TPS. 26 AND 27 N., R. 12 E.

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INTRODUCTION.

This report describes an area 12 miles long and a little less than 3½ miles wide, comprising the portions of Tps. 26 and 27 N., R. 12 E., west of the east line of Osage County, Okla.

The field work in this area was begun in the fall of 1917 by G. B. Richardson, assisted by E. F. Lines, and was finished late in 1920 by P. V. Roundy and K. C. Heald, assisted by P. H. Moyer and W. W. Rubey. The area was mapped with telescopic alidade and plane table. Stadia traverses were run and checked by triangulation. A very few elevations were obtained by aneroid barometers.

The present surface in these townships has been cut from an eastward-sloping peneplain. The dissection is still in a youthful stage, for although some of the stream valleys are very well developed, with wide, flat bottoms, the interstream areas are broad and but little modified by stream channels, valley walls are commonly steep, and tributaries to the main valleys are narrow with steep gradients.

The area is drained by Butler Creek and its tributaries in the northern township and by Sand Creek and its tributaries in the southern township. The amount of water carried by these streams varies greatly, and in times of drought their flow fails altogether, but pools, some of them more than a mile long, are cut below the level of ground water in the beds of the main streams, and are a reliable source of supply for drilling operations and for stock.

The Missouri, Kansas & Texas Railway crosses T. 26 N., R. 12 E., from east to west. A siding near the west line of sec. 17 is a supply point for drilling operations in the immediate vicinity, but most of the supplies are hauled from the city of Bartlesville, which is only 1 mile east of the east line of the area and almost opposite the dividing line between the two townships.

The road net is fairly adequate, but the roads themselves need much improvement. Considerable money has been spent on such improvements, but failure to maintain them commonly results in their speedy destruction.

STRATIGRAPHY.

EXPOSED ROCKS.

Age and general character.—The rocks that crop out in this area are of middle Pennsylvanian age and correspond approximately to the lower part of the Douglas group, all of the Lansing group, and the upper part of the Kansas City group in the Kansas section. This correlation has been discussed by Goldman[1] in an earlier chapter of this bulletin. They comprise a series of sandstones, shales, and thin limestones, aggregating about 720 feet in thickness, as shown graphically in column 4, Plate LV.

Limestone forms only a small part of the geologic section, and shale is but slightly predominant over sandstone. Very few of the beds are good key beds for mapping structure or for correlation owing to lateral lithologic changes and to the lenticularity of the sandstones. The thin limestones in the upper part of the section are particularly unreliable. Individual beds were traced continuously over considerable areas, but only by the most painstaking, time-consuming work. The fossil content of some of the sandstones was particularly helpful in some small areas. Particular types of ripple marks and the direction of ripple marking were in places valuable aids. The tendency of beds to joint in a certain manner, to form a definite type of weathered surface, and to contain certain concretionary types, as well as other local characteristics, were helpful in making short-distance correlations. The associations of beds was constantly used to check determinations, and many closed circuits were run to prove the accuracy of the correlations.

Dewey limestone and overlying beds.—The Dewey limestone, which is the lowermost of the key beds used in mapping these townships, was seen only in a small area, about 1 mile north of Sand Creek in the eastern part of T. 26 N., R. 12 E. The outcrop at this place is probably separated from the rocks to the northwest by a fault, the surface expression of which is concealed by alluvium. It is a crystalline gray fossiliferous limestone, which at Dewey, Washington County, is over 20 feet thick. Where seen within the area mapped its thickness could not be determined but was probably less than 20 feet. The interval of 275 feet between it and the top of the Panther Creek limestone was determined by a measurement about 1 mile southeast of the area mapped. This determination may be slightly in error because of concealed faults, but it is checked approximately by many of the available well records.

The Dewey limestone helped comparatively little in determining the surface structure.

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[1] Goldman, M. I., and Robinson, H. M., U. S. Geol. Survey Bull. 686–Y, p. 360, 1920.

The interval between the Dewey limestone and the Torpedo sandstone is occupied by nonfissile shale with thin platy beds of hard, fine-grained sandstone that thicken locally. One of these intermediate sandstones is in places as much as 30 feet thick.

Torpedo sandstone.—The Torpedo sandstone[2] is a series of fine-grained, gray to yellowish gray sandstone, ranging in thickness from about 25 to 70 feet. In some sections it contains many thick shale partings; in other sections it is nearly a continuous series of medium thick to massive sandstone beds with one or two prominent shale partings. Usually it makes two very prominent benches. Several of the beds are beautifully ripple marked.

Panther Creek limestone.—The limestone to which the name Panther Creek is herein applied either rests on the Torpedo sandstone or is separated from it by a thin shale. It is named from Panther Creek, in the southwestern part of T. 26 N., R. 12 E., where it is well exposed along the valley rim to the east and to the west. This limestone in T. 26 N., R. 11 E., was called the Stanton (?) limestone by Clark.[3] Later Goldman and Robinson[4] called a limestone in T. 28 N., R. 12 E., the Stanton (?) limestone, basing their correlation more on evidence tending to connect their limestone with the Stanton of the Kansas section than on evidence tending to prove the correlation of their limestone with that mapped by Clark. The mapping of the present area has definitely proved that the Stanton (?) limestone of Goldman is approximately 190 feet higher in the stratigraphic section than the Stanton (?) of Clark. The evidence presented by Goldman and Robinson tending to correlate their Stanton (?) limestone with the Stanton limestone of Kansas, although not conclusive, is still fairly convincing.

Fossils collected from these two limestones were referred to G. H. Girty, who reports in part as follows:

> The faunas in a general way would tend to locate both limestones above the Kansas City formation—that is, in the Lansing formation—and would tend to correlate the higher limestone (the Stanton (?) limestone of Goldman) rather than the lower limestone (the Stanton (?) limestone of Clark) with the Stanton limestone of the Kansas section.

With this evidence at hand it is inadvisable to continue the use of the name Stanton (?) limestone for the limestone mapped in T. 26 N., Rs. 11 and 12 E.

The Panther Creek limestone is thicker and is of more importance as a key bed in this area than to the south and to the west. In some sections it attains a maximum thickness of 14 feet. Usually the lower part is a rather siliceous impure limestone that weathers to an

[2] Hopkins, O. B., U. S. Geol. Survey Bull. 686–H, p. 76, 1918.
[3] Clark, F. R., U. S. Geol. Survey Bull. 686–I, p. 95, 1918.
[4] Goldman, M. I., and Robinson, H. M., U. S. Geol. Survey Bull. 686–Y, p. 367, 1920.

orange color. The upper part is a purer and lighter-colored limestone, in places almost white. The entire limestone contains an abundance of crinoid-stem segments and some other fossils. At the top occurs a very fossiliferous bed, partly argillaceous. The plates of crinoid cups and arms are especially abundant in this bed which also contains many Foraminifera, Ostracoda, and Bryozoa and smaller numbers of some other forms.

The several beds of the Torpedo sandstone and the Panther Creek limestone were the most useful key beds in mapping the southern township.

Beds between the Panther Creek limestone and the Revard sandstone.—Massive sandstones and thick shales compose the rocks for the first 150 feet above the Panther Creek limestone. The sandstones are in part locally replaced by shales.

A shale zone occupies the interval from 150 to 280 feet above the Panther Creek limestone. This zone is rather constant in thickness in the area mapped. It contains some sandstones and many thin sandy limestone beds, which individually are of very small extent. They usually range from 1 to 3 feet in thickness, and many of them contain numerous brachiopods. Usually one or two of these limy lenses are present in a single section, and in a few sections there are more. Few of these limestone beds are reliable for use in mapping. One of them, however, which is decidedly less sandy and contains more gastropods than the other beds in this zone, proved to be a reliable horizon marker over a part of the area. This bed is well exposed on the south escarpment north of Butler Creek in the eastern part of T. 27 N., R. 12 E. The limestone in T. 28 N., R. 12 E. described by Goldman and Robinson as the Stanton (?) limestone, occurs in this zone. Its relation to the Stanton limestone of the Kansas section is explained in connection with the Panther Creek limestone (p. 397).

The Torpedo (?) sandstone of the same authors, which occurs just below their Stanton (?) limestone, thins and locally disappears south of the area they describe. It is, of course, much higher in stratigraphic section than any of the sandstones exposed at Torpedo, the type locality of the Torpedo sandstone.

Revard sandstone.—The Revard sandstone[5] in T. 26 N., R. 10 E., is a massive sandstone 30 to 40 feet thick. In its northeastward extension into T. 27 N., R. 11 E., it thickens and in places contains much shale.

