# ANTICLINES IN THE CLINTON SAND NEAR WOOSTER, WAYNE COUNTY, OHIO.

By C. A. Bonine.

## INTRODUCTION.

The "Clinton" formation on the eastern flank of the Cincinnati anticline crops out in a narrow band extending in a north-south direction across Ohio and dips to the east under the great Appalachian coal basin. It has generally been assumed that the eastward dip is fairly regular and that where oil and gas pools have been found in the Clinton sand they are due to arrested dips or terrace structure, a structure that has been regarded widely in the State as particularly favorable for the accumulation of oil and gas since Orton's demonstration that it is the prevailing type in the Lima field.

Although some geologists engaged in private work state that they have mapped local anticlines and synclines in the Clinton sand and have found these folds to be the cause of the pools of oil and gas, very few such data have been published. It is therefore a common belief, especially in the northern part of the State, that no very definite relation exists between such folds and pools of oil and gas.

The Wooster oil and gas field was examined by the writer to determine, if possible, whether there is such a relation and, if not, to find what condition determined the location of the pools. The conclusion reached, after a detailed examination of the field, is that the accumulation of the oil and gas has been largely controlled by geologic structure. The gas occurs along the crest and sides of a sharply folded anticline pitching to the southeast and is confined entirely to the fold. Small quantities of oil are found along the flanks of the anticline, and a fairly large pool of oil occurs close to it, southeast of the gas field. It does not necessarily follow from these conclusions that all the Clinton gas or oil pools are due to the influence of anticlinal structure, but it establishes the fact that some of them are. A more definite knowledge of the structure should aid in the selection of locations for drilling.

Thanks are due to the Ohio Fuel & Supply Co. for well logs furnished and for the location of more than half of the wells shown on the accompanying map; Mr. W. M. Holland, of the Ohio Oil Co., and Mr. James Burtner, of the Columbia Chemical Co., for well logs and general information; to Mr. B. K. Maitland for well logs; to Mr. H. B. Odenkirk for drill samples; and to many other companies and persons for assistance.

## LOCATION AND SURFACE FEATURES.

The Wooster oil and gas field lies in northeastern Ohio, in the western and southern parts of Wayne County. Wooster, the largest town in the area, has a population of approximately 6,500 persons. It is on the Fort Wayne division of the Pennsylvania Railroad and the Millersburg branch of the Baltimore & Ohio Railroad.

The stream valleys in the vicinity of Wooster are generally steep sided and in places thickly wooded, but the slopes of the upland are more gentle and have been mostly cleared of timber and put under cultivation. Killbuck Creek, which is the major stream in this region, flows in a southerly direction. It occupies a valley averaging a mile in width, with steep sides but a floor so flat that in places it is swampy. Apple Creek, its main tributary, joins it a little south of the town of Wooster after a circuitous course through the country to the east. The surface relief along this stream is not so pronounced and the valley floor is not so wide as along Killbuck Creek. The many smaller streams which flow into Killbuck Creek from the east and the west have generally steep-sided narrow valleys covered with timber. The elevation of the valley of Killbuck Creek ranges from about 880 feet above sea level northwest of Wooster to about 840 feet at the southern boundary of the area considered. The highest point in the region is Munser Knob, which has an elevation of about 1,280 feet. It is 4 miles east of Shreve and 1 mile east of Killbuck Creek, near the southern boundary of the area represented by Plate XIII (p. 96). In the Wooster oil and gas field the difference in elevation of the creek and the hilltops is about 200 feet.

Four areas of development are included in this field, three of which yield gas and one oil. The oil pool, one of the few of economic importance yet found in the Clinton sand, is about 2½ miles due south of Wooster. It is, according to present development, about 2 miles long in a northeast-southwest direction and three-quarters of a mile wide at the widest point. The Wooster gas pool lies from 1 to 2 miles south and west of the town. It is approximately 4½ miles in length and half a mile or less in width and is being rapidly extended to the northwest. The Lattasburg gas pool is about 7 miles north-

west of the Wooster gas pool. The Shreve gas pool lies about 1 mile east of the town of Shreve and 8 miles southwest of Wooster. It is not yet well defined, as drilling began very recently.

