STRUCTURE OF THE BEREA OIL SAND IN THE SUMMERFIELD QUADRANGLE, GUERNSEY, NOBLE, AND MONROE COUNTIES, OHIO.

By D. Dale Condit.

INTRODUCTION.

Within the last 12 years the United States Geological Survey has, from time to time, been engaged in mapping the structural features of oil and gas fields in eastern Ohio and southwestern Pennsylvania. The first work was done by W. T. Griswold, who mapped the Berea oil sand in the Cadiz quadrangle, Ohio, and later supervised the preparation of maps for the Steubenville and Flushing quadrangles. In the meanwhile M. J. Munn, E. W. Shaw, and others carried on similar work in western Pennsylvania.

During the season of 1914 a complete geologic examination of the Woodsfield and Summerfield quadrangles, in southeastern Ohio, was made. In this survey the writer was assisted throughout the field season of four months by R. V. A. Mills and Frank Reeves and for a short time by C. A. Bonine. The results of the examination of the Summerfield quadrangle are set forth in a condensed form in this preliminary paper. A similar report has been prepared for the Woodsfield quadrangle. These advance papers are expected to be followed by a geologic folio and an economic bulletin for the two quadrangles, in which more detailed consideration will be given not only to oil and gas, but also to the general geology of the region, including coal and other mineral resources.

The many courtesies extended by the residents of the region during the work are gratefully acknowledged. Thanks are due in particular to the officers of the Carter Oil Co., Pure Oil Co., and Ohio Fuel Supply Co., and to numerous others who furnished maps, well records, and other information necessary to the successful completion of the work. The accompanying farm map (Pl. XXII, in pocket) was compiled from data furnished by the county engineers. It is somewhat inaccurate in places owing to the conditions of the surveys and county records, which are subject to error, especially in Noble County.

GEOGRAPHY.

Location.—The Summerfield quadrangle (Pl. XXIII, in pocket) includes parts of Guernsey, Noble, and Monroe counties, in southeastern Ohio. Its position and extent are represented in figure 13, which also shows other areas in southeastern Ohio and adjacent portions of West Virginia and Pennsylvania for which similar reports have been prepared.

Transportation facilities.—The Summerfield quadrangle is crossed in an east-west direction by two railroads, the Baltimore & Ohio in

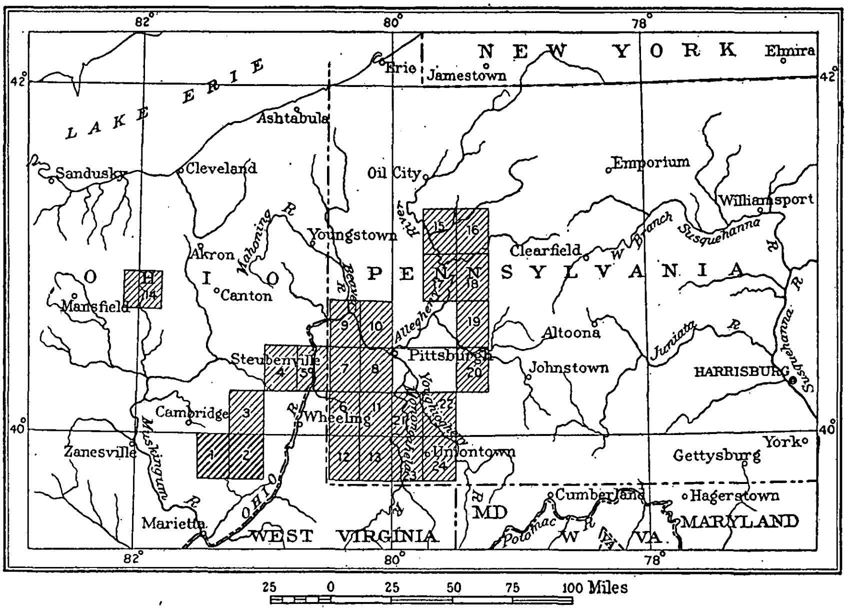

FIGURE 13.—Index map showing location of Summerfield and Woodsfield quadrangles, Ohio (Nos. 1 and 2, heavily shaded), and the names and positions of other quadrangles for which structural maps have been prepared (light shading). 3, Flushing; 4, Cadiz; 5, Steubenville; 6, Claysville; 7, Burgettstown; 8, Carnegie; 9, Beaver; 10, Sewickley; 11, Amity; 12, Rogersville; 13, Waynesburg; 14, Wooster; 15, Foxburg; 16, Clarion; 17, Kittanning; 18, Rural Valley; 19, Elders Ridge; 20, Latrobe; 21, Brownsville; 22, Connellsville; 23, Masontown; 24, Uniontown.

the northern portion and the Ohio River & Western in the southern portion. The latter is a narrow-gage line that follows a circuitous route over hills and valleys, with numerous steep grades. The principal villages in the quadrangle are Sarahsville, Summerfield, Quaker City, Salesville, Lore City, and Senecaville. The last named is a mining town within the great Cambridge coal field. The Upper Freeport coal is reached by shafts here and at numerous points to the west. Higher coal beds cropping out in the southeastern part of the quadrangle furnish a convenient source of fuel for the farmers.

