T. 24 N., R. 9 E.

By K. C. Heald, C. F. Bowen, and others.

INTRODUCTION.

The field work in T. 24 N., R. 9 E., was done by K. C. Heald, C. F. Bowen, D. D. Condit, and W. B. Emery. Their responsibility for the mapping of the entire township is indicated by the order in which their names are given. They were effectively assisted by W. L. Miller and J. M. Vetter, whose work with the plane table added materially to the detailed accuracy of the results.

The positions of the outcrops of the beds and the elevations on which the structure contouring is based were determined by plane table and telescopic alidade, with the exception of a few points which were located by compass bearing and pacing traverse, and whose elevations were determined by barometric observations.

ROCKS EXPOSED.

GENERAL FEATURES.

The rocks exposed in T. 24 N., R. 9 E., include sandstones, shales, and limestones of upper Pennsylvanian age. (See fig. 31.) The sandstones are by far the most noticeable rocks in the township because of their prominent outcrops, most of which are emphasized by a thick growth of oak and hickory, in contrast to the unforested condition of the adjoining areas where shales crop out, but the aggregate thickness of the sandstone is in fact less than that of the shales. The exact thickness of either sandstones or shales can not be accurately determined, because the basal sandstone beds are in most places slumped in such a manner that the exact contact with the shale can not be seen. In many places benches of shale between sandstone ledges are so concealed under blocks of sandstone that the presence of shale can be proved only by pulling up large fragments of sandstone and digging into the underlying soil. Limestones are conspicuous in only two localities in the township—near the north line of sec. 8 and in the extreme northeast corner of sec. 29. At these two places the lower beds of the Pawhuska limestone form outliers which are particularly prominent because they cap hills that stand

up above the general level of the surrounding ridge. The Oread limestone, which is the only other definite limestone bed in T. 24 N., R. 9 E., is extremely inconspicuous. A few of the beds that were particularly helpful in determining the geologic structure are described in some detail below.

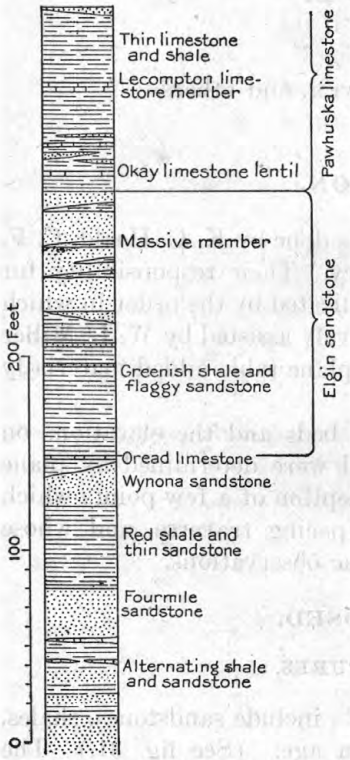


FIGURE 31.—Section of rocks exposed in T. 24 N., R. 9 E.

KEY BEDS.

Elgin sandstone.—The Elgin sandstone, which immediately underlies the Pawhuska limestone, is about 135 feet thick in T. 24 N., R. 9 E. The upper half of the formation is massive sandstone, with thin lentils of shale; in the lower half heavy beds of green shale alternate with thin, flaggy sandstone. Except in a few places, the flaggy sandstone in the lower part of the formation can be traced only for short distances, and it is extremely difficult to distinguish between the different beds—conditions which make correlation across concealed areas very uncertain. For this reason most of the structure in that part of the township where the Elgin sandstone is the surface formation was determined by work on the massive sandstone in the upper part of the formation. Where lentils of shale are present between members of this massive sandstone there are prominent ledges which may be traced with certainty, but the shale lentils are only local, and many of the sandstone ledges terminate abruptly, merging into thicker beds of unbroken sandstone. The most persistent of the shale lentils lies about 45 feet below the top of the Elgin sandstone. As much mapping as possible was done on the top of the underlying sandstone ledge. The shale above it can usually be seen only in freshly cut stream channels or by digging some distance into the soil above the top of this heavy lower ledge, but its presence is indicated by a persistent bench that may be followed with considerable certainty. The shale ranges in color from a bright red to an olive-green, with small crimson blotches, and in thickness from a few inches to 5 feet. The sandstone below the shale is in most places coarser in texture than the higher beds of the Elgin

sandstone, and its grains are less uniform in size. Shale inclusions are not uncommon, particularly near the very base of the bed, which in places presents a ragged appearance, due to the weathering out of these inclusions. However, similar ragged surfaces have been observed in some of the overlying beds, so that this characteristic is not of great value as an aid to correlation.