In T. 27 N., R. 12 E., the Revard sandstone is about 70 feet thick. It becomes differentiated into three distinct medium-heavy to massive bedded sandstone zones, separated by shales containing

[5] Clark, F. R., U. S. Geol. Survey Bull. 686–I, p. 94, 1918.

thin sandstones. The top of the Revard, which is about 350 feet above the Panther Creek limestone, for the purposes of mapping was considered to be the top of a massive bed which over most of this township is the actual top of the formation. However, in a few places a more loosely cemented sandstone is found above the main bed. This local sandstone showed very indistinct bedding planes, weathered into large rough knobs, and could as a rule be readily distinguished from the main bed that was considered to be the top. The top of the middle sandstone zone lies 42 feet below the top of the Revard. This zone is usually easier to follow in the field than the upper bed. Of the three it is usually the thickest and most massive. The lower sandstone zone, however, is the best one in the Revard to use in mapping. In fact, it proved to be the best key bed in this township. The top, which is usually ripple-marked, is about 63 feet below the top of the Revard and nearly everywhere makes a prominent bench. Its upper part is composed of massive platy sandstone beds. Just above this ripple-marked bed and separated from it by a foot or so of shale is a very thin sandstone band which is crowded with fossils. This band is distinguished from many other fossil zones by containing *Pleurophorus* (probably *P. subcostatus*) in great abundance. Unfortunately this fossiliferous bed is not everywhere present. The top beds of this zone are massive but remarkably smooth bedded. The lower beds of the Revard sandstone are typically exposed in the northeastern part of T. 27 N., R. 12 E., where they usually form the rims of the steep escarpments.

In some parts of T. 27 N., R. 12 E., either or both of the shales that separate the three sandstone zones are partly (in a few exposures almost entirely) replaced by heavy-bedded sandstone. Under these conditions it was found difficult, though not impossible, to distinguish and map all three zones.

In T. 28 N., R. 12 E., the Revard sandstone breaks up into more sandstone zones separated by shales, so that, for purposes of oil geology, it is better considered as several separate sandstones. In the work on that township parts of the Revard sandstone were mapped under the names Mission, Possum, Gap, and Hulah. The Mission sandstone is equivalent to the top of the Revard and the Hulah sandstone is the same as the sandstone 42 feet below the top of the Revard in the township to the south.

Cheshewalla (?) sandstone and underlying beds.—In the northwestern part of T. 27 N., R. 12 E., a high point and ridge are capped by a massive sandstone which is probably the lower part of the Cheshewalla sandstone.[6] It is almost indistinguishable in appearance from parts of the Revard sandstone. Between the base of the

[6] Winchester, D. E., and Heald, K. C., U. S. Geol. Survey Bull. 686–G, p. 61, 1918.

Cheshewalla (?) sandstone and the top of the Revard sandstone are thick beds of shale with thin, platy sandstones, none of which are prominent.

ROCKS NOT EXPOSED.

At least 703 wells have been drilled in the Osage County portion of these two townships, but the writers have been able to obtain records of less than half of them. Of the records obtained a few show only casing data and total depth, and some show only the producing portion of the Bartlesville sand. About half of them indicate the position of the "Oswego lime." Others are more or less complete. The character of the rocks is indicated in Plate LVI, which shows graphically the driller's interpretation of the rocks penetrated in this area These records are so alined that the top of the "Oswego lime," which is used as a datum, is a horizontal plane. Logs 1 to 14 represent wells along a north-south line through the portion of the area where the variation in interval between the top of the "Oswego lime" and the top of the Bartlesville is small. Logs 15 to 18 indicate one of the lines of rapid increase in this interval. Logs 2 and 4 are records of the deepest wells drilled in these townships. (See fig. 52.)

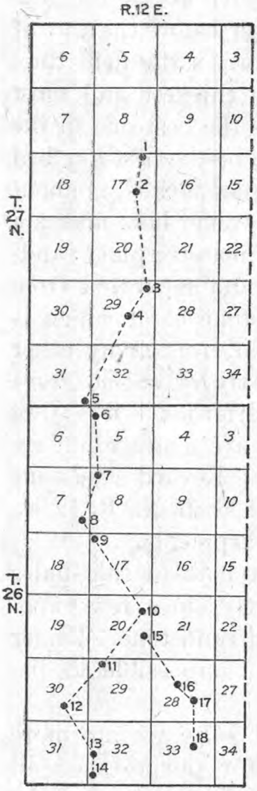
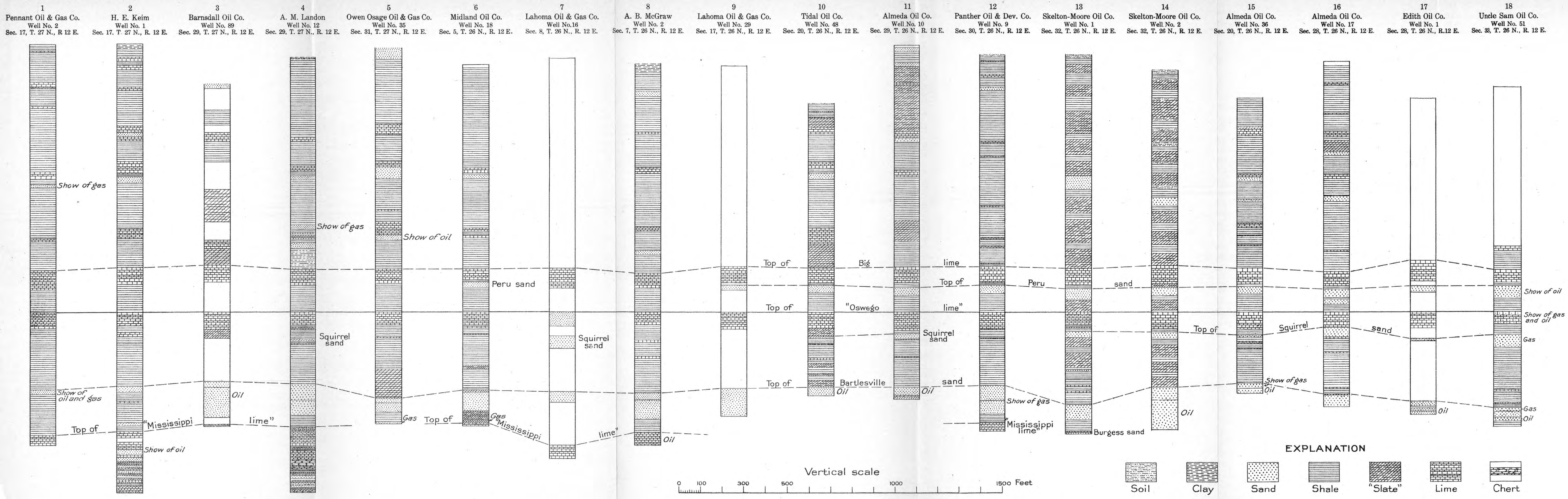


FIGURE 52.—Diagram showing location of wells whose logs are given in Plate LVI.

"*Oswego lime.*"—"Oswego lime" is the drillers' term for the probable equivalent of the Fort Scott limestone of the Kansas section. This limestone is probably the most carefully recorded and most widely recognized underground horizon marker in eastern Osage County. In the townships here considered it is generally recorded as being 50 to 100 feet thick, though one log gives a thickness of only 40 feet and five logs indicate a thickness of more than 100 feet. Though usually recorded as a solid limestone, a few logs record one or two shale breaks in it. The interval between the top of the Panther Creek limestone and the "Oswego lime" is 1,170 feet in sec. 31, T. 26 N., R. 12 E. To the north and to the east this interval decreases by 15 or 20 feet to the mile, being about 1,050 feet in sec. 5 and 1,000 feet in sec. 3. In sec. 17, T. 27 N., R. 12 E., it is about 950 feet. In some of the wells in these townships a little gas has been found in the "Oswego lime," and elsewhere in Osage County it contains notable amounts of both oil and gas.



WELL LOGS SELECTED TO SHOW UNDERGROUND CONDITIONS ALONG NORTH-SOUTH LINE IN TPS. 26 AND 27 N., R. 12 E., OSAGE COUNTY, OKLA.

Beds above the "Oswego lime."—The beds between the Dewey limestone and the "Oswego lime" consist of an upper shale series with thin limestones and sandstones, a massive limestone known as the Big lime, and a lower shale containing a sandstone known as the Peru sand. The logs vary so greatly in their interpretation of the upper shale series that only a few general deductions are possible. The limestones and sandstones together comprise only about one-third of the series, the remainder being gray, blue, brown, and black shales. Three of the thin sandstones locally show a little gas, and two have furnished showings of oil. One of the sandstones yielded large quantities of oil in the Wiser Hill pool. (See pp. 414–416.)

The Big lime is a white to gray limestone 60 to 100 feet thick. Only a few logs indicate one or two shale "breaks" in it. The top of this limestone is about 200 feet above the top of the "Oswego lime." As recorded in the logs this interval ranges from 150 to 250 feet, but no actual convergence appears to be indicated. The Peru sand with shale occupies the interval between the Big lime and the "Oswego." This sand, recorded in less than half of the logs, ranges from 10 to 100 feet in thickness. Considerable oil has been produced from it, especially in the southern and eastern parts of T. 26 N., R. 12 E.

Beds between the "Oswego lime" and the Bartlesville sand.—A sandstone lens, called by the drillers the Squirrel sand, attains a maximum thickness of 120 feet in this area. Its top lies from 72 to 140 feet below the top of the "Oswego lime." This sand is not recorded in as many logs as the Peru sand. It is of very little importance as an oil producer.