Drainage and relief.—The small areas in the southern part of the quadrangle are drained by Clear Fork of Muskingum River and branches of Duck Creek. These waters follow a rather direct route southward to the Ohio. The greater part of the quadrangle is drained by northwestward-flowing branches of Wills Creek, a tributary of Tuscarawas River. They are sluggish, muddy streams following winding courses in abnormally broad valleys of low gradient. The headwaters divide the hills into numerous parallel ridges of moderate relief, as a rule not more than 350 feet in any one vicinity and only about 480 feet for the entire area.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION.

The rocks at the surface in the Summerfield quadrangle are included in the Conemaugh and Monongahela formations of the Pennsylvanian series ("Coal Measures") and the Washington formation of the Dunkard ("Upper Barren") group of the Permian series. Formations below the surface to a depth of 2,000 feet are known through drill records, which show that as to sequence and general composition they agree rather closely with beds that crop out farther west. The dip or slope of the beds is in general southeastward, but there are numerous local variations in the direction and steepness of inclination. These structural features are represented on the accompanying map and are described under the heading "Structure."

The stratigraphy of eastern Ohio has been discussed in detail in previous reports, and only a brief outline is needed here. The several formations represented, with their approximate thicknesses, are listed below. The classification of the beds below the surface is that in use by the Geological Survey of Ohio.

General section of formations in eastern Ohio.

	Feet
Permian series:	
Washington formation ("Upper Barren")	400±
Pennsylvanian series ("Coal Measures"):	
Monongahela formation ("Upper Productive")	255–275
Conemaugh formation ("Lower Barren")	460–475
Allegheny formation ("Lower Productive")	250–265
Pottsville formation	155–170
Unconformity.	
Mississippian series:	
Maxville limestone (Big lime)	0–90
Unconformity.	
Logan formation (includes Keener sand)	600–700
Black Hand formation (includes Big Injun sand)	
Cuyahoga shale	
Sunbury shale	
Berea sandstone	
Bedford shale	

The Washington formation consists largely of sandstone and clay in which reddish or brownish colors predominate, but it also contains thin coal beds and limestone. Rocks of this formation occupy the hilltops in the southeastern part of the area.

The Monongahela formation contains the Pittsburgh, Meigs Creek, and other workable coal beds. These are interbedded with sandy shale, clay, numerous layers of limestone, and a few nonpersistent sandstones.

The Conemaugh formation contains a few coal beds of little economic importance in this region and several persistent beds of limestone. It is for the most part made up of shale and irregular, localized sandstone lenses interlain with clay, which is commonly of a reddish-brown color.

The Allegheny formation is the great coal-bearing formation in the northern Appalachian coal basin. In eastern Ohio, although only a little more than 250 feet thick, it includes numerous coal and clay beds of great economic importance. The Allegheny and lower formations are not exposed within the Summerfield quadrangle. Their sequence is illustrated by well records and by the general section (fig. 15). The thickness of the strata exposed within the Summerfield quadrangle is a little less than 800 feet. The lowest beds appear at the surface along the valleys in the extreme northwestern part of the area and are overlapped southeastward by successively higher and higher beds. The strata below the surface are known through their outcrop elsewhere and through information furnished by the driller.

ROCKS EXPOSED.

The Upper Freeport coal, constituting the uppermost member of the Allegheny formation, lies in the floor of Leatherwood Valley west of Lore City and is mined at Blacktop, Klondyke, and other places to the west and southwest. Over the coal is the Mahoning sandstone, which is well known among oil men on account of its yield of oil at Lore City and other places to the south. This sandstone may be seen in outcrop along the valley about a mile west of Blacktop. The Upper Freeport coal and higher strata are represented in the generalized section forming figure 14. Several beds in this section are especially useful as key rocks to the geologist because of their persistence and easy identification. Some limestone beds that are present throughout the area are in places more satisfactory for use in the mapping of structure than the coals. The more prominent limestones are described briefly.