Below this basal sandstone is a thick bed of yellowish to olive-drab shale, which by its creeping permits large blocks of the overlying sandstone to break off and slump down the hill. Accordingly the outcrop of this basal massive ledge is much more likely to be marked by large tilted and slumped blocks than those of any of the overlying sandstone members, which are underlain by comparatively thin lentils of shale.

The structure mapping over the western third of T. 24 N., R. 9 E., is based largely on work done on the Elgin sandstone. Good localities for studying are the central part of sec. 7, the NE. ¼ sec. 8, and the south-central part of sec. 17.

Oread limestone.—The Oread limestone, which in this township is about 135 feet below the top of the Elgin sandstone, crops out in only a few localities, but its failure to appear is probably due more to the thinness, solubility, and general inconspicuous character of the bed than to its actual absence. Such outcrops as were observed show it to be a hard, compact crystalline limestone, orange-red on the weathered surface and gray on the fresh surface, with few fossils. Associated with it are dark-gray shales, which in many localities are very fossiliferous. The fossils weather out, and the horizon of the Oread may be followed by finding them associated with small limestone nubbins, even where no outcrops are visible. In localities where even these markers are absent the general horizon of the bed is marked by tiny nodules of chalk-white lime which have weathered out of the shale. These nodules are probably of secondary growth, and similar ones have been observed at other horizons where there are limy shales, but near the Oread limestone they appear to be limited to the shales immediately adjacent to the limestone.

The horizon of the Oread limestone was traced through the township from north to south. (See Pl. XXXII.) A good locality for examining it is in the west-central part of sec. 27, where it has been uncovered in a pipe-line trench.

Wynona sandstone.—The Wynona sandstone, which lies from 2 to 15 feet below the Oread limestone, is a massive bed 15 to 25 feet thick, similar in characteristics to other sandstones in the Pawhuska quadrangle. In the south-central part of this township the sandstone loses its massive character and is a thin, flaggy bed which may

locally grade into a massive sandstone quite like that in the northern part of the township.

Above the Wynona sandstone is a bed of red shale 2 to 10 feet thick which terminates abruptly below the Oread limestone and is succeeded by the dark fossiliferous shales that accompany that bed. Below the Wynona sandstone there is a thick series of alternating red shales and sandstones.

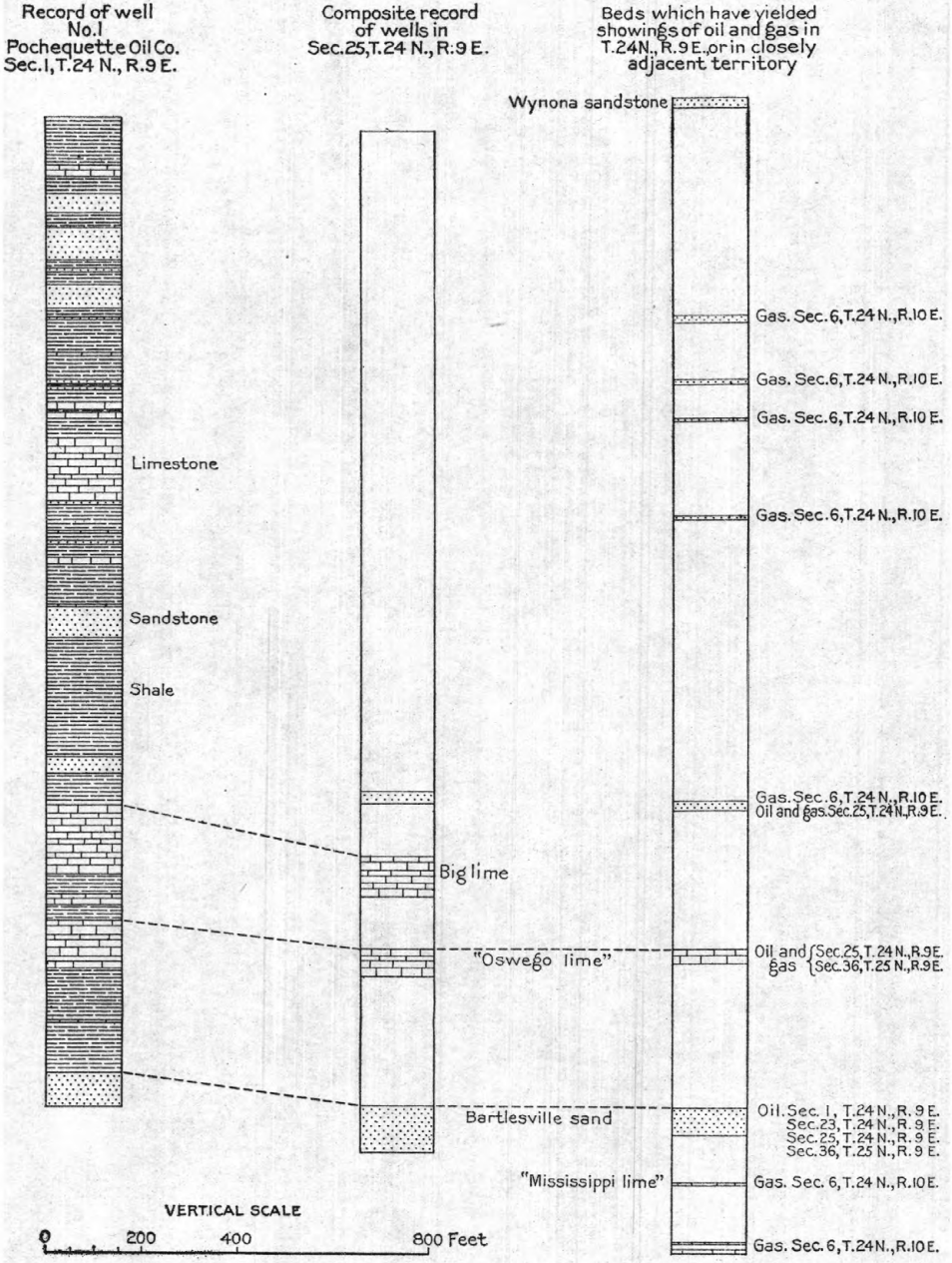
The Wynona sandstone covers the eastern half of the township, and the structure over this eastern half is determined from elevations either on the Wynona itself or on one of the underlying beds whose distance below the datum plane was determined by its relation to the Wynona sandstone. A good locality for studying this sandstone is just north of Wynona and in the northern outskirts of the town.

