

of East Franklin Township. In addition to these working banks there are a number along Glade Run that are now abandoned. There is a bank on Buffalo Creek at Fencilton, and a number of abandoned banks on a western branch of Buffalo Run in southern Donegal Township, about 1 to 2 miles northwest of Rattigan. Secs. 32 to 39 of the coal-section sheet show the thickness and character of the seam in those parts of the quadrangle in which it is known.

Upper Freeport coal.—While this seam is, except the Lower Kittanning, the best developed and most valuable coal of the quadrangle, it is worked on a commercial scale only at Karns. It was, however, formerly extensively mined in the vicinity of East Brady, by the Bradys Bend Iron Company, and has been worked out over a considerable area southeast of Kittanning. Aside from the operation at Karns, it is at present mined only at country banks for local use. There are two banks working about 1½ miles south of Chicora and two near Fencilton. There are several banks either working or abandoned south and southeast of Rattigan, toward Nichols. From Rattigan to the western margin of the quadrangle, and also along Buffalo Creek north of Rattigan, surface indications as well as reports indicate that the coal is poor. Near the top of the hill south of Rough Run and 2 miles due west of West Winfield the coal is worked and is of good thickness and quality. There are banks and abandoned workings in this locality and West Winfield, as well as in hills 1 to 2 miles northwest of that place. Near Boggsville and on Cornplanter Run it has been opened in a number of places and found poor, and it is not at present worked in those localities. On Cornplanter Run it is immediately overlain by heavy sandstones, by which it is locally cut out, so that mining is too uncertain to be profitable. About three-quarters of a mile above the mouth of Marrowbone Run there is a working bank. At Betty's mill, 1 mile north of the bank just mentioned, the coal shows in the bluff of the creek. It is about 3 feet thick, but slaty and worthless. At Worthington, judging from indications and reports, it is thin and of little value. In the vicinity of Adams the same seems to be true. Along the axis of the Kellersburg anticline from West Winfield to Browns Crossroads the horizon of the coal passes beneath many of the hilltops. Its blossom shows in some, but it has never been opened up and nothing is known of its value. In the extreme southwest corner of Sugarcreek Township there are several old workings and the coal is probably good. It has been worked near the top of a number of hills in northeastern Sugarcreek and northern Washington townships and is probably of good thickness, though the areas of it are small and in some places the cover is thin. It has been opened near the top of the hill in Madison Township, Armstrong County, near the eastern boundary of the quadrangle, and also has been worked in Madison Township, Clarion County, near the northern margin of the quadrangle. It has been opened in the ravine near the eastern margin of the quadrangle three-quarters of a mile due south of French's Corner, but the opening is now closed. At Cowansville and Cowansville station it is too thin to be of value, but southward along Glade Run to its mouth it has been opened in a number of places and is of good thickness. There are no workings at present along Glade Run except at one point about 1 mile north of North Buffalo. At the tunnel 1 mile southwest of Cowansville the coal is worked, and there are several openings in the ravines within a mile and a half south of this point, indicating that the coal is of good thickness. On Nicholson Run and along the little stream running into Allegheny River between that run and Glade Run the coal is now open at a number of places and is of good thickness. The fact that the Upper Freeport coal is good around so much of the margin of the Boggsville syncline, and the fact that it is noted in numbers of wells in that area, indicate that it is probably of minable thickness over most of the area of that syncline. This coal has been opened in several of the ravines along the western side of Allegheny River from Limestone Run to a point west of Manorville, but it is not worked to any extent. There is a working bank in Rayburn Township 1½ miles northwest of Kittanning, and the coal is stripped in a

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ravine at the eastern margin of the quadrangle 1½ miles east of Ford City. Between these two points along the eastern margin of the quadrangle the coal has been opened at several places and is probably of good thickness all along. In a ravine in the west side of the river opposite Ford City the coal is only 6 inches thick and is probably cut out locally, though to what extent is not known.

On the whole the Upper Freeport coal must be ranked as one of the most valuable resources of the quadrangle. The thickness and character of the seam are indicated in secs. 40 to 55 of the coal-section sheet, while some knowledge of its composition and fuel value is given by the appended analyses (p. 15). The value of the Upper Freeport coal is enhanced by the fact that it makes coke of fairly good quality. It was once largely used for that purpose at Bradys Bend and Kittanning.