## HISTORY AND DEVELOPMENT.

The first well drilled to the Clinton sand in the vicinity of Wooster is on the Quimby Jones farm, in the west edge of the town, near the point where the Baltimore & Ohio Railroad track crosses the Lincoln Highway. In this well, which was completed in May, 1910, by Barnhart & Maitland, a small show of oil and gas was obtained. In the following summer another well was drilled by the same company on the McSweeney farm, three-quarters of a mile north of the Jones well. This well is reported to have produced 2,500,000 cubic feet of gas in 24 hours, but the supply rapidly diminished, and water leaking through the casing drowned the gas. On September 10, 1911, the well of the Columbia Chemical Co., on the John Rockey farm, 2½ miles south of Wooster, was completed. Its initial production was at the rate of 2,500,000 cubic feet in 24 hours in open flow, with a rock pressure of 1,025 pounds to the square inch. Encouraged by this showing, the company drilled its next well on the Charles Correll farm, about half a mile east of the Rockey well. A 60-barrel oil well was the result. Drilling for oil was greatly stimulated by this discovery, and the oil field, as now defined, was rapidly developed. Fifty-four producing wells and eight dry holes have resulted from this drilling. The largest initial production was 175 barrels for the first 24 hours from the Albright No. 4 well. At present the daily production averages six barrels to the well. The Frank No. 3 well is the latest addition to the field and is producing 40 barrels a day.

The demand for gas being greater than for oil, drilling for gas was begun in the fall of 1913 by the Arco Oil Co. on the Edward Adair farm, 2 miles southwest of Wooster. The well was completed in October and a flow of 10,000,000 cubic feet of gas was obtained. After this remarkable showing, Murphy Bros. drilled five holes on the Charles Munsen farm. All were good producers, the initial production of the smallest well being about 6,000,000 cubic feet in 24 hours and that of the largest 12,000,000 cubic feet. Forty-three producing gas wells, several dry holes, and a few small oil and gas wells have been drilled in a strip of country 4 miles long and half a mile wide since the discovery of gas in the Adair well in 1913. At present this field is being rapidly extended to the northwest, and many wells are being drilled in adjacent untested territory.

The gas wells in this field do not maintain their initial daily capacity for any great length of time but rapidly diminish in volume and

pressure. Wells drilled about 18 months ago, which had an initial production of 5,000,000 to 15,000,000 cubic feet a day and a rock pressure of 1,025 pounds to the square inch, are now producing at the rate of 500,000 cubic feet open flow with a rock pressure of 180 pounds.

## FIELD WORK.

The examination made by the writer was begun in December, 1914, but owing to adverse weather only a few days were spent in the field at this time. The work was completed in the later part of April, 1915. As the object of the study was to determine the structure of the Clinton sand with respect to sea level as a datum plane, most of the time was spent in running spirit-level lines from United States Geological Survey bench marks to the mouths of wells and in collecting well records.

No attempt was made to map or study the surface rocks of the area, because the absence of any persistent key rock or stratum, such as a coal bed or limestone outcropping at the surface, the presence of two or possibly more unconformities in the sections of rocks between the Clinton sand and the surface rocks, and the abundant cover of glacial drift render futile any attempt to determine the attitude of the Clinton sand by examination of the exposed rocks.

## GEOLOGY.

### GENERAL SECTION.

For the information of those not familiar with the geologic formations of Ohio and for convenience in interpreting the well logs of this field, the following table of formations is given:

*Generalized section of rocks in the Wooster oil and gas field, Ohio.*

| System. | Formation. | Driller's name. | Thickness in feet. | Character. |
|---|---|---|---|---|
| Quaternary (Pleistocene). | Glacial drift. | Sand and gravel. | 0–75 | Bowlder clay, sand, pebbles, shale fragments, and bowlders. |
| Carboniferous (Mississippian). | Cuyahoga formation. | (?) | 500–650 | Dark shales with interbedded sandstones and sandy shales. |
| | Sunbury shale. | | | Black argillaceous bituminous shale. |
| | Berea sandstone. | Berea grit. | 30–60 | Medium-grained gray to buff-colored sandstone. |
| Devonian or Carboniferous. | Bedford shale. | Ohio shale. | 1,300–1,370 | Black and brown carbonaceous shale containing numerous "iron stone" concretions. |
| Devonian. | Ohio shale group. Cleveland shale. | | | |
| | Ohio shale group. Chagrin formation | | | |
| | Ohio shale group. Huron shale | | | |
| | Olentangy shale. | | | |
| Unconformity | Delaware limestone. | Big lime.[a] | 1,030–1,080 | Brown, blue, and gray limestones, containing a few thin sandstone and shale beds in the lower portion. |
| | Columbus limestone. | | | |
| | Monroe formation. | | | |
| | Niagara limestone. | | | |
| Silurian. | "Clinton" formation. | Little lime probably belongs here. | (?) | Gray or red sandstone and dark shale, with interbedded limestone layers. |
| | | Clinton sand. | | |
| | "Medina" shale. | Medina red rock. | (?) | Red clay shale. |