The outcrop line shown on the map (Pl. XXXII) does not represent the very top of the bed but is drawn so that it will include about 5 feet of the sandstone.

PENNSYLVANIAN ROCKS NOT EXPOSED.

The unexposed rocks above the "Mississippi lime" in T. 24 N., R. 9 E., are of the same general type as those which crop out. Sandstone and shale make up about 70 per cent of the total above what is known to the drillers as the Big lime (probably the Pawnee limestone of Kansas). Below that bed there is much more limestone and correspondingly less sandstone.

Either oil or gas has been reported from nine distinct beds in wells that have been drilled in T. 24 N., R. 9 E. (Pl. XXXIII). The uppermost of these beds have yielded only showings of gas, which will not be sufficient in volume to justify their utilization; but five deeper beds, three in the Pennsylvanian and two probably in the Mississippian, have yielded commercial amounts of oil or gas. The highest of these beds is about 1,470 feet below the top of the Wynona sandstone, and may perhaps be correlated with what is called the Peru sand in the fields northeast of T. 24 N., R. 9 E. The next lower productive bed is the Fort Scott ("Oswego") limestone, about 1,780 feet below the Wynona sandstone. In some wells just outside of T. 24 N., R. 9 E., oil and gas is reported to come from the limestone itself; in others it comes from a thin sandstone just above the Fort Scott. The third and most productive bed is the Bartlesville sand. Not enough work has been done to determine whether or not this is actually the same sandstone as the one that produces oil in the neighborhood of Bartlesville, but it is at approximately the same horizon. The most productive of the wells, both in T. 24 N., R. 9 E., and in the adjoining townships, obtain their oil from beds that occupy the general horizon of the Bartlesville sand. This sandstone is believed to



WELL RECORDS SHOWING DRILLERS' INTERPRETATIONS OF BEDS UNDERLYING T. 24 N., R. 9 E., AND GENERALIZED SECTION SHOWING APPROXIMATE POSITION OF OIL AND GAS BEARING BEDS.

be from 60 to 80 feet thick near the eastern border of the township and to grow thinner toward the west, so that near the western border it probably has a thickness of 15 feet or less. The two deepest of the producing beds are parts of the "Mississippi lime." They are comparatively thin beds of coarse limestone, and in wells drilled just east of the northeast corner of T. 24 N., R. 9 E., they contain large volumes of gas. This gas is reported to contain a considerable percentage of heavy hydrocarbons, which indicate the probability that these beds also contain oil. The lower of these two beds is about 2,400 feet below the Wynona sandstone.

STRUCTURE.

GENERAL FEATURES.

