western slope of the Bradley syncline. Although it is not certain that favorable artesian conditions prevail throughout the several basins of the quadrangles, the general structure is somewhat promising, especially along the deeper portions of the Wilmore, Mud Lick, Bradley, and Brush Valley synclines.