The rocks between the Bartlesville sand and the Squirrel sand, or between the Bartlesville sand and the "Oswego lime" where the Squirrel sand is absent, are shales with a few thin limestones. Occasionally a thin sand is recorded.

Bartlesville sand.—A sand that occurs between 1,200 and 1,300 feet below the surface at Bartlesville, Okla., is called the Bartlesville sand by the drillers. It is the most productive sand in this region and one of the principal oil and gas yielding sands of Oklahoma. Its top in this area lies from 330 to 460 feet below the top of the "Oswego lime." Although part of this apparent variation may be due to the drillers' interpretation of what is the top of the Bartlesville sand, most of it is probably due to convergence in the intermediate shale series. The interval is least in an area about 2 miles long from north to south and less than half a mile wide, about in the middle of the mapped part of T. 26 N., R. 12 E. From this area the increase in interval between the top of the "Oswego" and the top of the Bartlesville is most rapid to the southeast and to the northeast, less rapid to the southwest and the west, and slowest to the south and the north, and to the east from the south end of the area.

The Bartlesville sand in this region is generally recognized as consisting of two distinct portions, in many places separated by a shale break. The upper part, called by most drillers the "gas sand," is usually much thinner than the lower part, which is called the "Bartlesville oil sand." Some logs indicate the upper and some the lower part as the darker colored. The total thickness of the Bartlesville sand, as recorded in logs of wells which are said to have penetrated the shales below it, ranges from 10 to 170 feet in these two townships. The sand is thinnest in the center of the western part of T. 27 N., R. 12 W., where the drillers claim that the "gas sand" is absent.

Rocks between Bartlesville sand and "Mississippi lime."—The logs of the deeper wells indicate that the top of the "Mississippi lime" occurs from 20 to 200 feet below the base of the Bartlesville, though the most frequently mentioned intervals lie between 60 and 100 feet. This interval is usually indicated as occupied by shale or "slate." A few logs, however, record a sand, 30 feet or less in thickness, just above the "Mississippi lime." This sand is called the Burgess sand in these townships. In places it yields a little oil.

"Mississippi lime."—As known in this area, the "Mississippi lime" consists of limestone interbedded with chert and sandstone. The limestone is usually more or less cherty. Gas is obtained in considerable quantities from the upper part of the "Mississippi lime." Only two wells have penetrated it to any depth below the gas horizon. These two wells, in secs. 17 and 29, T. 27 N., R. 12 E., have drilled through 273 feet and 305 feet, respectively, of the lime without passing through it. Neither well appears to have penetrated a thin shale series such as usually lies above the "Wilcox" sand to the south, nor does the Ordovician limestone seem to have been reached. Both are dry holes. It is unfortunate that these wells could not have been drilled to about 350 feet below the top of the "Mississippi lime," as this might have demonstrated the presence of a deep productive bed. From a study of published data[7] on the "Wilcox" sand and the "300-foot break" in the "Mississippi lime" as well as a review of the logs of many of the deep wells in Osage County, the writers are of the opinion that the "Wilcox" sand may

[7] Greene, F. C., Oklahoma's stratigraphic problems: Oil and Gas Jour., vol. 18, No. 49, p. 54, 1920. White, L. H., and Greene, F. C., Correlation of the Wilcox sand in the Okmulgee district with the Osage: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 3, p. 399, 1921. Aurin, F. L., Clark, G. C., and Trager, E. A., Notes on the subsurface pre-Pennsylvanian stratigraphy of the northern Mid-Continental oil field: Am. Assoc. Petroleum Geologists Bull., vol. 5, No. 2, p. 117, 1921.

be present in these townships. If so, it probably lies about 350 feet below the top of the "Mississippi lime." Tests should be made on the Jessie Creek anticline and the Panther Creek anticline (see pp. 410, 411) either by deepening some of the present wells or by new drilling on the crests of the anticlines, to a depth 400 feet below the top of the "Mississippi lime." Great care should be exercised to obtain a complete and accurate record of the strata below the top of the "Mississippi lime." If this is done, two tests at the localities mentioned would be almost sure to prove the presence or absence of oil-bearing beds at the "Wilcox" horizon.

STRUCTURE.

GENERAL FEATURES.

In the eastern part of Osage County 1,500 to 2,000 feet of rocks, composed largely of shale, rest on a series of pre-Pennsylvanian strata consisting mainly of limestones with some sandstones, cherts, and thin shales. These in turn are underlain by crystalline rocks. In response to the various deformational forces these lower hard rocks, or competent strata, have been folded and faulted. The overlying softer or relatively incompetent Pennsylvanian rocks were naturally similarly deformed, but probably with a magnitude and complexity of structure decreasing upward, owing in part to the compression and squeezing out of the shales. However, small faults in the lower competent rocks might have resolved themselves into more complicated structure in the higher rocks. Therefore, the structure of the surface beds should be and probably is considerably different in detail from that of the lower beds.

To portray the deformation absolutely, a bed that was deposited in a perfectly horizontal position is needed as a datum plane. Very few beds are being deposited in such a position to-day, and probably none of the Pennsylvanian beds of Osage County were deposited in such a position. It is evident that the surface beds in the two townships here described must have been deposited more unevenly than those of the western Osage country, and therefore any contour map of the surface beds in these townships obviously could not portray the minute details of structural conditions if structure is defined as attitude due to deformation alone. However, the oil geologist and the person interested in the occurrence and recovery of oil are more interested in the present attitude of the rocks relative to sea level than in the details of deformation. Therefore, the term "structure," as used in this paper and in the previous papers in this bulletin, refers to the attitude of the rocks relative to sea level, regardless of whether that attitude is due to deposition or to deformation.

SURFACE STRUCTURE.

The 10-foot contour lines shown on Plates LVII and LVIII are based entirely upon observations made on rocks that crop out at the surface. They represent the elevation above sea level of a hypothetical bed 542 feet below the top of the Revard sandstone. This datum plane is 375 feet lower than the datum plane used in T. 25 N., R. 12 E., 465 feet lower than that used in Tps. 26 and 27 N., R. 11 E., and 765 feet lower than that used in T. 28 N., R. 12 E. This relation causes the contours to interfinger with those of the bordering townships where the structure is similarly interpreted. Along the east edge of T. 27 N., R. 11 E., however, a convergence of higher beds, which are absent from T. 27 N., R. 12 E., caused a different interpretation of the structure. This difference is also accentuated because the datum plane used west of the line between the two townships is above the surface of the ground, and the datum plane used east of the line is below the surface.

Several faults in this area are clearly indicated by the actual displacement of beds in one or more places along the fault line. The existence of other faults is proved by the relations and elevations of adjacent beds.

A small fault, in the northern part of sec. 19, T. 27 N., R. 12 E., has a maximum throw of about 10 feet. It is less than half a mile in length, strikes a little west of north, and probably has but little effect on the collection and recovery of oil.

A fault about 1¾ miles long, in secs. 16, 21, and 22, in the same township, is of the scissors type and has a maximum throw of a little more than 15 feet. Its main importance appears to be in relation to the collection of oil in a shallow sand, as noted in the description of the Wiser Hill pool (p. 415).

The outcrop of the Dewey limestone in the northwest corner of sec. 15, T. 26 N., R. 12 E., and its relation to the exposed beds to the northwest appear to demand a fault in the narrow alluvium-covered area between these exposures. The throw of this fault is probably 50 feet or more. The southwestward swing of Viza Creek is probaby due to this fault line. The direction of the two contour lines on the island of Dewey limestone is purely hypothetical, as an undetermined amount of the limestone has been eroded from part of this area—enough, at least, to make it impossible to determine the direction. High initial production of oil in the eastern part of sec. 9, just west of this line, is at least additional suggestive evidence of this fault.

Three faults, which are probably but not certainly connected, extend from the SE. ¼ sec. 20, T. 27 N., R. 12 E., through secs. 29, 28, and 33 in this township and secs. 5, 8, 7, 18, and 19 in the township to the south. The total length of the three faults is therefore about 7 miles. The end components of this system are northwest-southeast faults. The northern fault was seen in two places, with a downthrow on the west side of about 10 feet in the SE. ¼ sec. 20 and a maximum downthrow on the east side of about 30 feet in the SW. ¼ sec. 28. The conclusion that these two parts of this fault are connected under the cover of alluvium is based on observed directions of the fault strikes.

The southern fault of this system, in T. 26 N., R. 12 E., likewise has definite evidence of displacement with a maximum throw of about 20 feet. Although the writers believe it is confined to sec. 19, T. 26 N., R. 12 W., it may extend under the alluvium into sec. 18. The middle fault has a maximum throw of more than 200 feet in sec. 18, T. 26 N., R. 12 E. It extends northeastward into sec. 33, T. 27 N., R. 12 E. Except in sec. 18 the displacement is small, mainly less than 10 feet. There is a possibility that instead of being a single long fault this is a series of small faults with one major fault, all in a straight or nearly straight line. The fault line was actually observed only in the southern part of sec. 5. In sec. 18 the fault line occurs in the alluvium-covered area adjacent to Sand Creek. The relations of the well-exposed beds on each side of the creek flat, however, make the conditions perfectly obvious. The fault is of the compound scissors type. Unfortunately, the points where the ends of this fault or line of faults meet the smaller, northwest-southeast faults, are concealed by alluvium.