[a] This should not be confused with the Big lime of Pennsylvania, West Virginia, and Kentucky, which is of Carboniferous age.

The rocks exposed at the surface in the Wooster field are dark shale of Mississippian age, with interbedded sandstone and sandy shale. These rocks are for the most part concealed by a mantle of glacial drift, being exposed only where erosion has been active in removing the surficial material.

## FORMATIONS.

*Well logs.*—The character and thickness of the rocks as described by the driller in reaching the Clinton sand are shown in the following well logs, selected from different parts of the field. The descriptions of the rocks are quoted as given by the drillers.

*Logs of wells in the Wooster oil and gas field, Ohio.*

**Charles and J. J. Pressler No. 1 well, drilled by Lupher Drilling & Contracting Co. November 29, 1914.**

| | Thickness. | Depth. |
|---|---|---|
| | *Feet.* | *Feet.* |
| Gravel and sand | 40 | 40 |
| Sand and slate | 126 | 166 |
| Slate | 334 | 500 |
| Berea grit | 30 | 530 |
| Slate | 1,299 | 1,829 |
| Lime | 1,081 | 2,910 |
| Salt water in lime | ..... | 2,051 |
| Slate | 50 | 2,960 |
| Shell | 33 | 2,993 |
| Slate | 54 | 3,047 |
| Clinton sand | 32 | 3,079 |

**Curtis W. Thompson No. 1 well, drilled by Arco Oil Co. April 12, 1914.**

| | | |
|---|---|---|
| Berea grit | 60 | 710 |
| Interval | 815 | 1,525 |
| Little Cinnamon | 75 | 1,600 |
| Interval | 100 | 1,820 |
| Big Cinnamon | 120 | 1,700 |
| Interval | 180 | 2,000 |
| Big lime | 1,100 | 3,100 |
| First salt water in lime | ..... | 2,260 |
| Salt | ..... | 2,630 |
| Second salt water in lime | ..... | 2,920 |
| Interval | 30 | 3,130 |
| Red rock | 8 | 3,130 |
| Interval | 22 | 3,168 |
| Little lime | 35 | 3,195 |
| Interval | 18 | 3,213 |
| Stray sand | 1 | 3,214 |
| Interval | 34 | 3,248 |
| Clinton sand | 18 | 3,266 |

**Charles Correll No. 1 well, drilled by Columbia Chemical Co.**

| | | |
|---|---|---|
| Berea grit | 50 | 580 |
| Interval, slate | 1,354 | 1,934 |
| Big lime | 1,021 | 2,955 |
| Second salt water in Big lime | ..... | 2,844 |
| Interval | 135 | 3,090 |
| Little lime | 33 | 3,123 |
| Interval | 59 | 3,182 |
| Clinton sand | 24 | 3,206 |
| Total depth | ..... | 3,218 |

**William T. Stitt No. 1 well, drilled by Lupher Drilling & Contracting Co. March 26, 1914.**

| | | |
|---|---|---|
| Sand and gravel | 72 | 72 |
| Sand and slate | 128 | 200 |
| Interval | 440 | 640 |
| Berea grit | 40 | 680 |
| Slate | 1,370 | 2,050 |
| Lime | 1,030 | 3,080 |
| First salt water in lime | ..... | 2,280 |
| Second salt water in lime | ..... | 2,940 |
| Slate | 95 | 3,175 |
| Shell | 40 | 3,215 |
| Slate | 105 | 3,320 |
| Clinton sand | 11 | 3,331 |
| Total depth | ..... | 3,348 |

None of the well records obtained were taken with sufficient detail to permit a careful study and correlation of the formations cut by the drill. The drillers have, however, in nearly every log recognized the broader lithologic differences in the strata passed through and have made their records accordingly. The following paragraphs, in which the drillers' terms are used, are intended to give general descriptions of these rocks.

