

of shale. The occurrence of bands of red shale and red sandstone is very characteristic of the group. These are nearly always thin and may occur in any position.

Second or Hundred-foot sand.—At the top of the group lies a sandstone which is called the Second sand in the oil region of northern Butler County, and the Hundred-foot sand throughout the gas-bearing territory of Armstrong County. It is regarded by Mr. Carll as the equivalent of the First sand of Venango County, the change being due to a mistake in the identification of sands when drilling began in northern Butler County. It may be an unbroken bed 100 feet thick or it may be broken by thin bands of shale into three members, which in descending order are called the Second or Hundred-foot sand, Fifty-foot sand, and Thirty-foot sand. So far as the writer is aware this bed never produces oil in this quadrangle, but it is one of the most important gas-producing rocks of Armstrong County.

Blue Monday and Boulder sands.—Near the center of the group two thin sands are noted in many wells, known as the Blue Monday and Boulder sands, the former above the latter.

Stray, Third, and Fourth sands.—The oil-bearing beds are found near the bottom of the group. When drilling began in that part of Butler County in and adjacent to this quadrangle, the first oil-bearing sand was called the Third sand and was supposed to be the equivalent of the Venango Third sand. Later a lower oil-bearing sand was discovered, which was called the Fourth sand. Mr. Carll (Report B) believes, with good reason, that the correlation of the Butler County and Venango Third sands is a mistake, that the Butler Third is the equivalent of the Venango Second sand, and that the Butler Fourth sand really represents the Venango Third sand. However that may be, the names originally adopted for the sands in this region will be used here. These names have been applied to the various oil-producing sands of the region according as the drillers believed that they could identify them as the one or the other, so the oil-producing territory has been divided into Third-sand pools, Fourth-sand pools, etc., and where the sand could not be referred to either of these two sands the name Stray sand was adopted, making here and there a Stray sand pool. The Stray sand is regarded as occupying a higher position than the Third sand. Outside of the type region, near the northwest corner of the quadrangle, where both the Third and the Fourth sands occur, one above the other, it is doubtful whether these sands can be identified with any degree of certainty or that the Third sand of one locality is the same as the Third sand of another locality, and so forth. The Third sand yields a little gas in a few wells in the southern part of the quadrangle.

Variations.—The remarks concerning the variations in the Murrysville sand apply equally well to the various Venango sands. The Venango sands are not persistent but fugitive beds. They appear, thicken, thin out, disappear, and their places are taken by other beds of the same character at a little higher or a little lower horizon, or farther on at the same horizon. Thin bands of sandstone may be separated by thin bands of shale. The shale bands disappear and thick beds of sandstone take their places, or vice versa. Thus there are endless variations, such as may be seen to occur under similar conditions where the beds can be traced at the surface. About the most that can be safely said is that in some localities one or more of the sandstone beds occurring toward the bottom of the group bear oil in paying quantities.

The Fifth sand is recorded in various wells from 50 to 100 feet below the oil sands. It is generally thin. It is an important source of gas in a number of wells in the southwestern part of the quadrangle.

SPEECHLEY SAND.

In nine wells at an average depth of 830 feet below the Venango group occurs a sand 20 to 40 feet thick which recently has been found to bear gas in paying quantities at a number of places within the quadrangle. This is regarded by the drillers and gas producers as representing the Speechley sand of Venango and Forest counties. That name will be provisionally adopted here.

Depth below limestone.—The Speechley sand varies in depth below the Vanport limestone from

2080 feet in the Amos Steele well in Bradys Bend Township to 2320 feet in the Rayburn well near Slate Lick. In ten wells the average interval is 2200 feet. Within the quadrangle this sand has yielded gas in important quantities in only a few wells near Slate Lick and Worthington. It has been pierced in a number of other places, both in this quadrangle and in the Rural Valley quadrangle to the east, without very satisfactory results. In some cases, as in the Amos Steele well, where the interval below the limestone is smaller than usual, it seems possible that the true Speechley was not reached, but that the sand identified as such is a higher one. In other cases, however, as in well No. 21, on the Bradys Bend tract, and No. 13 of the well-section sheet, just north of the quadrangle, and in the Robert Smith well in Winfield Township, the drill penetrated more than a thousand feet below what was regarded as the Speechley sand, but neither oil nor gas was reported in these deeper beds.

STRATIGRAPHIC RELATIONS OF THE OIL AND GAS SANDS.

Under the heading "Rocks not exposed" it has been shown that the Murrysville and Hundred-foot sands probably occur in the lower part of the Pocono formation, the bottom of which is probably close below the bottom of the Hundred-foot sand. The oil-bearing sands proper which occur in the midst of the red beds are assigned to the Catskill formation.