The rocks in T. 24 N., R. 9 E., are so extensively folded and individual anticlines and synclines are so irregular in outline that a casual examination of the map (Pl. XXXII) may not reveal any

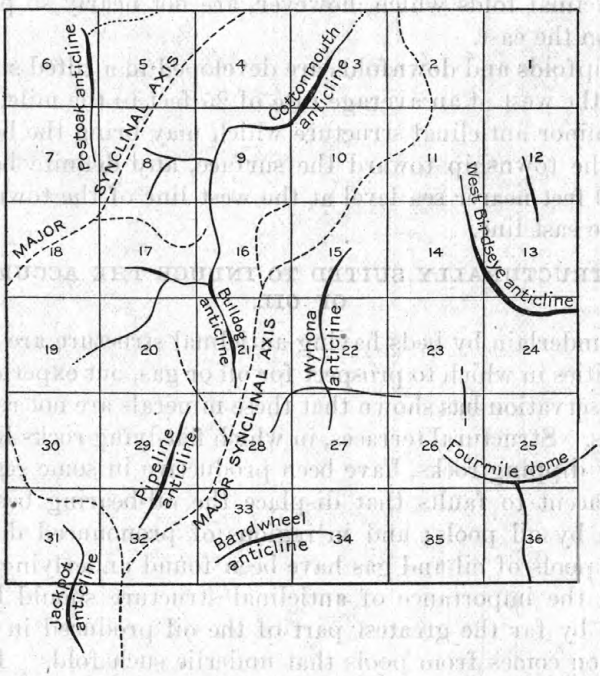


FIGURE 32.—Diagram showing positions of anticlinal and major synclinal axes in T. 24 N., R. 9 E.

particular system of deformation. Careful examination, however, shows that there is a very definite arrangement both of folds and faults. A major synclinal axis which marks the bottom of the structural trough passes through the next township to the south about a quarter of a mile east of the southwest corner of sec. 32 and goes northward through secs. 28, 21, 16, 15, 10, 11, and 2, whence it crosses

the line into T. 25 N., R. 9 E. On both sides of this syncline the rocks are buckled into anticlinal folds of irregular outline and dimension. The axes of the individual folds trend in various directions (see fig. 32), but the system taken as a whole is roughly parallel to the course of the major syncline. On the west side of the major syncline there is a series of small roughly parallel faults which cut the east flank and crests of several of the anticlines (Pl. XXXII).

In the western part of T. 24 N., R. 9 E., there is a second synclinal axis. This axis branches into the SW. ¼ sec. 32 from the one mentioned above and trends northwestward until it passes out of the township near the northwest corner of sec. 30. It reenters the township near the southwest corner of sec. 18, trends northeastward through secs. 18, 8, 5, and 4, and passes into T. 25 N., R. 9 E., a little west of the north quarter corner of sec. 4 (fig. 32). Between this axis and that of other major synclines is the line of faulted anticlinal folds mentioned in the preceding paragraph. West of it also there are some anticlinal folds which, however, are not nearly so pronounced as those on the east.

These upfolds and downfolds are developed in a tilted surface that slopes to the west at an average rate of 25 feet to the mile, so that in spite of minor anticlinal structure which may bring the beds in any part of the township toward the surface, any definite bed will be about 150 feet nearer sea level at the west line of the township than it is at the east line.

AREAS STRUCTURALLY SUITED TO INDUCE THE ACCUMULATION OF OIL.

Areas underlain by beds having anticlinal structure are by far the best localities in which to prospect for oil or gas, but experience in the Osage Reservation has shown that these minerals are not restricted to such areas. Structural terraces, in which flat-lying rocks lie adjacent to steeply dipping rocks, have been productive in some regions; terraces adjacent to faults that displace the oil-bearing beds may be underlain by oil pools; and in regions of pronounced deformation extensive pools of oil and gas have been found underlying synclines. However, the importance of anticlinal structure should be emphasized, for by far the greatest part of the oil produced in the Osage Reservation comes from pools that underlie such folds. It has also been established that the more pronounced the anticline and the greater its closure the greater is the likelihood of its yielding a large quantity of oil.

ANTICLINES.

COTTONMOUTH ANTICLINE.

The axis of the Cottonmouth anticline traverses sec. 3 from northeast to south, crosses the extreme northwest corner of sec.