The Cambridge limestone crops out along valleys in the vicinity of Senecaville and Lore City. Its position is about 155 feet above the Upper Freeport coal. It is a dark-gray, smooth-textured fossiliferous bed easily distinguished from the other limestones. In numerous places it does not appear as a continuous layer but rather as nodules embedded in clay, and in such places the outcrop is not easily discovered.

The Ames limestone crops out over the northwestern part of the Summerfield quadrangle. It is about 110 feet above the Cambridge limestone and 160 to 195 feet below the Pittsburgh coal. It has a granular texture, is highly fossiliferous, and assumes a greenish-gray to rusty-brown surface on weathering. The freshly broken rock is greenish and shows cleavage faces of calcite, cross sections of crinoid stems, to which is due the granular texture. From 15 to 20 feet above the Ames and a like distance below it are somewhat similar but less persistent limestone beds, and care is required not to confuse these with the Ames.

About 25 feet below the Pittsburgh coal is an important limestone member to which the name "Summerfield" was applied by the writer in 1912,[1] but which, being regarded as the same as the Lower Pittsburgh limestone member of the Conemaugh in Pennsylvania, is here designated by the older name Lower Pittsburgh. This rock has a characteristic roughened, lumpy surface that serves to differentiate it from other beds. Marine fossils are lacking in this limestone and all rocks higher in the geologic column in eastern Ohio.

About 25 feet above the Pittsburgh coal is a thin layer of dark

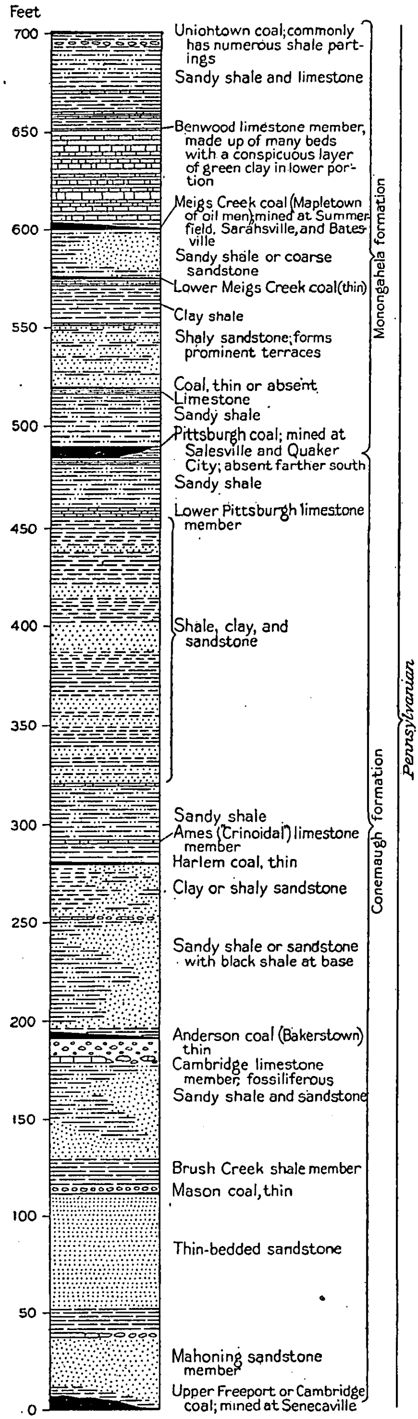

FIGURE 14.—Generalized section of rocks that crop out in the Summerfield quadrangle, Ohio.

[1] Condit, D. D., Ohio Geol. Survey Bull. 17, p. 23, 1912.

shale and limestone which apparently lies at the horizon of the Pomeroy coal. This bed and a limestone underlying the Lower Meigs Creek coal are both excellent structural keys.

The Meigs Creek (Sewickley of Pennsylvania) and Pittsburgh are the only important coal beds cropping out in the area. The Pittsburgh coal, which is so valuable to the east in Belmont County, is present over only a few square miles in the northeast corner of the Summerfield quadrangle. It is mined in the hills at Salesville and Quaker City, but to the southwest, where it is geologically due, only black clay or shale marks its place. The Meigs Creek coal is an important source of fuel in the hills north of Batesville and west of Summerfield, but is not present in workable thickness east of Summerfield or to the north in the vicinity of Calais.

In obtaining elevations on the several beds described above many measurements of the intervals between the beds were made. They were found to vary considerably from place to place. The interval between the Lower Pittsburgh limestone and Meigs Creek coal ranges from 118 to 140 feet where measured at six places in Beaver Township, Noble County, and the interval between the Ames limestone and Pittsburgh coal ranges from 160 feet to about 200 feet in the quadrangle.

ROCKS PENETRATED BY THE DRILL.