DISTRIBUTION OF OIL AND GAS.

Oil pools.—By examining the structure map it can be seen that the oil and gas are not distributed uniformly throughout the beds in which they occur. In the first place, the portions of the quadrangle yielding the two substances are rather sharply separated, the oil-producing territory being confined to the western side, to the northwest corner, and to the northern margin west of Allegheny River. Throughout the remainder of the quadrangle only gas occurs.

Within the oil-producing portion of the quadrangle the drill has revealed the fact that in certain rather well-defined areas the oil has accumulated in much greater quantities than in the surrounding territory. These very productive areas are generally elongated and comparatively narrow and are called belts or pools. What is true of the accumulation of oil is also true of the accumulation of gas. The mapping of the oil pools is based upon the grouping of producing wells at the present day and probably does not fully represent the pools as they existed previous to the drilling of the territory. Many more large wells were probably drilled in the region between Chicora and Karns than now remain, and that region probably constituted one of the most important belts of the quadrangle.

Relation to structure.—It will be seen by the map that in the western part of the quadrangle the longer axes of the oil pools run in a northeast-southwest direction and that the Fourth-sand pool along the northern margin and the Kaylor pool near Kaylor have a general east-west direction. In both regions the pools, as a general thing, lie low on the flanks of the anticlines and are arranged with their long axes approximately parallel to the structure lines and to the axes of the anticlines and synclines, in accordance with the anticlinal theory of the accumulation of oil and gas. The east-west extension of the Fourth-sand pool along the northern margin of the quadrangle was once believed to be at variance with the anticlinal theory, but at that time the Bradys Bend anticline was believed to follow a straight northeast-southwest course. With the determination of the true structure of the region the facts and the theory are found to be in perfect accord.

The accumulation of gas in the quadrangle seems to be also largely controlled by structure. The main reservoirs of gas have been found across the southern end of the Kellersburg anticline and along the axis of the McHaddon anticline. Many good wells have been struck on both flanks of the Kellersburg anticline, and such wells on the western flank are located east of the oil-bearing territory and higher on the anticline. The gas wells extend lower on the eastern flank of the Kellersburg anticline, where oil does not occur, than on the west, and in the vicinity of Slate Lick a few

paying wells have been drilled to the Speechley sand in the bottom of the Boggsville syncline. A number of good wells were obtained in the Murrysville sand at Ford City near the axis of the Fairmount syncline. The general rule, however, is that the most extensive and most productive gas territory occurs well up on the flanks or along the crests of the anticlines.

Conclusions.—So far as this quadrangle is concerned, a study of the relation of the distribution of oil and gas to structure seems to warrant the following conclusions:

- (1) Where both oil and gas occur in the same basin, as in the region west and north of the crest of the Kellersburg anticline, they are distributed according to their densities, the oil occurring in the lower and the gas in the higher portions of the dipping strata.
- (2) Oil and gas both occur in the synclines, along the pitching axes, where the rocks are descending toward the deeper parts of the synclines.
- (3) Where gas alone occurs, as south and east of the Kellersburg anticline, it may be found in the lower parts of the folds as well as in the parts usually occupied by gas in areas where both oil and gas occur.
- (4) Structure is not the only condition determining the occurrence of gas or oil. The structure may be favorable, yet neither oil nor gas occur. The chief condition other than structure is the existence of rock of such character as to act as a reservoir.
- (5) It is manifestly futile to attempt to follow a gas or oil pool along a 30° or 45° line or along a straight line at any other angle, since the structure lines are curves and not straight lines for any considerable distance.

Clay and shale.

At Kittanning fire clay and shale associated with the Lower Kittanning coal are utilized largely in the manufacture of brick and tile, especially the former. The relationship and thickness of the different beds as they are developed at the quarry of the Kittanning Clay Manufacturing Company are shown in the following section:

Section at Kittanning.

	Feet.
1. Dark clay shale.....	25
2. Lower Kittanning coal.....	3 +
3. Kittanning fire clay.....	12
4. Sandy shale.....	10
5. Buhlstone ore.....	1
6. Vanport (Feriferous) limestone.....	9
7. Dark sandy shale or shaly sandstone.....	10
8. Shale or slate.....	29
9. Little or no coal.....	2
10. Clarion fire clay.....	8 to 10

Shale.—From No. 1 is made a fine vitrified brick for building fronts; from No. 4 are made a vitrified brick and building brick; from No. 7 is made a building brick. No. 8 will be utilized for buff fire brick and for sewer pipe.

Kittanning fire clay.—This is a plastic clay. It is extensively used by the Kittanning Clay Manufacturing Company for buff brick. In places in the clay at this quarry occur thin streaks of coal containing much sulphur, which seriously impairs the quality of the clay.