Analyses of coals.—In the table (p. 15) below are a number of analyses of samples from the various coal seams of the quadrangle. With two exceptions these samples were collected in the quadrangle. Several of the analyses were made by A. S. McCreath, of the Second Geological Survey of Pennsylvania, and published in Report 115, on Armstrong County. The remainder of the analyses were made by various chemists of the United States Geological Survey. These latter analyses present considerable differences from those made by McCreath. They are higher in fixed carbon and much higher in ash and sulphur. On the other hand they run much lower in volatile hydrocarbons. The fuel ratio is also much higher. These differences may be accounted for in part on the assumption that the two sets of samples were selected differently. The United States Geological Survey samples were taken by stripping a section from the face of the seam about 1 inch deep and 2 inches wide, then thoroughly pulverizing and dividing the samples into quarters and rejecting opposite quarters. This process was repeated until the sample was reduced to a convenient quantity. In taking the section such partings were rejected as are rejected in mining, so that the samples fairly represent the character of the seam.

PETROLEUM AND NATURAL GAS. HISTORICAL STATEMENT.

Development of the petroleum industry.—For the last thirty years petroleum has been a most important source of wealth in the western and northwestern part of the quadrangle, while natural gas has been scarcely less important in other parts during the last twenty years. The first oil wells in the quadrangle were drilled in 1873 at Karns. Development proceeded rapidly and by 1875 the most productive parts of the quadrangle had been discovered and drilled over. Over much of the territory the production of individual wells ranged from 100 to 2000 barrels per day. One well near Chicora, though possibly not in the quadrangle, is reported to have produced 150,000 barrels of oil in nineteen months. The wells flowed at first; as the flow decreased, they were pumped; and as production diminished still further, torpedoing was resorted to in order to keep up the production. Since these early days the production has steadily diminished, until now it is but a small part of what it originally was. Many of the wells drilled in those early days, however, are still pumping small quantities of oil. In the meantime, additional small pools have been developed, and between the main pools many wells have been recently drilled which would not have been profitable in the early days, but which, with cheaper methods of drilling and production and careful management, yield fair returns. Possibly there is more such territory in the quadrangle still awaiting development, and, while the palmy days of the oil industry have passed, oil will long continue to be an important though constantly diminishing source of wealth. The relation of the Kittanning quadrangle to the oil and gas producing areas of the northern Appalachians is shown in fig. 12 on the illustration sheet.

Development of the natural-gas industry.—Since the eighties the production of natural gas has been an important industry in the quadrangle. Gas was first encountered in drilling for oil, and allowed to go to waste, but as soon as its value for fuel and power and its suitability for use in various lines of manufacturing came to be appreciated, and methods of handling it were developed, active operations

began in search of gas itself. These operations were highly successful in many localities heretofore described; larger reservoirs of gas were tapped by the drill and much wealth has been derived from this source. The limits of these large reservoirs have been fairly well ascertained, and, in spite of the fact that many wells have been drilled in other parts of the gas-bearing portions of the quadrangle, no new reservoirs of equal extent and productiveness have been discovered. A number of wells have been drilled to the Speechley sand within the last two years and some notable strikes have been made, especially at Slate Lick and Worthington. The Kerr well at Worthington, drilled in October, 1902, is a good example of the possibilities of the Speechley sand. This well started off at an estimated flow of from 22,000,000 to 30,000,000 cubic feet in twenty-four hours. As late as June, 1903, however, no other well larger than 1,000,000 to 2,000,000 cubic feet in twenty-four hours had been struck in the Speechley sand, and wells have been drilled into it in many parts of the quadrangle. While, therefore, a big well like the Kerr well may be found occasionally in the deeper sands and smaller ones in the upper sands in territory that has not been thoroughly drilled, it seems improbable that any more large and highly productive reservoirs will be discovered; so the production of natural gas is bound to become a much less important source of wealth than in the past.

DESCRIPTION OF THE OIL- AND GAS-BEARING ROCKS.

The oil-producing territory of the quadrangle lies north and west of a curving line roughly drawn through East Brady, the northwestern part of Sugarcreek Township, southward to 1 mile southeast of Coyleville, and thence to the margin of the quadrangle where it is crossed by Rough Run. The remainder of the territory may be regarded as gas bearing to a greater or less extent.

The oil of the quadrangle is mostly obtained from the Third and Fourth oil sands included in the Venango oil group, and the gas from the Murrysville sand, the Hundred-foot sand, and the latter's lower bench, the Thirty-foot sand. In a number of wells, however, more or less gas is obtained from the Third sand and from the Fifth sand below the oil sands. Recently a few good gas wells have been struck in the Speechley sand, several hundred feet below the Fifth sand.

In the discussion of this subject the Vanport (Peciferous) limestone, which has always been a guide to the drillers of the region, is used as a reference stratum.

MURRYSVILLE GAS SAND.