*Medina red rock.*—The oldest and deepest rock reached in the Wooster field, called Medina red rock by the drillers, is possibly equivalent to the Medina formation of New York. It consists of red clay shale, having in some places a mottled appearance due to the presence of purplish shale layers. None of the well logs record the thickness of this formation, as drilling was stopped when the top was reached.

*Clinton sand.*—Next above the Medina red rock is the oil and gas bearing formation commonly known as the "Clinton." The drill records show that this formation consists of sandstone and shale, with interbedded calcareous or limestone layers. The principal sand, from which most of the oil and gas is obtained, lies near the base of the formation and is known to the drillers as the Clinton sand. It is in most places a fine-grained compact gray rock, although in some wells a considerable thickness of reddish sandstone is recorded. The thickness of this sandstone in the Wooster field ranges from a few feet to 44 feet, and a few wells report no sand at all. Above this sandstone are several small "stray sands" and limestones, interbedded with dark-gray shale. One or more of these sands is oil bearing in a few localities. "Red rock" is reported in many of the wells a short distance above the Clinton oil sand. This is regarded by the drillers as an indication of the nearness of the sand. It is possibly the same ferruginous material which farther east becomes much thicker and constitutes the Clinton iron-ore bed.

*Big lime.*—The base of the Big lime in this field is a blue-gray magnesian limestone with several thin layers of shale and sandstone. Considerable quantities of salt water are generally encountered 120 to 130 feet above the base.

The limestone forming the middle portion of the Big lime is blue-gray and brown in color and corresponds in chemical composition to a dolomite—that is, a magnesian limestone. A salt bed 40 feet thick occurs about 600 feet below the top of the Big lime, and salt water is found from 200 to 250 feet below the top. The upper 200 feet of the Big lime is composed of brown and blue granular limestone, which contains interbedded layers of brown calcareous shale near the top.

The Big lime shows a gradual thickening toward the east in the oil and gas fields of northeastern Ohio. Along Lake Erie its thickness

increases from 850 feet at Norwalk to 1,470 feet west of Cleveland. In the northeastern part of Cleveland a thickness of 1,720 feet is recorded, but this is probably a local expansion, as the Hermitage well, near Mentor, farther east, shows a thickness of 1,580 feet. A well at Mansfield gives the thickness of the Big lime as 915 feet, and one at Barbertown, 30 miles farther east, shows 1,415 feet. At and north of Wooster considerable irregularity in thickness is shown, and a noticeable thinning of the Big lime toward the east for a distance of about 10 miles is illustrated by the records of a number of wells. Northeast of Jeromeville the Big lime is 1,155 feet thick; farther east, near the edge of the Wooster gas field, it is 1,081 feet; in the Wooster oil field, about 1,030 feet; and north of Mount Eaton, 1,365 feet.

*Ohio shale.*—Above the Big lime is a mass of black and brown bituminous shale, known to geologists as Olentangy shale, Ohio shale, and Bedford shale. All these formations collectively are known to the driller as Ohio shale. Small quantities of oil and gas have been found in this shale, but not in paying quantities. Like the Big lime, this shale also thickens toward the east, but the increase is more rapid and constant. The well at Mansfield records 700 feet of shale between the Berea sandstone and the Big lime; a well near Hayesville, 13 miles east of Mansfield, 920 feet; the Pressler No. 1 well, 3½ miles west of Wooster, 1,299 feet; the Stitt No. 1 well, 3 miles south of Wooster, 1,370 feet; and the S. P. Beats well, near Mount Eaton, 1,490 feet. This is an increase of 970 feet in about 37 miles, the thickness being more than doubled. At Wooster, where the thickness can be determined in greater detail by reason of the abundance of the wells, there appear to be some irregularities, but the general eastward increase in thickness still holds good.