SUBSURFACE STRUCTURE.

Elevations of about two-thirds of the wells drilled in these townships were obtained by the writers. Unfortunately the logs of many of these wells appear to be unobtainable, and some of the records that are available are so incomplete as to be of little use. However, enough information has been gathered to reveal some very interesting facts regarding the underground structural conditions. As indicated on page 401, a convergence between the Bartlesville sand and the "Oswego lime" centers in T. 26 N., R. 12 E., where the interval between the tops of these beds is as small as 330 feet. This convergence is practically continuous from an area at least as far south as T. 15 N., R. 12 E., where the interval exceeds 800 feet, if the writers are correct in assuming that the Bartlesville sand of the Bartlesville region is in part equivalent to the Glenn sand of the Okmulgee region. Westward from T. 26 N., R. 12 E., the interval probably increases more slowly. However, there is considerable doubt as to the continuity of the sandstone beds in the Cherokee shale in that direction and also to the east. Probably a number of different beds or lenses have been called Bartlesville sand. The evidence at present available suggests that these sandstone lenses in the Cherokee shale of eastern Osage County were deposited as long, narrow north-south sand bars which, at least in places, overlap.

The upper part of the Bartlesville sand is shown by contour lines on Plates LIX and LX. In mapping this structure some logs were used which gave only the depth of the top of the producing sand, and in connection with such logs estimates were made as to the depth of the top of the Bartlesville sand (top of the so-called "gas sand"). This depth varies even between adjacent wells and much more between widely separated areas. It must therefore be recognized that, although the maps show the general surface of the Bartlesville sand, they may be somewhat inaccurate in minor details. The uneven surface and channels in this sand would of course make its surface differ considerably from that of the contoured upper beds, as shown on Plates LVII and LVIII.

In T. 26 N., R. 12 E., so many of the logs fail to indicate the position of the "Oswego lime" that no contours on that bed are shown. In T. 27 N., R. 12 E., where sufficient information exists, the tops of both the Bartlesville sand and the "Oswego lime" are contoured. In the Wiser Hill pool the "shallow sand" offers the only evidence sufficient for drawing underground contours.

A comparison of the major structural features shown on both the subsurface and surface maps shows that there is a general resemblance. However, these features are slightly displaced horizontally and are of somewhat greater magnitude and complexity in the lower beds than in the surface beds. The subsurface evidence would suggest that the throw along fault lines is greater in the lower beds than at the surface. Unfortunately, the writers were unable to obtain many logs of the wells in sec. 18, T. 26 N., R. 12 E., where the greatest surface fault throw exists.

No attempt will be made to present positive statements regarding the relations of surface structure to that of the oil-bearing beds, for the data available in this area are too incomplete to justify it. The relations suggested below are far from established, but the available evidence indicates their probability, and they should be borne in mind by students of adjacent areas.

Domes and closed anticlines expressed in the surface beds are almost invariably associated with domes in the oil-bearing beds, although these domes rarely coincide exactly. The doming in depth is, as a rule, much sharper than that at the surface. For example, the dome in the Bartlesville sand under the Jessie Creek anticline has a closure of 30 feet or more, as compared with 10 feet at the surface. The Midland dome has a closure of 40 feet or more in the oil sand, as against 20 feet in the surface beds.

The crests of the deep-seated folds lie to the north of the surface crests in both the Jessie Creek anticline and the Midland dome. In the former the highest point in the Bartlesville sand is about 500 feet due north of the corresponding point shown by the surface beds. In the latter the crest of the Bartlesville dome is about 2,000 feet east-northeast of the crest in the surface beds. Neither of these folds shows pronounced similarity between shallow and deep-seated folding, but in each the offset lies along one axis of the dome.

The relation between the axes of plunging anticlines or anticlinal noses seems to be fairly regular. Without exception, in those available for study, the shallow and deep axes are approximately parallel. On one of the offshoots of the Jessie Creek anticline they practically coincide. On a second they are parallel, but the Bartlesville fold is offset about 1,000 feet to the north. This last relation is shown also by the anticlinal nose in sec. 30, T. 26 N., R. 12 E., and more doubtfully by the one in sec. 18, T. 27 N., R. 12 E. The axes of surface and deep plunging anticlines in sec. 22, T. 27 N., R. 12 E., coincide.

Although all the domes and plunging anticlines manifested at the surface appear to be associated with similar features in depth, the reverse does not necessarily hold, as is shown by the South Butler Creek pool. In that pool the Bartlesville sand is flexed into two domes separated by a shallow syncline. The only surface feature that may be interpreted as a possible reflection of this domal structure is a very gentle anticline whose northeastward-plunging axis crosses above the saddle between the two anticlinal folds in the Bartlesville sand. The fact that the axes of the Bartlesville folds parallel that of the surface fold indicates a relationship, in spite of its slight surface manifestation.

The relation between surface and deep-seated synclinal axes is remarkably regular. With the exception of the sharp trough in the Bartlesville sand in sec. 28, T. 26 N., R. 12 E., such deep and shallow axes agree surprisingly in position, although of course the surface folds are much broader and more gentle than the deeper ones. The Bartlesville syncline in sec. 28, T. 26 N., R. 12 E., appears to be reflected in the surface beds about 2,000 feet to the north.

RELATION BETWEEN STRUCTURE AND PRODUCTION.

It would not be justifiable to attempt, from the meager evidence presented by these two fractional townships, to draw general conclusions applicable to the entire Osage Reservation or even to a large fraction of it. However, the relation between structure and production in these townships should be pointed out in order that it may be a basis for future comparisons.

It may be stated without hesitation that anticlinal structure exhibited by surface beds in this area has in most places indicated commercial amounts of oil. There are within the area eight folds that are marked by gentle doming of the surface beds. Of these, seven have been drilled, and on six of them oil in commercial volume has been found. On four of them oil or gas was found underlying the portion of the surface encircled by closed contour lines on the maps. The one anticline that has failed to yield oil or gas in response to drilling has not been adequately tested, and it is believed certain that oil will yet be found there.

Of the oil pools that have been developed on closed anticlines the largest and most productive pools are on the largest and steepest folds. The best pool on an anticlinal fold in this area is on the Panther Creek anticline, in secs. 18, 19, and 30, T. 26 N., R. 12 E., which is the most pronounced anticline in the area. Second in magnitude is the pool on the Jessie Creek anticline, and third is that on the Midland dome.

The relation of productivity to surface expression of structure is irregular. However, it is worthy of note that the largest wells were not found under the crests of the surface folds on any of the anticlines. On the Panther Creek anticline they are both east and northwest of the crest and about 10 feet below it. On the Jessie Creek anticline they are on the north flank, 10 to 30 feet below the crest. On the North Jessie Creek dome they are low on the north flank. On the Midland dome they are 20 to 30 feet below the crest, on the northeast flank. Without exception the large wells are found north of the surface crest. This is in large part explained by the relation of the surface structure to that of the oil-bearing beds. (See pp. 406–407.)

No general relation between steepness of dip and productivity could be established in this area. Of the anticlines in these townships those with steep flanks have yielded more oil and better wells than the more gentle folds, but it is known that in many other parts of Osage County no such relation exists.

The importance of plunging anticlines can not be judged by the evidence in these townships. It is believed that such anticlines are developed along definite lines of deformation, and that where two such lines intersect, as in the SE. ¼ sec. 18, T. 27 N., R. 12 E. there will be doming of the oil sand with consequent accumulation of oil. Except where such doming is present the plunging anticlines are believed to be only a little more promising territory than the unflexed monoclines, although the excellent yield of the northeastern part of the Wiser Hill pool, in sec. 22, T. 27 N., R. 12 E., may be considered by some to refute this statement.

The single broad terrace or structural flat in this area yields no criteria for comparative statements. On it a number of dry holes and about an equal number of producing wells have been drilled.

The potency of faults in bringing about oil pools is believed to be demonstrated by the Wiser Hill pool and the producing area along Viza Creek. Faults are unquestionably present in these pools, and the existence of the pools may be explained by the presence of faults, known or assumed. However, it must be conceded that the demonstration rests largely upon theory and can not be considered proved.

A review of the locations of dry holes with respect to the structure of the outcropping beds is illuminating. Some 81 dry holes were located by the writers. Of these 10 are high on anticlines, 12 are low on anticlinal flanks, 36 are on monoclines or gentle anticlinal noses, and 23 are in synclines. One well on the Midland dome, shown as a dry hole on the map, did not reach the oil sand. The 22 dry holes listed as on anticlines include five on the North Butler Creek terrace, which is not, properly speaking, an anticlinal fold. Most of the other dry holes on anticlines are either surrounded by producing wells or mark the outer limits of pools. The dry holes in the synclines, on the other hand, are for the most part not associated with producing wells. Of the 35 wells known to have been drilled in clearly defined synclines as shown by the surface beds, 12 have produced some oil, as contrasted to 23 that have been barren.