At a varying interval below the Pecora, and separated from it in most of the wells generally by shale, lies the Murrysville gas sand. This sand is generally known in this region as the Butler gas sand, but to avoid confusion with the Butler sandstone, described as a member of the Allegheny formation, the name Murrysville gas sand will be used here, since this is probably the same sand as that from which gas is obtained at Murrysville, in Westmoreland County, and which is widely known as the Murrysville sand. In many wells this sand is an important source of gas; in others it is of much less importance than some of the underlying sands of the oil group, especially the Hundred-foot sand at the top of that group.

Depth below limestone.—So far as available records show, the Murrysville sand was first noted as gas bearing in some of the oil wells near the border of the gas-bearing territory. It is probably represented in wells about Petrolia and Karns by what the drillers call the "1000-foot shells." Northward it probably has no representative. In these wells the top of the sand varies from 700 to 825 feet below the Vanport limestone and from 125 to 160 feet above the top of the Venango oil sands. In the southern part of the quadrangle the former interval may reach 930 feet and the latter as little as 60 feet. Assuming that the sands noted as the Murrysville sand in the different parts of the quadrangle are really the same—a doubtful assumption—there seems to be a gradual increase in its depth below the limestone from north to south and southeast and a gradual approach to the top of the Venango oil sands. In the Allegheny Furnace No. 3 and in the Mont-

gomery No. 3 wells, both near the eastern margin of the quadrangle, the Murrysville sand seems to be almost immediately on the top of the Hundred-foot sand at the top of the Venango "group" or to be separated from the latter by only a few feet of shale, a condition that is noted in many wells farther east in the adjoining quadrangle. In 52 wells selected from the various parts of the quadrangle the average interval between the Vanport limestone and the Murrysville sand is 802 feet, in 47 wells the average interval between the top of the Murrysville sand and the top of the Hundred-foot sand, or top of the Venango group, is 147 feet.

Thickness.—The Murrysville sand varies as greatly in thickness as the intervals above described. In some wells it is a thin layer, in others it may reach a thickness of 100 feet, in others it was not found at all, and in still others it seems to be broken into two benches by a bed of shale of varying thickness.

Extent.—So far as records at hand show, the Murrysville sand can not be identified even as a gas-bearing horizon in the oil regions north of the quadrangle, though gas is occasionally noted in the rocks above the Venango sands. South and east it persists as an important gas-producing rock as far as Murrysville, in Westmoreland County.

Variations.—It is much to be doubted whether the Murrysville sand as noted in the various wells at such varying depths below the Vanport limestone is really one and the same continuous stratum. It seems very certain that the sands occur as discontinuous lenses. It may even be doubted whether these lenses occupy the same geologic plane and are even approximately contemporaneous deposits and that the varying depth below the limestone is due to greater thickness of the intervening strata in some places than in others. The actual condition seems to be that in the 200 feet of strata immediately overlying the "Venango oil group," beds of gas-bearing sandstone occur at various levels, the higher generally lying to the north and the lower to the south, and that the first of these gas-bearing sands encountered in drilling a well has been called the Murrysville sand.

VENANGO OIL SANDS.

The oil produced in the quadrangle comes from a group of coarse sandstones, frequently interbedded with red shale and sandstone, which are believed to lie near the top of the Catskill formation. In descending order these sands are known as the Stray, Third, and Fourth sands, and with several overlying non-oil-bearing sands constitute the "Venango oil sand group" (Carl, Second Geol. Surv. Pennsylvania, Rept. 13, p. 130).

Thickness and depth below limestone.—The distance from the top of the Venango oil sands to the Vanport limestone varies from 920 feet in the northwestern part of the quadrangle to 1000 feet in the southern part. The former interval is shown in the Hazelwood and Evans wells near Karns, just north of the quadrangle, and the latter, which is very extreme, in the Rayburn well near Slate Lick. The average of 61 wells gives the interval at 985 feet. The bottom of the Fourth sand, which seems to be the lowest oil-producing rock, is here taken as the bottom of the "group." It varies from 1250 feet below the limestone in the northwest corner of the quadrangle, as shown in the Hazelwood and Evans wells, to the extreme of 1490 feet in the Lewis Baker well near Slate Lick. Owing to the difficulty of identifying this sand outside the oil-producing territory, there may be a mistake in the latter case and a lower sand taken as the Fourth. However that may be, the depth of the bottom of the Fourth sand, and therefore the depth of the bottom of the "group," increases from north to south just as the depths to the Murrysville sand and the top of the Venango sands increase. Thirty-four wells give an average interval of 1347 feet between the limestone and the bottom of the Fourth sand, and an average thickness for the group of 363 feet.

Character of the sand.—The Venango oil sands form a very well-defined group which has large extent in western Pennsylvania. It is composed predominantly of a series of sandstone beds of varying shape and extent, rarely exceeding 50 feet in thickness, separated by thicker or thinner beds