*Berea grit.*—The Berea grit is one of the widest-known and best horizon markers in Ohio. Although it generally averages less than 75 feet in thickness, it is a remarkably persistent formation and is used by oil men and geologists as a key for drilling and for the mapping of structure. It is one of the most prolific oil sands in the State, but in the Wooster field has never been found to contain oil or gas in paying quantities. Salt water occurs abundantly in the Berea at Wooster and is always cased off in drilling. This formation is a medium-grained gray to buff-colored sandstone having a tendency to break into slabs. In the Wooster field it ranges from 30 to 60 feet in thickness.

From the Berea grit to the surface in this vicinity the drill encounters a series of black and blue shales and gray sandstones of Mississippian age, about which the well records obtained give

no information. The thickness of these rocks from the top of the Berea to the surface, including a cover of glacial material, varies from 500 to 650 feet, depending on the location of the well.

## STRUCTURE.

Sedimentary rocks as originally deposited on the floor of the sea are essentially horizontal or nearly so. The modification of the original attitude of these rocks by earth movements produces geologic structure of various types. An upward fold or arch is called an anticline, and a downward fold or trough a syncline. Where rocks have been so tilted as to cause them to dip in one direction only, the resulting feature is called a monocline. Any condition tending to arrest this monocline produces a structural terrace or flattening of the rocks. The axis of a fold is the line marking the highest points of an anticline or the lowest points of a syncline. Structure contours are lines represented as drawn through points, on the top or bottom of a stratum of rock, that have the same elevation above or below a given horizontal plane, generally sea level.

The Wooster oil and gas field is situated along the northern part of the eastern flank of the Cincinnati anticline and is a little west of the outcrop of the Pottsville and Allegheny formations, which mark the northwestern limit of the great Appalachian coal basin. The surface rocks and those cut by the drill have a general dip to the east and southeast of about 50 feet to the mile. This dip has been flattened in many places, producing structural terraces. Cross folding of a more or less intense character has likewise taken place, producing anticlinal and synclinal folds at right angles to the strike of the formations. These folds are especially pronounced in the Clinton sand and exist in a modified form in the Berea sandstone. The surface rocks near Wooster are not well exposed, and consequently it is difficult, if not impossible, to determine whether or not they are similar in structure.

The principal structural feature of the gas field, as shown by the 10-foot structure contours drawn on top of the Clinton sand on Plate XIII, is the sharp, steeply pitching anticline west and southwest of Wooster, along the crest and sides of which the gas has accumulated. The narrowness of the gas-producing area is due to the sharpness of this fold, and the presence of dry holes in close proximity to large gas wells is also partly explained by this fact. Although reported as dry holes, some of these wells produced gas, but not in paying quantities. As far as the anticline has been followed toward the northwest there is no indication of its diminution, but its form and position in this area can be told positively only by more drilling in secs. 1, 2, and 12 of Plain Township. There seem to be two possibilities—either

that the Wooster anticline extends northwestward in untested territory, as indicated on Plate XIII by the broken axial line, or that the anticline dies down suddenly and possibly breaks up into a number of minor wrinkles. According to the first hypothesis, the small fold in sec. 36, Chester Township, would be a secondary wrinkle on the flank of the major anticline. Similar structure is suggested in secs. 5 and 6 of Wooster Township by several dry holes, small gas wells, and an oil well.

On the second hypothesis the axial line would follow the most pronounced of the smaller folds, which might be the one to the north shown on Plate XIII. The first hypothesis seems the more plausible, but the second must be regarded as a possibility, even though it involves possibly a curving fold. If these cross folds are due to torsional stresses in the rocks, curved axial lines are not improbable, and long, straight folds are hardly to be expected.

Not enough drilling has been done in the vicinity of Lattasburg, which is about 8 miles northwest of Wooster, to enable the geologist to determine the details of structure. The altitude of the sand in the wells shows that there is only a very slight dip to the east or southeast and suggests a fairly broad, level structural terrace. Although it is a common belief in the field that the Wooster anticline continues indefinitely toward the northwest and serves to connect the Lattasburg and Wooster gas fields, the lack of such a connection is indicated by the drilling done in the area between these fields, because of the discordant altitude of the sand and the nonproductiveness of the wells. On the other hand, the Lattasburg pool is certainly connected with the Ashland field to the southwest.