Rocks not exposed in the area but known through drilling and outcrops elsewhere are, in descending order, the Allegheny and Pottsville formations, of the Pennsylvanian series, and the Maxville limestone and underlying formations, of the Mississippian series. Their sequence is represented by several well records, given below. The numbers assigned to the wells correspond to numbers used on Plate XXII.

Log of well No. 39 (No. 1 on William Secrest farm), Senecaville.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand and gravel	18	0-18	Sand, blue, limy	6	221-237
Cambridge limestone	4	18-22	Shale	13	237-250
Shale, light red	38	22-60	Slate	18	250-268
Slate	40	60-100	Coal [Lower Kittanning?]	1	268-269
Sand	69	100-169	Fire clay	1	269-270
Coal marker		169	Sand, dark	5	270-275
Fire clay	20	169-189	Fire clay	6	275-281
Sand	27	189-216	Sand, show of oil	4	281-285
Coal [Lower Freeport?]	2	216-218	Fire clay.		
Fire clay	3	218-221			

Log of well No. 126 (No. 2 on Silas McLoughlin farm), sec. 19, Seneca Township, Noble County.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Ames limestone	3	45-48	Sand (record incomplete).		
Shale	57	48-105	Sand	20	680-700
Sand	55	105-160	Shale	100	700-800
Fire clay, bad cave (record incomplete).			Sand	20	800-820
			Shale	47	820-867
Sand	55	275-330	Sand, Keener (show of oil at 878 feet)	143	867-1,010
Fire clay	10	330-340	Shale	15	1,010-1,025
Sand	10	340-350	Sand, Big Injun	10	1,025-1,035
Shale	15	350-365	Shale	391	1,035-1,426
Coal marker		368	Berea sand (oil at 1,432 feet).		
Sand, show of gas	62	368-430	Total depth		1,436
Shale	45	430-475			

Log of well No. 535 (No. 1 on M. A. Rader farm), near Summerfield.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Coal, Mapletown or Meigs Creek	4	0-4	Big Injun sand, white	25	1,090-1,115
Coal [Lower Freeport?]	4	722-726	Big Injun sand, black	45	1,115-1,160
Coal [Middle Kittanning?]	4	771-775	Big Injun sand, white	123	1,160-1,283
Stray sand	15	775-790	Lime and shale	264	1,307-1,571
Schramm sand	40	835-875	Slate and lime	55	1,571-1,626
Big lime	25	960-985	Berea sand (gas)		1,669
Keener sand	12	1,070-1,082	Total depth		1,676

OIL AND GAS SANDS.

Few other oil fields have as many producing sands as are found in southern Noble County and the adjacent portion of Washington County, to the south, there being at least ten sands that are productive at one place or another in this area. However, many of these have proved of little importance, and the principal sands in the Summerfield quadrangle are only five in number. These, named in ascending order, are the Berea, Big Injun, Keener, Big lime, and Buell Run sands. The chief objective sand in the search for oil in this quadrangle is the Berea, well known from exposures at Cleveland, Ohio. A few wells have been drilled deeper than the Berea sand; these, with two exceptions, prove that the Berea is underlain by a great thickness of shale practically devoid of oil-bearing sands in eastern Ohio. The Clinton sand, which yields much oil and gas in the central and northeastern parts of the State, lies at least 3,000 feet below the Berea sand, if present in this area.

Names are applied by oil men to nearly every sand penetrated in drilling, and these sands, together with the associated coals and limestones, are represented in figure 15. The oil men are far from consistent in their use of several of the names applied in the section. For example, the term Second Cow Run is applied to almost any