10, and runs west to a point near the center of the NW. ¼ sec. 9, where it swings south and divides, one branch going west into sec. 8, the other south into sec. 16, where it joins the northern extension of the Bulldog anticline. This is a well-developed fold with a closure of at least 40 feet. The rocks slope in all directions from the extreme northwest corner of sec. 10. The dips to the northeast and southwest along the axis are gentle but none the less definite; those to the northwest and southeast are abrupt. The anticline is cut by four roughly parallel faults which strike about N. 30° W. and range in maximum throw from 10 to 35 feet and in length from a quarter of a mile to a mile. Two of these faults dislocate only the rocks on the east side of the fold; the other two cut across the axis. Only one of them is large enough or in a position to have any probable effect on the oil-bearing possibilities of the anticline. This one cuts squarely across the axis of the fold just southwest of the northeast corner of sec. 9 and drops the strata to the southwest a maximum distance of about 35 feet without obliterating the anticlinal arch. It extends well down to the synclines on the northwest and southeast flanks of the anticline but dies out without reaching their axes. If this fault is as extensive in the oil-bearing strata as it is in the surface strata, it has probably a decided effect on the shape and location of any oil pool that may have formed below the axis of the anticline in the sands above the Bartlesville sand. Its effect is believed, however, to be limited to these shallow sands, because they are comparatively thin and a break of 35 feet could seal their entire thickness, whereas the Bartlesville, if present, is probably more than 35 feet thick and so could not be effectively broken by the fault. (See fig. 33.)

The Cottonmouth anticline is about 2 miles from the nearest oil field, which lies in secs. 25, 26, 35, and 36, T. 25 N., R. 9 E.; it is but little farther from a field in sec. 6, T. 24 N., R. 10 E., and there are two wells in sec. 1, T. 24 N., R. 9 E., which lie between these two fields. In these fields gas was encountered in five distinct sands above the Fort Scott ("Oswego") limestone, but no effort has been made to utilize this shallow gas. The Fort Scott limestone yields both oil and gas in the field in T. 25 N., R. 9 E., and gas in sec. 6, T. 24 N., R. 10 E. The highest initial daily production of oil from this bed was about 20 barrels. The Bartlesville sand, about 300 feet below the Fort Scott limestone, yields most of the oil in both the fields mentioned above. In sec. 6, T. 24 N., R. 10 E., some wells have had an initial production as high as 600 barrels; in the other field the best initial production was about 1,000 barrels. Below the Bartlesville there are at least two limestones which are known to be gas bearing and which probably also contain oil but whose possibilities have not been determined. However, the deep gas-bearing beds are believed to be comparatively thin, so it is not to be expected that

they will rival the Bartlesville sand in total oil yield, although they may yield large amounts of oil for short periods.

The Cottonmouth anticline is believed to be splendid prospective oil and gas territory; it has ample gathering ground on its flanks and in the adjacent syncline to furnish a large amount of oil and gas; it has a large enough closure to make it an effective trap for these minerals; such faults as cut it do not injure its oil-retaining capabilities; and sands which presumably underlie it are known to contain oil and gas a short distance away.

Good locations for wells to prove this fold are the center of the SW. ¼ SW. ¼ sec. 3; the center of the SE. ¼ NE. ¼ sec. 9, and the center of the NW. ¼ sec. 9. Wells drilled at these locations should encounter the Fort Scott ("Oswego") limestone at a depth of about 1,800 feet, the Bartlesville sand at about 2,120 feet, and the deep gas-bearing beds in the "Mississippi lime" at about 2,420 feet. Test holes should be drilled to about 2,500 feet unless oil or gas is found in paying quantities at less depth.

POSTOAK ANTICLINE.

The Postoak anticline is a small, inconspicuous fold in the northwest corner of T. 24 N., R. 9 E. Its major axis, which is a little more than a mile long, extends from a point a little west of the east quarter corner of sec. 6 to a point northwest of the east quarter corner sec. 7, where it is lost in a saddle that separates the Postoak anticline from the Wooster anticline (fig. 32). The highest part of the fold is about 900 feet west of the east quarter corner of sec. 6, and the area surrounded by the lowest closed contour includes the central part of the E. ½ sec. 6 and of the W. ½ sec. 5, embracing about 160 acres in all. The closure is about 30 feet. (See Pl. XXXII.)

Almost all the elevations by which the shape and size of this anticline were determined were taken on members of the Elgin sandstone, and because of the difficulty of tracing these beds accurately over the timber and soil covered slopes on which this anticline lies, it is entirely probable that the shape and size of the fold may not be exactly as shown on the map. However, the work was done with care and in detail, and it is believed that the portrayal of the structure is correct except in very minor points.

Not enough data are available to justify a definite forecast of the possibilities of this anticline. Such wells as have been drilled near by have been so located that their failure to yield commercial quantities of oil has no bearing on the possibilities of the anticline. Furthermore, no records of these wells are available, and it is not known whether or not they were drilled deep enough to encounter the beds that yield oil and gas in the nearest fields. Only one of these wells

was seen by the writers; it is in the northwest corner of sec. 8, in the syncline southeast of the Postoak anticline. At the site there were the remains of an old demolished rig but no boiler foundation, clinker pile, sludge pit, or other definite evidence that drilling had actually been done.