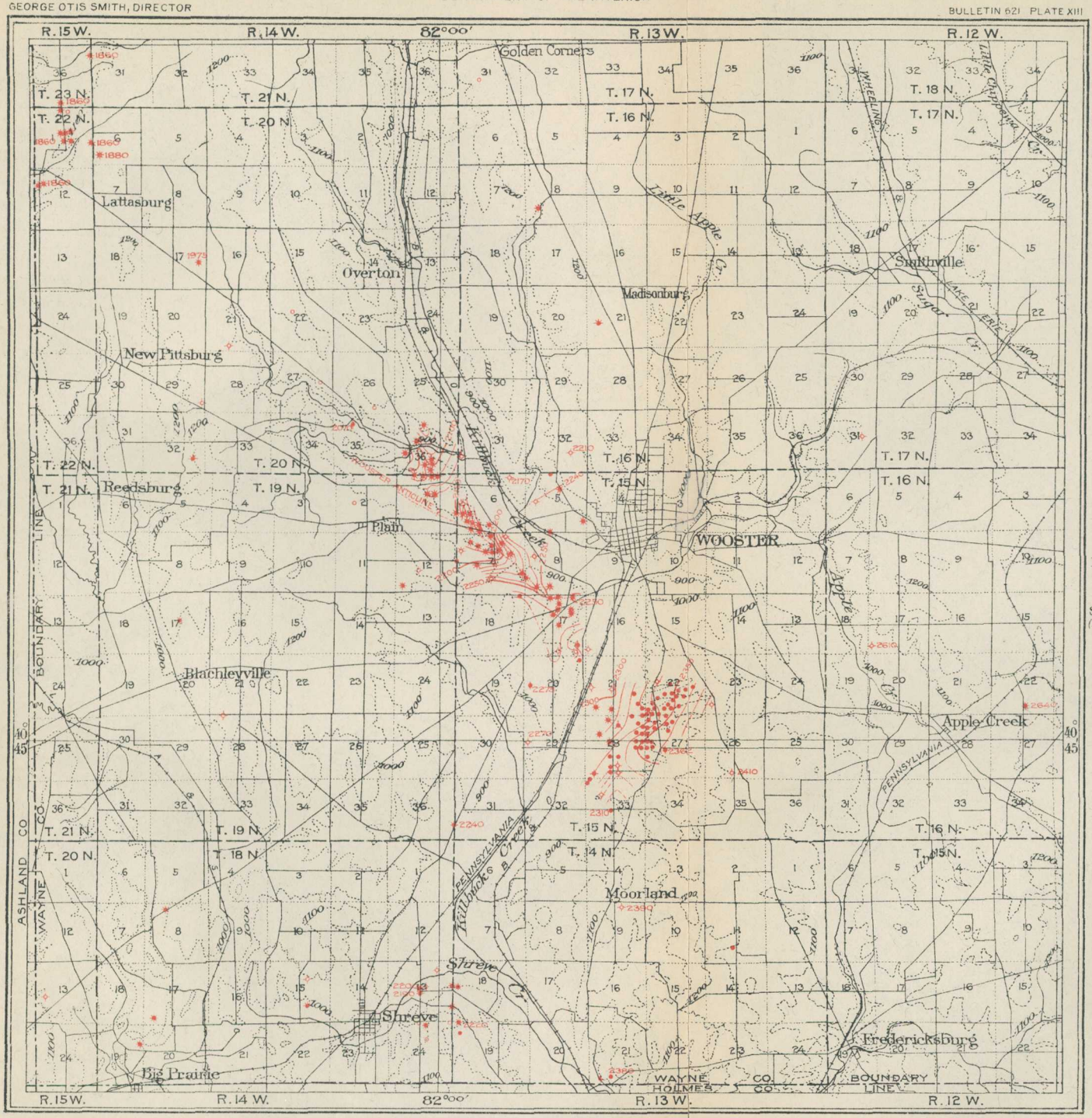
The structure of the sand in the Shreve gas pool could not be determined, owing to the small number of wells drilled. There are, however, indications of an anticline, for the altitude of the sand, as reported in the well logs from this field, is about 100 feet higher than the normal position of the sand as determined by contouring the Clinton sand in a broad way over a large area in this part of the State.