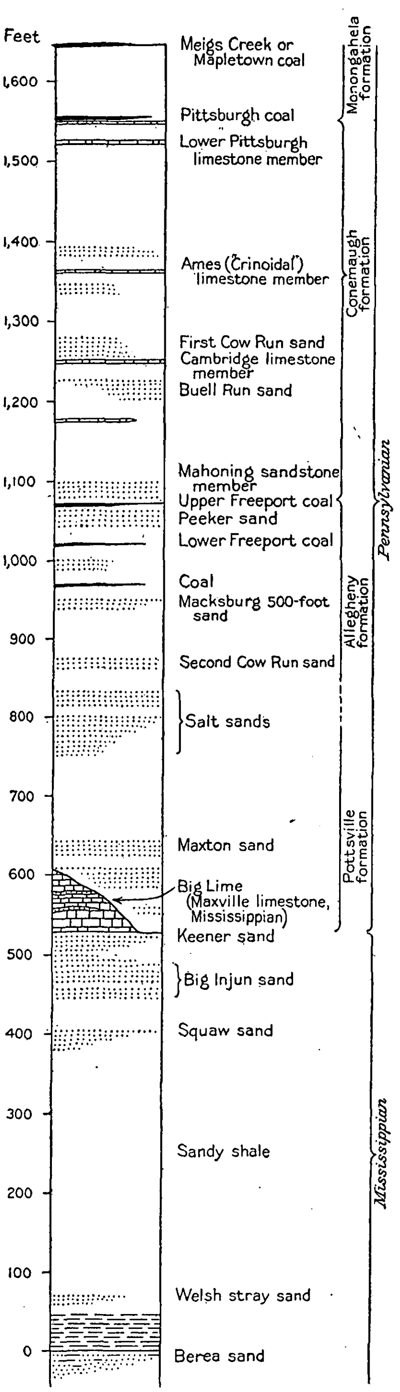

FIGURE 15.—Generalized geologic section showing oil sands of Summerfield quadrangle, Ohio.

sand 100 to 500 feet below the First Cow Run. Names applied to the sands in the Summerfield quadrangle are in part derived from the Macksburg and other pools in Washington County, Ohio, and in part from localities in western Pennsylvania and northern West Virginia. The same sand may be designated by several names in different localities. The confusion of terms is to be expected, for none of the sands maintain a uniform thickness over any considerable area, and in not a few places several of them are found combined into one great mass of sandstone. Locally, the sands are "broken" into a series of alternating beds of shale and sandstone or are even entirely missing and only "shells" are recorded in their places.

No large oil pools have been discovered in the Summerfield quadrangle, but a considerable area still remains untested. The principal production is limited to three fields—one at Chaseville, where there are several dozen small oil and gas wells; a second, the Smith pool, in the Buell Run sand, near the southwest corner of the quadrangle; and the third in the vicinity of Summerfield, where one of the most valuable and enduring gas fields yet found in the Berea has been developed.

The Berea sand is probably the most important source of oil and gas in southeastern Ohio. It is the principal productive sand in the great Scio pool, in Harrison County; the Macksburg pool, in

Washington County; and the "Grit" pool at Woodsfield, Monroe County. The position of the Berea is about 1,375 feet below the Ames or "Crinoidal" limestone at Chaseville, and 1,550 feet below the base of the Pittsburgh or No. 8 coal at Quaker City. At Summerfield it is about 1,665 feet below the Meigs Creek or No. 9 coal (Mapletown). The distance of the Berea below the beds near the surface is far from uniform, varying as much as 80 feet in the Summerfield quadrangle and several hundred feet in other quadrangles. The correction in the mapping of the Berea necessary because of this variation in interval is described on page 227.

The Berea varies considerably in thickness, being at most 48 feet, as found in the Chaseville field, and diminishing to less than 10 feet near Salesville. In texture also the sand varies widely from place to place, being locally so shaly and fine grained that it is recorded as "shells" or "no sand" by the driller. Elsewhere it may contain several feet of gray to white fine-grained sand which is known as the "pay." Some wells pass through several of these porous layers interbedded with dense impervious layers. The position of the pay sand varies, being near the top of the formation at Summerfield and near the bottom at Chaseville. Immediately above the Berea sandstone is the black Sunbury shale, which is persistent throughout eastern Ohio and which serves the driller as a notice of the nearness of the Berea sand.

The Big Injun sand is, in general, coarser textured than the Berea and commonly contains quantities of salt water, which not infrequently brings to an untimely end the yield of gas and oil found within the sand. The sand is the source of a small quantity of oil at Brister, 3 miles east of Summerfield, and yields gas at several points near Summerfield and at Chaseville. It has generally one or more shale "breaks" but in some wells is recorded as a continuous bed 200 feet thick, though here and there it is almost entirely replaced by shale. This great diversity is not peculiar to the Big Injun but is characteristic of all sands in the area, especially those in the "Coal Measures."

The Keener sand is generally separated from the underlying Big Injun by shale and is closely overlain by the Big lime. It supports a few oil wells in the Chaseville pool but is far less productive than in the Woodsfield quadrangle, to the east, where it is the principal sand in a number of oil fields.

The Big lime is apparently missing at Chaseville but is recorded in a well recently completed near Sarahsville. Where present it ranges in thickness from a few feet to nearly 100 feet. Its absence in places is attributed to erosion which took place in Carboniferous time subsequent to the deposition of the limestone, and the uneven upper surface thus produced is evident in numerous outcrops in central and southern Ohio. The Big lime is of little value as a source of oil and gas in this area, only small quantities of either having been found in a few wells in the southeastern part of the quadrangle. Farther east at Lewisville and several other localities in Monroe County and southern Belmont County it has yielded large quantities of oil and gas. The oil occurs in layers of quartz sand which are interbedded with shaly limestone.