The oil fields nearest the Postoak anticline are those in the southeast corner of T. 25 N., R. 9 E., and the northeast corner of T. 24 N., R. 10 E., which are mentioned in the foregoing description of the Cottonmouth anticline. In sec. 33, T. 25 N., R. 8 E., 4 miles west of the Postoak anticlines, a well that was drilled since the completion of the field work on which this report is based found large volumes of gas in three sands above the Big lime and enough oil at the horizon of the Fort Scott limestone to make a 5-barrel well. Farther south, in sec. 15, T. 24 N., R. 8 E., a well drilled to the Fort Scott limestone found several gas-bearing sands and one sand that yielded a small showing of oil. The greatest yield in this well comes from the Big lime, although the Fort Scott limestone is also fairly productive. As the beds at the general horizon of the Fort Scott limestone have been proved to be productive east, west, and southwest of the Postoak anticline, it is a fair conclusion that they probably contain oil or gas in this anticline also. The productivity of the deeper beds is more uncertain. The record of the dry hole that was drilled to the "Mississippi lime" in sec. 18, T. 25 N., R. 8 E., does not report any sands between the Fort Scott limestone and the "Mississippi lime," and it is entirely possible that the sand is also lacking in the northwest corner of T. 24 N., R. 9 E. If so it will probably be profitable to sink wells into the "Mississippi lime" to tap the beds which yielded gas in the deep wells in sec. 6, T. 24 N., R. 10 E., and which carry gas and oil elsewhere in Osage County. In spite of the small size of the Postoak anticline its prospects are believed to be very good. It has an ample gathering ground from which oil and gas may migrate up smoothly dipping beds to accumulate under the anticlinal fold. The reversal of the dip is sufficient to make an effective trap to stop the movement of the oil and gas; the fold is in a general zone of pronounced deformation, such as has yielded large volumes of oil and gas elsewhere in the Osage Reservation; and oil sands which have been reached in wells both east and west of the fold are probably also present at this locality. A good place for a test well is about the middle of the north line of the SE. ¼ sec. 6. At this point the Fort Scott limestone probably lies between 1,900 and 1,950 feet below the surface, the Bartlesville sand, if it is present, at about 2,250 feet, and the "Mississippi lime" at about 2,400 feet. The test should be carried to a depth of 2,700 feet unless a good yield is obtained at shallower depths, and even though oil in quantity is found in one of the

higher sands, a test should ultimately be sunk to determine the contents of the lower beds in the "Mississippi lime."

WEST BIRDSEYE ANTICLINE.

The West Birdseye anticline lies in the eastern part of T. 24 N., R. 9 E., and joins the East Birdseye anticline near the west line of T. 24 N., R. 10 E. Its axis follows a curving line from a point a little south of the northeast corner of sec. 24 through the southwest corner of sec. 13 and the northeast corner of sec. 14 into the southeast corner of sec. 11. (See fig. 32.) The closure is only about 30 feet, but the dips to the north, west, and south are so pronounced and the opening to the east is so narrow that a large pool of oil and gas should have accumulated in the fold. The area included within the lowest closed contour is less than 640 acres, but the structure has probably influenced the accumulation of oil and gas over a much larger area.

At the time the field work for this report was completed there were two wells on the West Birdseye anticline. One of these, in the SW. ¼ sec. 13, produces gas from what is believed to be the Bartlesville sand; the other, in the NE. ¼ sec. 23, produces oil from a sand which is also called the Bartlesville but which lies beneath the sand in the gas well. Since the completion of the field work a second well has been completed in the northeast corner of sec. 23. This well, which is reported to have had an initial yield of 150 barrels a day, is the best of those that have been drilled on the anticline to date.

Not enough drilling has been done to determine to what extent the entire anticline contains oil and gas. However, the relation of the oil wells to the gas well and the conditions known to exist in other anticlines in the Osage Reservation indicate that the crest of the fold may be occupied exclusively by gas and that the flanks on all sides may yield oil. The general experience in the Osage Reservation is that the west flanks of anticlines are more likely to be oil-bearing territory than the other flanks, but in this particular region there is reason to believe that the generalization does not hold. On the Saucy Calf anticline, 2 miles north of the West Birdseye anticline, the east flank yields oil; the same is true of the Thirty-six anticline, in sec. 36, T. 24 N., R. 8 E., and of the Fourmile dome, just south of the West Birdseye anticline. Accordingly, in the absence of the positive evidence which drilling will afford, the east flank of the West Birdseye anticline is considered very favorable territory. The evidence of the wells that have been drilled on this fold and in fields to the north and south shows that the principal oil-bearing bed below this fold will probably be at the general horizon of the Bartlesville sand. However, it is probable that somewhere on the anticline beds

above the Bartlesville will also be productive and that exploration of the "Mississippi lime" below the Bartlesville sand will reveal oil or gas bearing beds.