The relations between production and the structure of the oil sand are more complex than those of production and surface structure. The fact that every important field in the area, with the exception of the Wiser Hill pool, shows doming of the oil sand unquestionably signifies that such doming is important, if not essential. It is true that sharp synclinal folding is also present in the oil sand in some of these fields, but the oil wells are almost without exception in the heads of such synclines, where they rise steeply on the flanks of anticlinal folds. In the Wiser Hill pool, where there is no doming of the oil sand, the accumulation is almost certainly due to faulting. (See p. 415.)

The relation of dry holes to anticlinal structure in the oil sands can not be stated, for the structure of the oil sands is known only in comparatively small portions of these townships. However, it is noteworthy that of all the dry holes in this area but three are known to be on pronounced anticlinal folds in the oil sand.

The outlines of the oil fields are more closely connected with the anticlinal folding of the oil sands than with that of the surface rocks. In all the anticlinal pools the crests and much of the axes of the subsurface anticlines are within the oil-yielding area. The positions of big wells with respect to axes and crests, however, vary greatly.

Only in the South Butler Creek field are the large wells over the crests of the domes. Elsewhere they are from 10 to 60 feet below the crests and are commonly on the west or northwest flanks of the fold; although some have been found on both south and east flanks.

A tendency for oil to be found along certain lines or trends has frequently been suggested. In this area such a tendency is strikingly apparent in the Wiser Hill pool and is also very noticeable southwest of the Viza Creek dome. In both of these localities the trends are to the northeast. There is a suggestion of a northeast trend in the Panther Creek pool. In the South Butler Creek pool the line of producing wells trends due north.

These trends appear to be determined by structural conditions rather than by the distribution and nature of the oil sand or the subjacent shales. The two fields that show the most definite trends are thought to be related to faults that trend in the same directions as the oil pools. Elsewhere the trends conform closely to the axes of deformation in the underlying beds.

STRUCTURE IN DETAIL.

T. 26 N., R. 12 E.

In the parts of T. 26 N., R. 12 E., that are covered by alluvium the structure could not be determined from the surface geology. Such areas include the valley of Turkey Creek in sec. 6, the valley floor of Sand Creek, and portions of secs. 3, 4, and 10. The large synclinal basin, centering in the SW. ¼ sec. 4 and the NE. ¼ sec. 8 would suggest that the west slope of a fold favorable to oil accumulation occurs in sec. 3. This suggestion is corroborated by the presence of oil wells drilled in the north half of that section and in the section to the east. A structure probably due to faulting occurs in the N. ½ sec. 15.

Panther Creek occupies about the center of a north-south syncline, the largest syncline in the township.

This township has been drilled extensively, and probably the higher sands, including the Bartlesville, have been drained of much of their extractable oil. The drilling, however, has not been deep enough to determine the presence or absence in this township of oil-bearing beds below the top of the "Mississippi lime." The writers have suggested some locations for such exploration in the following detailed descriptions.

Jessie Creek anticline.—The Jessie Creek anticline, so named because it is near the head of Jessie Creek, lies mainly in secs. 33 and 34. It extends northeastward an undetermined distance and southwestward into sec. 4, T. 25 N., R. 12 E., where it is separated from the Forty-seven anticline by a short saddle. The oil obtained in wells on the Forty-seven anticline is said to come exclusively from the Bartlesville sand, the Peru sand being unproductive.[8] In the Jessie Creek anticline, however, many of the wells obtain oil from the Peru sand and many from the Bartlesville sand. The Squirrel sand, though recorded in many of the logs of the deeper wells, is usually noted as barren. One well, however, produced 3,000,000 cubic feet of gas from this sand. Both oil and gas have been produced from this anticline. To the north and the west of its crest the only holes that proved to be dry were far down the sides of the anticline. Of the many wells drilled on this anticline in T. 26 N., R. 12 E., only one, a gas well, appears to have reached the "Mississippi lime." In the northwestern part of the SW. ¼ sec. 32 a dry hole penetrated the Burgess sand, but it is so far down the flank of the anticline as to be almost in the bottom of a syncline and could hardly be expected to produce oil in quantities from any sand. The Jessie Creek anticline is pretty well explored for oil in the Bartlesville and higher sands, but should be drilled to determine the possibility of oil in or below the "Mississippi lime." Good locations for tests of the lower beds are near the center of sec. 33, the center of the west line of the SW. ¼ sec. 33, the center of the SE. ¼ sec. 33, and the center of the south line of the SW. ¼ sec. 28.

During the first quarter of 1921 the portion of this anticline in this township furnished approximately two-fifths of the total production for the township.

North Jessie Creek dome.—The North Jessie Creek dome lies mainly in the SE. ¼ sec. 20 and SW. ¼ sec. 21, with a small part in the extreme northwest corner of sec. 28 and the northeast corner of sec. 29. It has a closure of about 20 feet, but its top is divided into two small slightly domed areas. The southwestern part of this dome has been well tested and is now producing from the Bartlesville sand. It seems possible that the producing area may be extended to the north and to the west. There seems to be a definite trend of productive area southwestward from the Viza Creek dome, which if extended would cross the anticlinal nose extending west from the North Jessie Creek anticline in the SE. ¼ sec. 20. Testing the Bartlesville sand in the center of the SW. ¼ SE. ¼ sec. 20 accordingly seems justifiable. The north half of the top of the dome has not yet been tested, although about half a mile to the northeast some dry holes have been drilled.

Panther Creek anticline.—The Panther Creek anticline is in the western part of secs. 19, 30, and 31 and the adjacent sections of T. 26 N., R. 11 E. As the datum planes used in mapping this township and T. 26 N., R. 11 E., are 465 feet apart, the contours on the map in

[8] Hopkins, O. B., U. S. Geol. Survey Bull. 686–H, pl. 11 and p. 85, 1918.

this paper interfinger with those on the map of the adjacent township.[9] This interfingering slightly changes the shape of the upper closing contours. The fault in sec. 19 is just east of the area mapped by Clark and consequently was not noted by him. The presence of this fault changes somewhat the aspect of the small domes on this anticline, showing that there are but three, instead of four, as he describes.[10]

The oil produced on this anticline is obtained mostly from the Bartlesville sand, although some comes from the Peru sand. The anticline has been fairly well explored so far as these sands are concerned, but the "Mississippi lime" has not been penetrated by many wells nor to any great depth. The deepest well stratigraphically in this township of which the writers have knowledge is in the NW. ¼ sec. 31. This well is said to have been drilled 126 feet into the "Mississippi lime" and to have had an initial production of 26,000,000 feet of gas from the first break in the lime. Most of the oil produced from this anticline is obtained in the township to the west. There is a good possibility, however, that oil may be found below the gas horizon in the upper part of the "Mississippi lime." The 350 or 400 feet of strata below the top of the "Mississippi lime" on this anticline should unquestionably be tested by wells located high on the anticline.

Midland dome.—The Midland dome, named from the Midland Oil Co., which owns the lease on it, occupies the western two-thirds of sec. 5 and probably much of sec. 6. There is also a small subsidiary dome in the SE. ¼ sec. 5. The main dome has a closure of about 30 feet. The fault to the east, if persistent in depth, would add somewhat to the area from which oil might be recovered. The rocks are concealed in the greater part of sec. 6 by alluvium and wash, so that the surface structure there can not be determined. The beds appear to lie very flat, dipping slightly to the west with steeper dips along the south and west edges of the section. It is possible that either a small dome or a small depression may occupy the central part of sec. 6. Four dry holes have been drilled in this section, two on the east edge of the NE. ¼ and one each in the northwest corner and the southwest corner of the NW. ¼. The two latter wells were drilled to the "Mississippi lime," but the writers have no data on the two eastern holes. Just to the east of these holes, in the western part of sec. 5, wells are producing oil from the Bartlesville sand and gas from the top of the "Mississippi lime." Several interpretations of the underground conditions are suggested by the presence of the two dry holes in the eastern part of sec. 6. They may have encountered "tight" sands; they may be just west of the area where the oil has