Several small pools of oil have been found in comparatively shallow sands in the southwestern part of the Summerfield quadrangle. Among these are sands known as the Second Cow Run, Macksburg 500-foot, Peeker, and Buell Run. Of these the most productive is probably the Buell Run. Their positions are represented in the diagram (fig. 15). Below is given a section of a well in the Buell Run sand at Low Gap, Enoch Township. From the position of the Buell Run sand it evidently lies between the Cambridge limestone and the Mahoning sandstone of the general section (fig. 14, p. 221) and is probably the Buffalo sandstone of geologists.

Log of well No. 599 (No. 4 on E. W. Wickham farm), sec. 33, Enoch Township.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Coal, Mapletown (Meigs Creek)	5	25-30	Buell Run sand	42	363-418
Red rock	105	200-305	Pay sand (oil)		418
Lime with gas (140-foot sand)		365			

The Mahoning sandstone is saturated with oil at many points near Senecaville and Lore City, and this oil is even so plentiful as to be a nuisance in some of the mines in the underlying Upper Freeport coal. It is interesting to note that some of the shallow sands support valuable oil wells at points less than 3 miles from their outcrops. Several wells near Britton station, a little beyond the southwest edge of the quadrangle, have for more than 40 years yielded oil from a sand that is probably the Buell Run. The depth of these wells is less than 100 feet, and the productive sand may be seen in outcrop a few miles north of the town of Caldwell.

STRUCTURE.

PREVAILING DIP.

The prevailing direction of slope or dip of the rocks in eastern Ohio is southeastward. The region forms the west side of a broad, shallow basin which constitutes the Appalachian coal field. The slopes of this basin are far from uniform and are traversed by numerous minor wrinkles that form anticlines and synclines. These are very insignificant when the basin is considered as a whole, but their influence in the accumulation of petroleum and natural gas has long been known, and for this reason accurate mapping of them is of importance to the oil operator.

PREPARATION OF STRUCTURAL MAP.

There are several methods of preparing structural maps of oil sands. Where an area has been extensively drilled and the sands recorded are easily recognizable, it is necessary only to determine the elevations of a large number of well heads from which, if the depth of the oil sand beneath each well head is known, the lay or attitude of the sand can be determined. Another method, employed in this investigation, is to obtain a large number of elevations on some persistent outcropping stratum, such as a coal or limestone. The region under discussion is favored with a number of excellent key beds, which can be used together for this purpose. The intervals between the several beds do not vary greatly from place to place, and all lie nearly parallel to the shallow oil sands.

In preparing the map of the Berea sand that accompanies this report elevations were determined on about 1,000 outcrops. The instrument used was the Gale telescopic alidade, and bench marks of the United States Geological Survey were used as starting points for the traverses. The resulting elevations of the several key beds were then reduced to one datum, the Pittsburgh coal, by the addition or subtraction of the appropriate interval for each bed. With the elevation of the Pittsburgh coal thus determined throughout the area the position of the upper surface of the Berea sand at each point was calculated. Unfortunately, the undulations and flexures of the Berea sand do not exactly coincide with those of the Pittsburgh coal and other strata near the surface, and this discrepancy necessitates a correction. The refinement with which this correction can be made depends upon the number of well records available. The total variation in the Pittsburgh-Berea interval for the entire Summerfield quadrangle is about 80 feet. The change is not constant in any one direction and varies rather abruptly over small areas, and for this reason the correction can be applied with precision only in areas where many well records are available. In some portions of the quadrangle the wells are several miles apart, and it is probable that between these wells many local variations in the interval exist for which no correction can at present be made. The interval, as shown in all wells of which correct records are obtained, is recorded on a drawing known as the convergence sheet, which is described in an earlier report of the Survey.[1] The drawing indicates the amount

[1] Griswold, W. T., and Munn, M. J., Geology of oil and gas fields in Steubenville, Burgettstown, and Claysville quadrangles, Ohio, West Virginia, and Pennsylvania; U. S. Geol. Survey Bull. 318, pp. 23-24, 99-113, 1907.

to be subtracted from each elevation of the key bed (Pittsburgh coal) in order to determine the position of the Berea at any point in the area. This amount in the Summerfield quadrangle is greater than the elevation of the Pittsburgh coal, showing the Berea to be considerably below sea level. In order to avoid using the minus sign in numbering the contours of the oil sand, 2,000 feet is added to each elevation of the key bed. This is equivalent to assuming a datum plane 2,000 feet below sea level for the map of the oil sand. After subtracting from each elevation of the key bed plus 2,000 feet the appropriate number, as shown by the convergence sheet, contour lines connecting points of equal elevation are drawn at 10-foot intervals. The resulting contour map, a representation of the lay or attitude of the upper surface of the Berea sand, is given on Plate XXII. On this map are shown all wells drilled up to the date of completion of the report. The locations of many coal test holes are also represented. All wells drilled to the Berea are represented in red. Wells drilled to shallower sands are represented in black, the appropriate abbreviation being used for the sand where known.