At Dougherty Brothers' Brick Works, also at Kittanning, the Kittanning fire clay is 7 feet thick and the underlying shale 12 feet thick. Both are used for brick. At West Winfield the Kittanning fire clay has been opened by the Duquesne Fire-Proofing Company, which has established a large plant for the manufacture of clay products. The clay is 11½ feet thick, but more suitable for tile than for brick, since it does not make an article of uniform color.

Clarion fire clay.—At Kittanning the Clarion fire clay is beneath the surface, but it rises rapidly northward, and at Ewing, as well as at the mouth of Cowanshannock, it is about 140 feet above Allegheny River. This is also a plastic clay and from it is obtained the material used in the brick works at Neale and Cowanshannock. At the former place a buff and gray building brick is made and at the latter the ordinary fire brick. At West Winfield, according to the report of the superintendent, the Duquesne Fire-Proofing Company is using this clay for sewer-pipe.

Freeport fire clay.—The Freeport fire clay becomes thick in places and may be profitably used in the future. Immediately south of Chicora

this seam becomes a flint clay, 10 feet or more thick, which apparently has an extent of several square miles. While nothing is known of its qualities, the thickness and extent of the bed and its proximity to the railroad would seem to warrant an investigation on the part of investors. It might become the basis of a profitable industry at Chicora.

It is hardly to be doubted that these beds of fire clay and shale will be found available in other parts of the quadrangle as facilities for shipment are developed.

Iron Ore.

Buhlstone ore.—This ore lies at the top of the Vanport (Feriferous) limestone and was formerly extensively mined along both sides of Allegheny River north of Kittanning and in the northeast corner of the quadrangle, in both Clarion and Armstrong counties, in Bradys Bend Township, and along Buffalo Creek and Rough Run. The ore occurs either as a compact layer averaging 8 inches thick at the top of the limestone or as nodules in the immediately overlying shales. In the former case it may be carbonate, limonite, or impure hematite, according to locality; in the latter case it is carbonate. In its unaltered condition, where it has not been changed by weathering, it is probably always a carbonate. The ore was mined along the outcrop by stripping off the overlying disintegrated material, and in some cases, as along Redbank Creek, where the ore could no longer be obtained by this method, it was obtained by drifting beneath the surface. Miles of these old strippings can be followed around the hillsides in the northeast corner of the quadrangle, in Madison Township, in both Armstrong and Clarion counties. This ore was mined also on Buffalo Creek at Buffalo Mills and Craigsville. It seems likely that about all the ore that could be obtained in close proximity to the various furnaces by this comparatively inexpensive method had been exhausted about the time that the higher grade and less expensively mined ores of the Lake Superior region came into use. These two circumstances, combined with the superior quality of the iron from the lake ores, put an end to the production of iron from the ores of this region.

The carbonate ores unroasted contained 33 to 38 per cent of metallic iron, the other ores often as much as 50 per cent. The most damaging impurities in the iron from these ores was phosphorus and silica, and their presence was due, it is believed, to imperfect methods of smelting and to the use of the Feriferous limestone as flux, which communicated so much phosphorus to the metal that it was unsuited for making Bessemer steel but not for the ordinary uses of mill iron (Second Geol. Surv. Pennsylvania, Rept. H5, pp. ixli-ixlii).

Lower Freeport ore.—This occurs in the southwestern part of the quadrangle, in Winfield and West Franklin townships. It was mined for use at the Buffalo furnace near the top of a hill one-half mile north of the Butler pike, just east of the county line. The ore at this place was regarded by Platt (Second Geol. Surv. Pennsylvania, Rept. H5) as the Upper Freeport, and apparently by L. C. White (Second Geol. Surv. Pennsylvania, Rept. A, p. 94) as the Lower Freeport ore. The writer's observations seem to bear out White's opinion, for the ore in question probably lies from 50 to 60 feet below the Upper Freeport coal, and about 180 to 200 feet above the Vanport limestone, which is opened on the hillside below the old ore strippings. The ore at this point could not be observed, but it is associated with an impure limestone and coal, for debris of both were noted at the diggings. On Rough Run the ore is described by White, in the report referred to above, as occurring about 70 feet below the Upper Freeport coal and 130 feet above the Lower Kittanning coal. It is a mixture of blue carbonate and limonite, running from 1½ to 6 feet in thickness. White expressed the opinion that the ore would probably yield 35 to 50 per cent of iron. This ore largely supplied the old Winfield furnace.

Upper Freeport ore.—This ore was most extensively mined at Bradys Bend. Like the Buhlstone ore, it was mined mainly by stripping, but to some extent by drifting. The old strippings may be seen at the present day in both sides of Holders Run and on the ridge between Harris Run and