That extensive and remunerative oil fields are certain to be developed on the West Birdseye anticline is indicated by the oil wells already drilled, by the sharpness of the anticlinal fold, and by the ample gathering ground on the north, west, and south from which the oil may have moved to collect under the anticline. Good locations for further testing are the center of the SE. ¼ NE. ¼ sec. 14 and the center of the SE. ¼ NW. ¼ sec. 24. The wells should be drilled at least 300 feet below the top of the "Mississippi lime" unless oil is obtained at a shallower depth.

WYNONA ANTICLINE.

The Wynona anticline is a terrace-like fold that might be considered a part of the West Birdseye anticline, as there is no continuous syncline between the two folds, but it is sufficiently pronounced to deserve a separate description. The principal axis of the Wynona anticline follows a slightly sinuous course with a general northerly trend, passing from the north-central part of sec. 27 to a point a little east of the center of sec. 15. Crossing this main axis almost at right angles are two minor axes, the northern one near the south line of sec. 16 and the other near the south line of sec. 22. At each end of the main axis there is a domelike swell whose center coincides with the point at which the main axis is intersected by the minor axis, and between these domes there is a broad saddle. The crown of the north dome is just northwest of the south quarter corner of sec. 15. The closure of this dome is but a little more than 10 feet, and the area surrounded by the lowest closed contour is only about 160 acres, but it seems probable that the doming has exerted an influence over double this acreage. The crown of the south dome, which is even smaller than the other, is in the southeast corner of the SW. ¼ sec. 22. This dome also has a closure of a little more than 10 feet, but the area inclosed by the lowest closed contour is only about 10 acres. However, there is a pronounced anticlinal arching of the beds both to the east and to the west, and this territory appears almost as promising as that on the north dome. Just east of the lowest closed contour on the south dome is a small fault, but its throw is so small that it has probably had no serious influence on any oil pool which may have formed beneath the fold.

The single well which has been drilled on the Wynona anticline is on the flank of the north dome, fairly well down toward a syncline which borders the dome on the north. This well was unsuccessful, but no record of it could be obtained, and therefore

its significance is not known. If it reached the Bartlesville sand it has a material bearing on the potential value of the anticline, but if, like many of the tests which were drilled in the Osage country years ago, it was abandoned before it reached the Bartlesville sand it signifies little. In the absence of definite knowledge concerning its depth little weight should be attached to it as evidence condemning territory that is structurally favorable for the accumulation of oil and gas.

To judge from the conditions in the producing wells on the West Birdseye anticline, a mile and a half to the east, the formation which is most likely to yield oil under the Wynona anticline is the Bartlesville sand, although it is not impossible that some one of the shallower beds may also prove productive. If drilling is carried below the Bartlesville sand the "Mississippi lime" will probably be found to contain gas and perhaps oil. The "Mississippi lime" is known to be gas bearing under the North Cochahee dome, 4 miles to the northeast, and both oil and gas have been produced from it elsewhere in the Osage Reservation.

The prospects of production from the Wynona anticline appear good. There is a very well defined closure, particularly in the dome at the north end of the fold, and a reasonably large gathering ground to the north, west, and south. Wells drilled a short distance to the east which have found oil in quantity and producing wells a few miles to the southwest which obtain oil from beds at the same general horizon make it seem probable that there is a continuous sand between the two fields, and such a sand would necessarily underlie the Wynona anticline. Good locations for test wells are the center of the SW. ¼ SW. ¼ sec. 15 and the center of the SE. ¼ SW. ¼ sec. 22. Wells drilled at these locations should reach the Fort Scott ("Oswego") limestone at a depth of about 1,800 feet, the Bartlesville between 2,100 and 2,200 feet, and the lower productive strata of the "Mississippi lime" at about 2,400 feet. To be adequate a test hole should be drilled to a depth of at least 2,500 feet.

FOURMILE DOME.

The Fourmile dome lies in the southeast corner of T. 24 N., R. 9 E. Its axis passes in a crescentic line from a point near the center of sec. 26 across sec. 25 near its south line and into sec. 30, T. 24 N., R. 10 E. Near the middle of the south line of sec. 25 a minor axis branches off and runs almost due south across sec. 36 and into T. 23 N., R. 9 E. The closure in this fold is about 20 feet, but the beds on its flanks dip so gently that it has more the appearance of a terrace and it is quite unlike most of the more productive anticlines in the Osage Reservation, which have steeply pitching flanks.