SALIENT STRUCTURAL FEATURES.

The structural contour map shows the Berea sand to lie at 1,690 feet above the assumed datum plane, or 310 feet below sea level, in the northwest corner of the area and at 1,220 feet (780 feet below sea level) in the southeast corner. This indicates a drop of 470 feet southeastward across the quadrangle. From the map it will be seen that the dip is not uniform in direction or magnitude, there being places where the rocks lie nearly flat for a mile and abruptly drop 50 feet or more in the succeeding mile, thus producing terrace-like structures. The general southeastward direction of dip is varied by minor flexures that extend across the faces of the terraces, producing downfolded embayments, which alternate with promontory-like benches, such as those 2 miles southwest of the village of Summerfield.

The principal anticlinal fold of the area extends through Chaseville in a northeasterly direction. This fold is bordered on the northwest by a shallow synclinal depression and on the southeast by a comparatively steep slope for a distance of about 2 miles. In the Chaseville oil and gas field it assumes the form of a dome, but toward the northeast it becomes less prominent. Another anticlinal fold extends southward from Quaker City to the vicinity of Summerfield and is paralleled on the west by a synclinal trough. East of Quaker City, at the edge of the quadrangle, is a shallow syncline, succeeded in turn by another anticline along which lies the Barnesville oil and gas field. The major anticlinal and synclinal folds are varied by numerous minor cross flexures, which produce the anticlinal "noses" and embayments already described.

RELATION OF STRUCTURE TO ACCUMULATION OF OIL AND GAS.

The occurrence of oil and gas pools along the crests or slopes of anticlines has been demonstrated at so many places during the 40 years since the introduction of the anticlinal theory that no one can fail to recognize the importance of these structures in oil accumulation. An excellent illustration is furnished in the Chaseville oil and gas field, in the western part of the Summerfield quadrangle, where the gas occupies the high portion of the anticlinal dome and is flanked by an oil-producing belt a little lower on the slope. The conditions there indicate a fairly open-textured sand, which permitted the circulation of water currents. It is conceivable that the oil particles were gathered from the steep slopes to the southeast and carried upward and united into the body of oil along the narrow terrace indicated by the contours. The Berea oil sand is regarded by the writer as probably saturated with salt water throughout the area, and while the oil and gas particles are in circulation they are buoyed up by the water and tend to accumulate near the crests of arches. Thus it would appear that Chaseville furnishes an example of the simplest application of the anticlinal theory, where the oil sand is fairly open-textured, saturated with salt water, and bent into an anticlinal arch. A study of other oil and gas pools indicates that this combination of ideal conditions is not usual and that there are numerous modifying influences which must be considered. For example, well-defined anticlines are far from plentiful in southeastern Ohio, and more commonly the arches are merely promontory-like "noses," such as that in the extreme southeast corner of the Summerfield quadrangle. Another modifying factor is the condition of the sand. The Berea is not made up of a single sheet of open-textured sand readily permeable by water but consists for the most part of hard, compact, fine-textured "lime" or "shells" with localized beds of "pay" sand of lenticular shape and only a few feet thick. Such is the condition in the Summerfield gas pool, where the pay sand is compact and of variable thickness, and the pool is bordered on the south by several "dry holes," in which "no sand" is reported by the drillers. The limited extent of the lenticular pay sand has prevented the migration of the gas up the slope to a location structurally more promising, and it is retained on the flank of a shallow synclinal embayment.

The quantity of salt water yielded by wells in this field, though very slight, is not believed by the writer to indicate incomplete saturation, but rather to show that the rock is so fine in texture that it holds the water, even though it rises in the rock as the gas is exhausted.

The water conditions in the Big Injun and other shallow sands are decidedly different from those in the Berea. In many wells the water flows from the sand into the hole and rises within a few hundred feet of the surface, and the flow is so great that it can not be reduced by bailing. Oil wells found in these sands are commonly brought to an untimely end by being "drowned out."

SEARCH FOR NEW POOLS.