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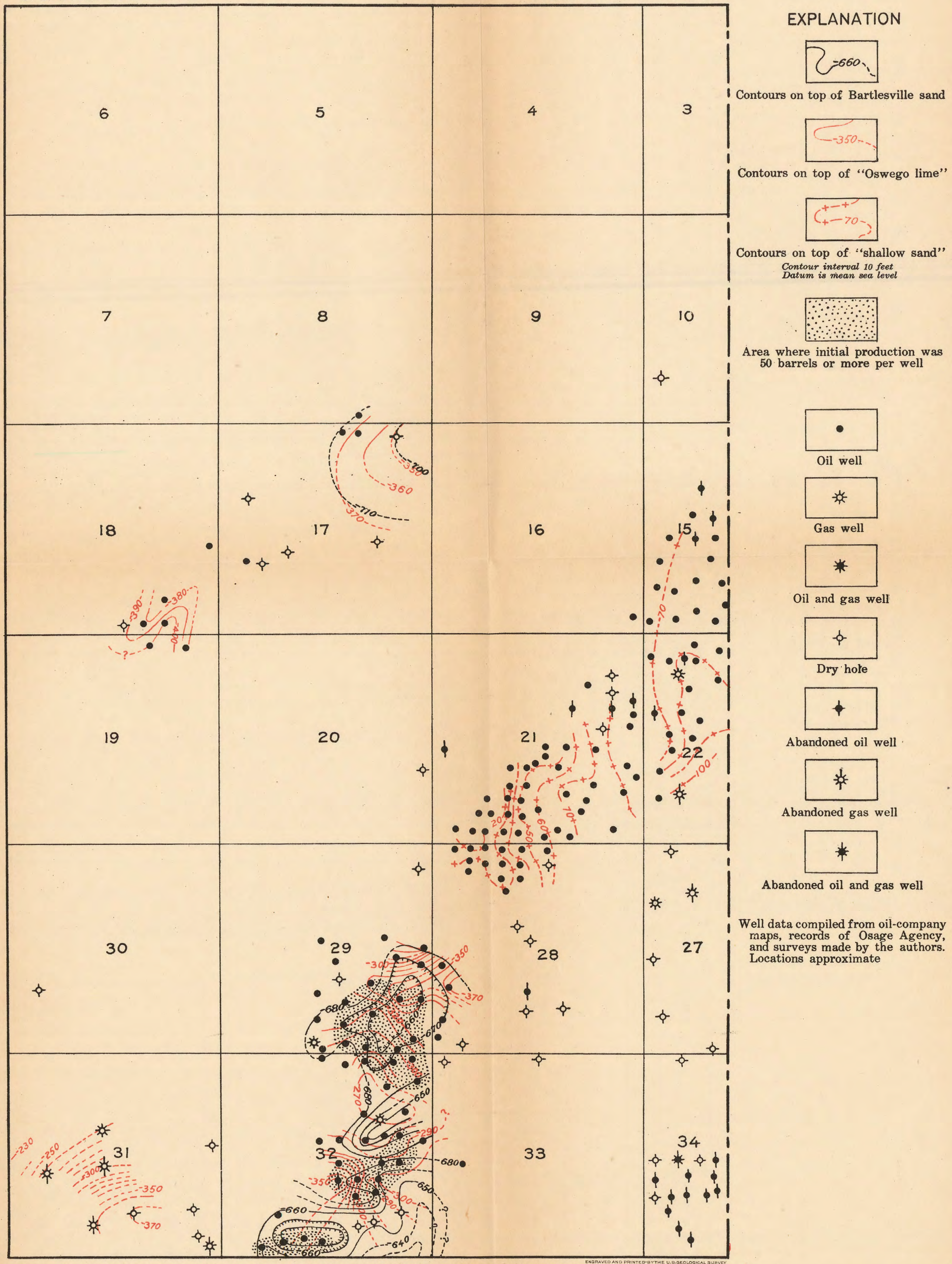
[9] Clark, F. R., U. S. Geol. Survey Bull. 686–I, pl. 15, 1918.
[10] Idem, p. 116.



MAP SHOWING WELL LOCATIONS AND CONTOURS ON SUBSURFACE BEDS IN T. 27 N., R. 12 E., OKLAHOMA

Scale $\frac{1}{31,250}$

0 ½ 1 Mile

1922

collected; or there may be a small dome in the center of sec. 6, which would mean that these two holes were in a small syncline.

On this dome, as on other favorable oil areas in this township, no well has tested the horizons below the upper part of the "Mississippi lime." It is a particularly advantageous location for such a test, as the development has permitted determination of the position of the folding in the Bartlesville sand. The best place for a deep test would appear to be the center of the NW.¼ NE.¼ sec. 5, T. 26 N., R. 12 E.

It is possible that a small pool can be developed on a little dome just east of the fault line in the SW.¼ sec. 5. There is a distinct axis of folding here, and even though the area of the fold is very small, there is a possibility of fair production. The presence of faults suggests the possibility of production from some shallow sand as well as from the Bartlesville sand or the "Mississippi lime."

Sec. 18.—A half dome occupies the SE. ¼ sec. 18. It is made up of beds showing a steep reverse dip on the east and is bounded by a fault plane on the west. There is a probable closure of at least 70 feet against the fault. As the greater part of sec. 18 is covered with alluvium, it is not possible to determine the exact structural conditions. Unless an unmapped fault occurs in the alluvium-covered area of Sand Creek, the structure is probably about as indicated on the map (Pl. LVII). This half dome has a very small area from which to drain oil and may for that reason yield but little. However, the fault plane may have acted as a conductor of oil from deeper beds, and the dome should certainly be tested. A good location for such a test is a little north of the center of the SW.¼ SE.¼ sec. 18.

A depression occurs in this section, and its deepest part is just a little east of the center of the section. A number of wells have been drilled in the SW.¼ sec. 18, but the writers have been unable to procure logs of these wells. From the surface structure it would appear to be undesirable to drill more wells in this section, except as suggested above.

Viza Creek dome.—The Viza Creek dome occupies the NW.¼ sec. 15 and part of the NE.¼ sec. 16. Its presence is suggested by the outcrop of the Dewey limestone. The cover of alluvium conceals most of the surface detail of this dome. The underground structure shows strong dips to the east and south, but lack of positive evidence leaves the condition of the northwest side of the dome a matter of surmise. However, the suggestive evidence (see p. 409) indicates that a major portion of the dome closes against a concealed fault to the northwest. Unlike the somewhat similar dome in sec. 18, this dome is probably free to drain oil from the south and southwest. Oil is obtained in it from both the Peru and the Bartlesville sands.

T. 27 N., R. 12 E.

A small portion of T. 27 N., R. 12 E., is covered with alluvium, so that no surface structure contours could be drawn for sec. 34 and parts of secs. 27, 28, and 33. The most prominent structural features are a flat with slight doming that occupies the central part of the township, a pronounced syncline that plunges westward across the township about 1½ miles south of the north edge, four faults, and five plunging anticlines, two of them with local doming. To the lack of pronounced doming is probably due in part the small amount of drilling that has been done in the north half of the township. The presence of these faults and the long axes of the plunging anticlines, considered in connection with their probable relation to oil production and subsurface conditions, make the study of this township of special interest to the oil man as well as to the geologist.

Wiser Hill pool.—The Wiser Hill pool occupies the NE. ¼ and S. ½ sec. 21, the north third of sec. 28, and most of secs. 15 and 22. This area is locally known as Wiser Hill, from the oil company that is operating the leases. Over 90 wells have been drilled in this pool. The oil is obtained from a sand 12 to 22 feet thick, known locally as the "shallow sand." This sand is recorded as being from 30 to more than 100 feet above the Big lime and from 117 to 222 feet or more above the Peru sand, but some of this variation is probably due to inaccuracy in the logs, for the logs showing the lower sands are old and appear to be generalized. The wells drilled in this pool to the Peru and Bartlesville sands found them nonproductive of oil. Wells east of the pool, in the Washington County part of this township, obtain oil from the Bartlesville sand but none from the "shallow sand." This sand, or at least a thin sand that bears the same relation to the Big lime, is recorded in some of the logs from other parts of the two townships considered in this paper, but no oil appears to have been noted in it, although some of the wells whose logs record its presence are favorably located with reference to the structure. Showings of gas recorded in secs. 29 and 32 of this township appear to come from this sand.

At least three sands that lie stratigraphically above the "shallow sand" of the Wiser hill pool have given showings of gas in wells drilled in Tps. 26 and 27 N., R. 12 E., and apparently they have in some logs been confused with the sand of the Wiser Hill pool. These sands are about 675, 560, and 450 feet above the Big lime, and the lowermost of them is therefore 300 feet or more above the horizon of the "shallow sand" of the Wiser Hill pool. The highest of these sands contains some gas in sec. 34, T. 26 N., R. 12 E. The next lower one yielding gas shows in sec. 29, T. 27 N., R. 12 E., and in secs. 5 and 34, T. 26 N., R. 12 E. The lowermost sand showed a gas content in sec. 17, T. 27 N., R. 12 E., and secs. 5 and 34, T. 26 N., R. 12 E.

The surface geology shows that a fault in secs. 16, 21, and 22 cuts through the middle of this pool. The subsurface geology indicates that this fault has a greater throw at the horizon of the "shallow sand" than at the surface. The portion of the pool on the west side of the fault is on a gentle raise from a structural flat or terrace to the northwest. The portion of the pool on the east side of the fault is on beds having a much steeper northwest dip. A second fault occurs just southwest of this pool. West of this fault oil is produced from the Bartlesville sand but none from the "shallow sand." It is also noteworthy that the long fault in sec. 33 and in T. 26 N., R. 12 E., is parallel in trend to the Wiser Hill pool. Whether or not this particular fault affects the "shallow sand" southeast of the pool, the fact that the Wiser Hill pool has practically the same alinement must be considered significant.