The structure contours in the oil field south of Wooster show several small, irregular folds in which oil has accumulated and a small but higher structural terrace along the western edge of the field, where gas has collected. From the data at hand no certain prediction can be made as to the structure north of the oil field and east of the main gas field. The anticline of the gas field is evidently flatter toward the east, and it is probable that this disturbed condition of the sand continues some distance in that direction, but whether it continues for 1 mile or 4 miles can not be told until some drilling is done north of the oil field.

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

DEPARTMENT OF THE INTERIOR

BULLETIN 621 PLATE XIII




LEGEND

- Contours on top of Clinton sand (Contour interval 10 feet. Numbers indicate depth below sea level)
- Oil well
- Show of oil
- Oil and gas
- Show of oil and gas
- Gas well
- Show of gas
- Dry hole
- Drilling well
- Surface contours (Interval 100 feet)
- Road

MAP OF THE WOOSTER OIL AND GAS FIELD, OHIO

## SUGGESTIONS FOR PROSPECTING.

It is in general very difficult if not impossible to determine the character and position of folds in the Clinton sand from a study of the surface rocks in northern Ohio. However, after considerable drilling has been done it may be possible to outline, at least in part, the anticlines, synclines, and structural terraces and thus to predict, so far as geologic structure controls the accumulation of oil and gas, the most favorable territory for future drilling. This does not apply to new pools, but merely to the extension of known pools into new territory.

The most promising area for the location of gas wells is along the supposed northwestward extension of the Wooster anticline in secs. 1 and 2, Plain Township, but it must be clearly understood that the extension of the axis of this anticline is hypothetical and, even if it extends into this new territory, its exact location can not now be determined. No one should be encouraged to make such a test unless he has the capital and can afford to take what may be considered almost even chances of success or failure.

No prediction can be made as to the extension of the gas field toward Lattasburg. The evidence in this vicinity gives no basis for the assumption that the Wooster "gas streak" connects with the one at Lattasburg, as most of the operators believe. The existence of gas in the Hileman well, in sec. 17, Chester Township, about half way between these pools, does not prove this point, for the well is only a small producer, and similar amounts of gas may be struck at any place in the region.

The finding of dry holes along the northern margin of the oil field in secs. 16, 21, and 22, Wayne Township, has discouraged drilling between that field and Wooster. From the Leisle dry hole, in the NW. ¼ sec. 22, Wayne Township, in which only 3 feet of sand was reported, it seems probable that the lack of oil is due to an area of thin sand, but as the Clinton sand is generally present wherever the drill has penetrated to its depth, it seems probable that the area of thin sand south of Wooster is a local feature and may extend for less than a mile in any direction. If, therefore, it is assumed that there is a possibility of thick sand north of the present oil field, it is probable that the structure is such as to warrant further prospecting. Unfortunately, in the light of present knowledge, this assumption can not be verified until more drilling has been done. The writer is of the opinion, however, that the probability of the eastward extension of the Wooster anticline is sufficiently strong to justify drilling in new territory in sec. 15, Wooster Township.

As some oil has already been found on the flank of the Wooster anticline, the chances for finding more oil along the flanks of the

fold to the northwest seem fair and worth considering, though not as good as they are south of Wooster.

Wherever dry holes are encountered the sand is either thin or "broken," or the location has been chosen in a structurally unfavorable place. There seems to be no danger of striking salt water in low places in this field. Water has been reported in several wells in the Clinton sand and at Wooster, but on the whole the sand is considered to be "dry" by the drillers. Water thus reported is assumed to have leaked through the casing from some higher bed.

A significant conclusion to be drawn from the presence of the Wooster anticline in northern Ohio is that the Clinton sand has been subjected to forces tending to produce sharply accentuated folds in a direction at right angles to the normal strike of the beds. Such folds are shown by this investigation to be favorable for the accumulation of oil and gas in this field, and it is safe to assume that other folds of like character occur in this general region. Their presence can be proved only by drilling. Wells drilled to the Berea sandstone only may aid in the determination of structure in the Clinton sand, for both the Berea and Clinton sands, as well as the intervening strata, have been without much doubt subjected to the same deformative forces.

In prospecting east of Wooster much deeper wells will be needed to reach the Clinton sand, for the general eastward dip will be accentuated by the thickening of the overlying formation in that direction.