The study of the Berea oil sand in the Summerfield and other quadrangles of southeastern Ohio forces the conclusion that conditions of oil accumulation are controlled by so many intangible factors that no one can with certainty predict the location of oil pools in advance of drilling. The structural map, even though made most carefully, may not accurately represent the surface of the Berea sand in a country that has been little drilled, owing to the variable distance of the Berea below beds that lie near the surface. Furthermore, it does not follow that oil or gas will be found in even the location structurally most favorable, for the reason that the accumulation in pools is controlled by many factors, such as the trend, extent, and texture of a lens of pay sand and its degree of saturation with salt water. It is noteworthy, however, that even in a sand such as the Berea most of the pools closely follow the strike of the rock or in other words extend parallel to the structural contours. The utility of the structural map in predicting the extension of pools after the first successful wildcat well is drilled is thus at once evident. In addition the driller will be able to determine in which direction the next location should be made in order to find the oil sand at a higher point after a well showing oil and considerable salt water has been drilled.

In selecting territory favorable for prospecting in the Berea no points in the south third of the quadrangle can be regarded as promising on account of the poor condition of that sand as reported in numerous test holes. This is especially true in the vicinity of Sarahsville and the region south of Summerfield. It is probable that many gas wells will yet be drilled in the Summerfield pool, especially at the northeast end, but the finding of any considerable accumulation of oil seems improbable.

In the vicinity of Kennonsburg there is a large untested area. It lies along the southeast slope of the Chaseville anticline, and to the east the rocks drop about 100 feet in a distance of 2 miles. The terrace on the west side of the village and also to the northeast, along the 1,500-foot contour, would seem favorable territory for prospecting. There is also a possibility of finding oil or gas along the crest of the axis 3 miles due east of Senecaville. Territory almost equally favorable lies a little east of the syncline in Beaver Township, along the valley of Beaver Creek 1 to 2 miles west of Batesville.

Extensions of the Chaseville oil pool along the strike will probably be made. The chances of finding a valuable accumulation of oil on the northwest side of the anticlinal axis seem slight, for the reason that the anticline is paralleled by a shallow syncline that furnishes only a small gathering area from which the oil could be collected.

Since the preparation of this report a gas well in the Berea sand has been drilled 1½ miles northeast of Mount Ephraim. Another discovery is a gas well near Sarahsville, reported to be in the Gordon sand. This is of interest, but probably not of great importance, as this is the second place in eastern Ohio where gas has been obtained from the Gordon. The other place is at Macksburg, in Washington County.

A structural map prepared for the shallow sands shows that the small pools in the southern part of the quadrangle are intimately related to troughlike folds, although this is not so evident on the map of the Berea sand. This map can not be included here but will appear in a report now in preparation, in which detailed attention will be given to the oil fields and also to coal and other mineral resources in the Summerfield quadrangle.

QUALITY OF THE OIL.

The oils of this region are shown by analyses to be of the best Pennsylvania grade, ranging from 36° to 50° Baumé in gravity and from light amber to dark green in color. Asphalt and sulphur are lacking, and the percentage of paraffin ranges from 2.5 to more than 10. A number of analyses have been published by the United States Geological Survey.[1]

PUBLICATIONS.

The United States Geological Survey has published the following bulletins concerning oil and gas fields in eastern Ohio and adjacent parts of West Virginia and Pennsylvania:

198. The Berea grit sand in the Cadiz quadrangle, Ohio, by W. T. Griswold. 1902. 43 pp., 1 pl.

286. Economic geology of the Beaver quadrangle (southern Beaver and northern Allegheny counties), Pa., by L. H. Woolsey. 1906. 132 pp., 8 pls.

318. Geology of oil and gas fields in Steubenville, Burgettstown, and Claysville quadrangles, Ohio, West Virginia, and Pennsylvania, by W. T. Griswold and M. J. Munn. 1907. 196 pp., 13 pls.

346. Structure of the Berea oil sand in the Flushing quadrangle, Harrison, Belmont, and Guernsey counties, Ohio, by W. T. Griswold. 1908. 30 pp., 2 pls.

456. Oil and gas fields of the Carnegie quadrangle, Pennsylvania, by M. J. Munn. 1911. 99 pp., 5 pls.

541–A. Oil and gas in the northern part of the Cadiz quadrangle, Ohio, by D. D Condit. 1913. 9 pp., 1 pl.

621–H. Anticlines in the Clinton sand near Wooster, Wayne County, Ohio, by C. A. Bonine. 1915. 11 pp., 1 pl.

[1] U. S. Geol. Survey Mineral Resources, 1913, pt. 2, pp. 1212–1217, 1914.