The oil in this pool may have been derived from the shales just below the "shallow sand," or it may have escaped from lower sands along a fault plane or planes and collected in the "shallow sand." If the subjacent shale was capable of yielding enough oil to justify the drilling of more than 90 wells, at least two of which were put down as early as 1904, it is only reasonable to expect that similar oil-producing conditions at this horizon would manifest themselves elsewhere in these townships. If such conditions exist, however, they have not been discovered. On the other hand, if the occurrence of a large amount of oil in the "shallow sand" in this pool is due to the collection of oil that has escaped from a deeper sand along a fault line, the barrenness of lower beds in this pool and of the "shallow sand" outside of this pool is explained.

No anticlinal structure is present in this pool, either in the surface beds or in the oil sand, and although the southern part of the field is on the edge of a terrace in the surface beds, no such structure is certainly present in the producing sand. This condition argues against a normal type of oil accumulation.

It seems probable that the pool contains oil that migrated up the dip of deep oil-bearing sands and found an avenue of escape to the "shallow sand" along the faults in secs. 20, 28, and 29 and in secs. 16, 21, and 22. The retention of the oil was probably effected either by sand conditions or by a third fault, not manifest at the surface, which trends northeastward along the southeast boundary of the field. The outline and extent of the pool may also have been influenced by the northward-plunging anticlinal nose in sec. 22. If this hypothesis is correct oil is not necessarily to be expected in the deep beds below this pool, as there is no reason to believe anticlinal structure favorable to its accumulation exists there.

South Butler Creek pool.—The South Butler Creek pool occupies the southeast third of sec. 29, the E. ½ and part of the SW. ¼ sec. 32, and a small area in the SW. ¼ sec. 28. From the surface structure this pool appears to be merely the steeply dipping north slope of the Midland dome, which lies in the northern part of the township to the south. The only doming shown by the surface beds is on a nose in the western part of sec. 32 and the NW. ¼ sec. 31, which has a single closed contour on its north end. This closure is west of the pool, and the area has not yet been tested. The east edge of the pool is limited by two faults, to which is probably due in part the marked difference in the structure of the surface beds and the Bartlesville sand. Plate LVIII (p. 408) shows that in the E. ½ sec. 32 and the SE. ¼ sec. 29 the surface beds have a slightly varying northward dip.

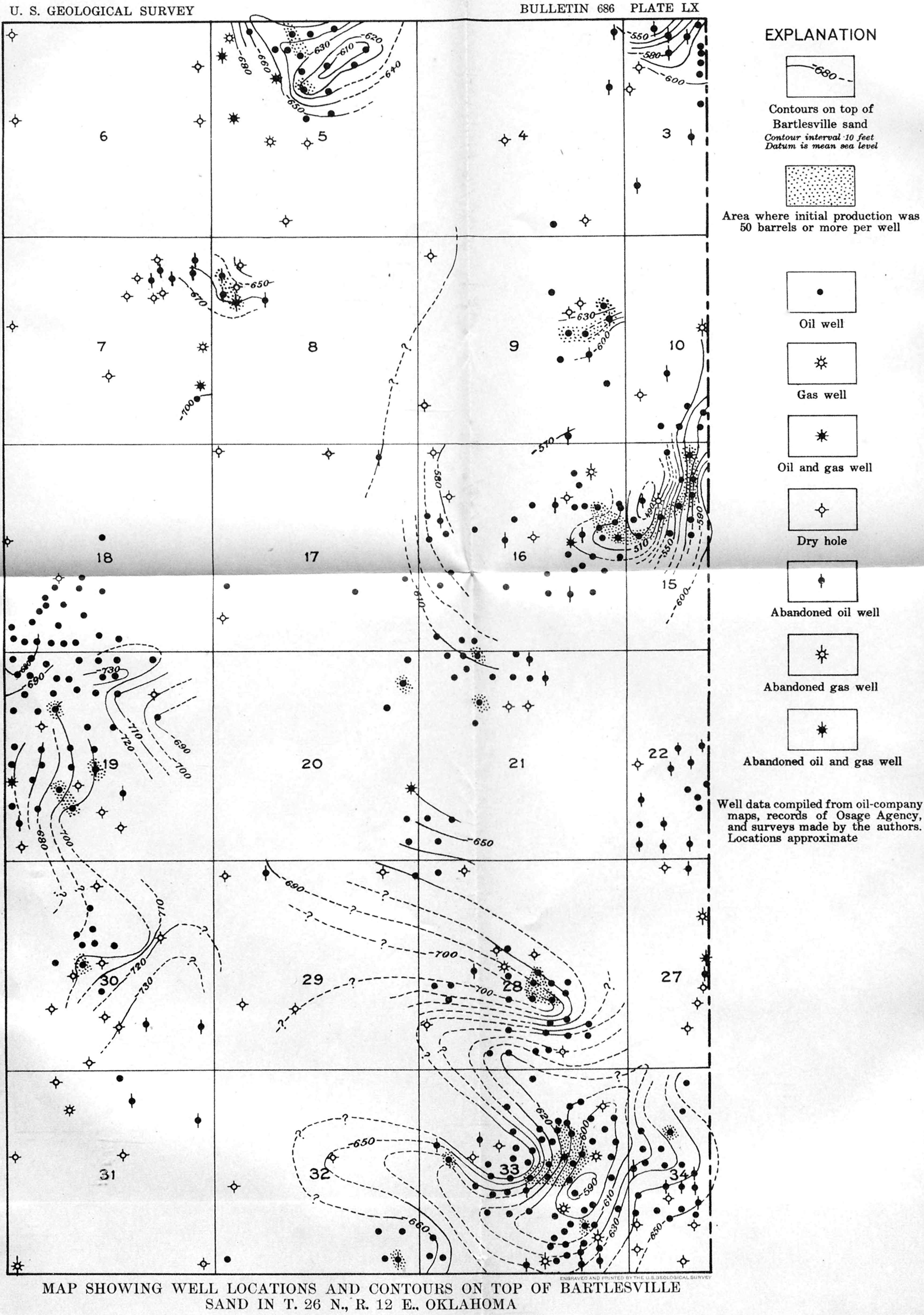
Plate LIX (p. 412) shows that the "Oswego lime" is arched into a low dome whose crest is near the center of the NE. ¼ sec. 32. South of this dome there is an anticlinal nose that plunges northwestward across the SE. ¼ sec. 32.

The folding in the Bartlesville sand in this area agrees in a general way with that in the "Oswego," but it is more complex. Instead of a single dome, two are shown, one in the SE. ¼ sec. 29 and the other in the NE. ¼ sec. 32. There is also a plunging anticline in the SE. ¼ sec. 32 which is more pronounced than the similar fold in the "Oswego."

This pool has not been outlined by dry holes, and it seems probable that it will extend from the south-central part of sec. 29 into the NW. ¼ sec. 32. Certainly the surface structure and the observed relations between the surface and deep folding justify a test there. A good location for such a test would be the center of the NW. ¼ NW. ¼ sec. 32. A good location for testing the beds in and below the "Mississippi lime" would be the center of the SE. ¼ SE. ¼ sec. 29.

Backius anticline.—Most of the Backius anticline lies in T. 27 N., R. 11 E., but a curved spur extends eastward into the west-central part of sec. 31, T. 27 N., R. 12 E., dying out in a structural saddle about 1,000 feet northwest of the south quarter corner of the section. This anticline has yielded both oil and gas in notable amounts. The portion in T. 27 N., R. 12 E., was drilled many years ago, and a small gas field was developed on it. So far as known the wells yielded no oil.

North Butler Creek terrace.—The North Butler Creek terrace occupies the eastern two-thirds of sec. 17, the W. ½ sec. 16, and the adjacent parts of secs. 20 and 21. In sec. 17 there is a single closed contour. In the center of the area outlined by this contour a dry hole was drilled 273 feet into the "Mississippi lime." From the



MAP SHOWING WELL LOCATIONS AND CONTOURS ON TOP OF BARTLESVILLE SAND IN T. 26 N., R. 12 E., OKLAHOMA log of this well it appears that the Peru and Squirrel sands are absent and that the Bartlesville sand is thin. This log is shown as No. 2 on Plate LVI. Oil, however, is produced from the Bartlesville sand and from a sand at the top of the "Mississippi lime" on the edges of this terrace.

The portion of this terrace that is structurally most favorable is the SW. ¼ sec. 18, where an axis of folding extending westward from the central low flat of the North Butler Creek terrace is intersected by a northward-trending axis that is parallel to and about 1,000 feet west of the east line of secs. 30 and 19. There seems to be anticlinal folding in the "Oswego lime" where these two axes intersect. A number of wells have been drilled in the SE. ¼ sec. 18 and the NE. ¼ sec. 19, but the producing territory can probably be extended to the north and east.

It is probable that there is a similar intersection of less pronounced axes on the northeast flank of the terrace in the northeast corner of sec. 17 and the southeast corner of sec. 8. This inference is strengthened by the contour of the tops of the "Oswego lime" and Bartlesville sand as revealed by the records of two oil wells and two dry holes that have been drilled on this part of the terrace. There seems to be decided doming in these lower beds, and it will be noted that this doming is to the northeast of the surface doming, its relative position agreeing in this respect with that of the subsurface folds in other parts of these townships. It seems probable that prospecting north and east of the corner of secs. 7, 8, 17, and 18 will be repaid by production.

Secs. 4 and 5.—A structural nose or plunging anticline trends westward across the northern parts of secs. 4, 5, and 6. This nose is modified by gentle doming on the line between secs. 4 and 5, due, apparently, to the north-south axis of folding that affected the northeastern part of the North Butler Creek terrace.

No wells have been drilled in this area, and as the surface structure indicates that there should be pronounced doming in depth, and as this nose should receive the oil from much of secs. 5 and 6, it is recommended that a test be drilled near the east line of the S. ½ NE. ¼ sec. 5. Oil may be found in the Bartlesville sand, at the top of the "Mississippi lime," or about 350 to 400 feet below the top of the "Mississippi lime."

OIL AND GAS.

Development.—Oil was discovered at Bartlesville, just east of the area mapped, in 1894, but owing to complications in leases, active operations were not begun until about 10 years later. There were no wells of great yield, although some are said to have had an initial daily production of 1,000 barrels, but there were many that started with several hundred barrels a day, and the Bartlesville-Dewey pool soon attracted widespread attention. The pool was rapidly developed, and in 1906 the production began to decline. In that year the average initial daily production was about 73 barrels, and by 1914 this average decreased to 10.4 barrels. It is reported that at the end of 1914 there were 4,816 producing wells in the pool.[11]

The western part of the Bartlesville-Dewey pool extends into the area here mapped, but because of its location in Osage County, where conditions of leasing are different, development has been retarded.

Active drilling was begun in 1903 in the eastern tier of sections of T. 26 N., R. 12 E., in Osage County, adjacent to the developed area in the vicinity of Bartlesville. A number of good wells were found, including a few small gushers. Drilling soon spread throughout the leased area, and by 1917 at least 464 wells had been sunk in the area here considered. Of these, 139 were in T. 27 N., R. 12 E., and 325 in T. 26 N., R. 12 E. About 20 per cent of those in the northern township and 14 per cent of those in the southern township were dry holes. By the middle of 1921 at least 703 wells had been drilled in this area, about 232 in the northern township and 471 in the southern township, of which about 20 per cent and 18 per cent respectively are dry. Many wells have, of course, been abandoned.

Production.—For the three months of January, February, and March, 1921, the total production of oil in the Osage County portion of T. 27 N., R. 12 E., was 20,132.4 barrels from 134 wells, or an average of about 50 barrels per well per month. During the same period the southern township did slightly better, producing 49,712.9 barrels from 267 wells, or an average of about 62 barrels per well per month. The production from six sections, three in each township, containing a total of 48 producing oil wells, was 2,111.6 barrels for this three-month period, or an average of about 14⅝ barrels per well per month, or half a barrel per day. These six sections were selected as representing the smallest production, but the producing wells are situated near more prolific wells in adjacent sections. During the corresponding three months of 1917 the average production for the same six sections was about 27 barrels per well per month.

Many of the older wells declined so that they produced but little oil, yet during the period of high prices for crude oil they could be pumped with profit when the pumper could attend to them in addition to more productive wells.

The logs of many of the wells in these two townships are very incomplete, some of them giving only the depth from which oil was produced. Many of the present lessees do not even possess records of all the wells drilled on the area now under their control. Of the

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[11] Oklahoma Geol. Survey Bull. 19, pt. 2, p. 510, 1917.

available logs many fail to mention initial production. Some indicate only the production in the first 24 hours after the well was shot and some only that in the first 24 hours natural yield. Therefore the term "initial production" as used here may indicate either period, but where the production for both periods is given in the logs, the larger production has been used. In the following discussion and averages dry holes are not considered.

In the Osage portion of T. 27 N., R. 12 E., records of the initial production of 94 wells have been procured. Of these, 22 wells showed 50 barrels or more, including 7 that came in with 100 barrels or more. The average initial production was 35¼ barrels. In T. 26 N., R. 12 E., of 130 wells whose initial production is on record, 38 made 50 barrels or more, including 10 that produced 100 barrels or more. The average was 38⅓ barrels.

Wells having an initial production of 50 barrels or more occur in 15 sections in this area, and most of these are located where the structure as determined from surface outcrops is favorable. Faults and anticlinal folds appear to be the main factors in determining the favorable localities. One area, the eastern part of sec. 9, T. 26 N., R. 12 E., where the initial production was large and the surface structure not exceptionally favorable, is adjacent to an alluvium-covered area on the east, under which a concealed fault probably exists, causing the larger production in that area. Structural evidence of a concealed fault was found in the section to the south, and this occurrence may be suggestive evidence of the northeastward extension of that fault.

Quality.—The quality of the oil and gas obtained in this area is shown by the following analyses:

Analyses of crude petroleum from Tps. 26 and 27 N., R. 12 E.

[By Ernest W. Dean, Bureau of Mines. Air distillation with fractionating column; barometer 735 millimeters for Nos. 00107 and 00106; 747 millimeters for No. 00108.]

Laboratory No.	Source and character of sample.	Temperature (°C.).	Fractions (per cent by volume).	Total distilled (per cent by volume).	Specific gravity.
00107	Peru sand, well No. 23, Skelton-Moore Oil Co., SW. ¼ sec. 34, T. 26 N., R. 12 E. Specific gravity at 15° C., 0.854 (33.9° Baumé). Sulphur, 0.13 per cent.	Up to 75	5.0	5.0	0.684
		75–100	5.2	10.2	.724
		100–125	4.3	14.5	.752
		125–150	5.2	19.7	.768
		150–175	5.1	24.8	.788
		175–200	3.8	28.6	.804
		200–225	4.5	33.1	.816
		225–250	5.5	38.6	.832
		250–275	5.5	44.1	.846
00108	Composite sample from "shallow sand" from several wells of Wiser Oil Co., sec. 21, T. 27 N., R. 12 E. Specific gravity at 15° C., 0.856 (33.6° Baumé). Sulphur, 0.15 per cent.	Up to 75	2.5	2.5	....
		75–100	4.5	7.0	.720
		100–125	6.1	13.1	.745
		125–150	4.5	17.6	.762
		150–175	4.9	22.5	.780
		175–200	4.6	27.1	.796
		200–225	4.6	32.7	.812
		225–250	5.3	38.0	.826
		250–275	5.7	43.7	.840

Analyses of crude petroleum from Tps. 26 and 27 N., R. 12 E.—Continued.

Laboratory No.	Source and character of sample.	Temperature (°C.).	Fractions (per cent by volume).	Total distilled (per cent by volume).	Specific gravity.
00106	Bartlesville sand, well No. 24, Indian Territory Illuminating Oil Co., SE. ¼ sec. 32, T. 27 N., R. 12 E. Specific gravity at 15° C., 0.866 (31.7° Baumé). Sulphur, 0.15 per cent.	Up to 75	4.3	4.3	.713
		75–100	4.5	8.8	.762
		100–125	2.0	10.8	.792
		125–150	3.5	14.3	
		150–175	3.0	17.3	.808
		175–200	5.4	22.7	.818
		200–225	4.5	27.2	.826
		225–250	6.4	33.6	.832
		250–275	7.0	40.6	.842

These results show that the samples tested represent high-grade petroleum, the specific gravity of which at 15° C. ranges from 0.854 to 0.866 (33.9° to 31.7° Baumé) and which yields on distillation up to a temperature of 200° C. between 22.7 and 28.6 per cent by volume.

Analyses of natural gas from Tps. 26 and 27 N., R. 12 E.

[By S. H. Katz, Bureau of Mines.]

Laboratory No.	Source of samples.	Methane (CH_4).	Ethane (C_2H_6).	Carbon dioxide (CO_2).	Nitrogen (N_2).	Oxygen (O_2).	Specific gravity (air=1).	British thermal units per cubic foot at 760 millimeters.
9294	Top of "Mississippi lime," gas well No. 45, Indian Territory Illuminating Oil Co., NW. ¼ sec. 31, T. 27 N., R. 12 E.	93.2	0.8	4.0	2.0	0.0	0.60	1,008
9316	Composite sample from Bartlesville sand, wells Nos. 9, 12, 15, and 28, Skelton-Moore Oil Co., sec. 34, T. 26 N., R. 12 E.	40.7	57.7	.3	1.1	.2	....	....
9315	Peru sand, well No. 23, Skelton-Moore Oil Co., SW. ¼ sec. 34, T. 26 N., R. 12 E.	11.9	85.7	.5	1.6	.3	....	....

The above analyses show the composition of three samples of natural gas from the sources indicated, collected in November and December, 1917, by air displacement. The high methane content of sample No. 9294, 93.2 per cent, is typical of a dry gas although the 4 per cent of carbon dioxide is somewhat unusual. The other samples show different proportions of methane and ethane in wet gases. The small amounts of oxygen probably represent air leakage.