It is known that at least one oil-bearing sand underlies this fold, for a small field has been developed on the east flank of the dome in sec. 25, T. 24 N., R. 9 E., and sec. 30, T. 24 N., R. 10 E. The oil in this field comes from the Bartlesville sand, which is reported to be about 70 feet thick, and wells with an initial production of 50 barrels a day have been completed, although the average initial production was considerably lower. Much larger wells might be expected were it not for the position of the field far down on the east flank of the anticline—indeed, some of the wells are in the shallow syncline that separates the Fourmile dome from the West Birdseye anticline. The fact that oil in commercial quantities is obtained from wells drilled in the syncline probably indicates either that the sand conditions are unusually favorable at this locality or that the underground structure is not similar to that at the surface. A pool might much more logically be expected to the south and west of the existing field, higher on the flanks of the anticline, and there is every reason to hope that exploration of parts of the dome which are structurally more favorable than the existing field will result in the discovery of larger accumulations of oil.

The anticline should be developed by the extension of the existing field toward the south and west. However, even should attempts to expand this field result in failure other portions of the dome should be tested. The structure is sufficiently favorable to justify thorough prospecting, regardless of any barren patches which may be demonstrated to underlie portions of the fold. It is known that some barren patches exist under almost every productive anticline in the Osage Reservation. Good locations for tests are the center of the SW. ¼ SE. ¼ sec. 25, the extreme southeast corner of sec. 25, the center of the SE. ¼ SE. ¼ sec. 26, and the center of sec. 36. The Bartlesville sand should be found less than 2,100 feet below the surface at all these locations. If oil or gas in commercial quantity is not found in the Bartlesville sand the wells should be deepened to the "Mississippi lime" and should not be abandoned at a depth of less than 2,400 feet.

The Fourmile dome is in a zone of marked deformation, and there is a strong possibility that some folding of the deep-lying beds took place before the rocks now exposed at the surface were deposited. If this was so the anticlinal structure is almost certainly more pronounced in the "Mississippi lime" than in the Bartlesville sand, and with this possibility in view wells should ultimately be bored deep into the "Mississippi lime," even though the Bartlesville sand proves to contain great volumes of oil.

BANDWHEEL ANTICLINE.

The Bandwheel anticline is just north of the south line of T. 24 N., R. 9 E., in secs. 33 and 34. Its curving axis is shaped like a bow with one end to the south, in the SW. ¼ sec. 33, and the other near the center of sec. 34. (See fig. 32.) It is a low, inconspicuous fold with a closure of only a little more than 10 feet. The flanks of the anticline incline gently to the north, east, and south and very steeply to the west. South of the crown of the Bandwheel anticline the rocks dip southwestward for only about half a mile and then the dip is reversed and they mount to the summit of another anticlinal fold which appears to be somewhat larger than the Bandwheel anticline. Only a part of this second fold was mapped by the writers, but enough of it was seen to justify the statement that it is a true anticline and is accordingly prospective oil-bearing territory. It is introduced into this discussion of the Bandwheel anticline because its presence indicates that the structural saddle which limits the Bandwheel anticline on the south should probably not be considered as unfavorable for oil accumulation as the other marginal synclines.

No oil wells have been drilled nearer to the Bandwheel anticline than those in sec. 36, T. 24 N., R. 8 E., some 2½ miles to the west. These wells, which are on a large anticlinal fold known as the Thirty-six anticline, obtain oil and gas from five beds, all above the "Mississippi lime." The highest of these beds, the Layton sand, lies 500 to 600 feet above the Big lime and is reported to yield only small volumes of oil and gas. The Big lime itself has contributed a little oil and gas to the total production, but like the Layton sand it is relatively unimportant in the field in sec. 36. A little below the Big lime is the Peru sand, about 25 feet thick, which in some of the wells mentioned above yields oil and gas. The Fort Scott ("Oswego") limestone is about 200 feet lower, and just above it there is a thin sand from which some of the wells obtain most of their oil. About 300 feet below the Fort Scott limestone is a sand about 15 feet thick which is known as the Bartlesville, although it can not be certainly correlated with the Bartlesville sand that yields oil in other parts of the Osage Reservation. This sand contains oil but is very "spotted"—that is, it is not uniformly oil bearing but may yield abundantly in one well and practically nothing in other wells near by.

A single well has been drilled on the Bandwheel anticline, but as no record of the formations encountered is available it is not known whether any of the above-mentioned beds were recognized in this well or, indeed, if it was drilled deep enough to reach even the shallowest of them, although the accumulation of sludge in the old

sludge pit indicates that a considerable depth was reached. A well that was drilled a short distance to the east of the Bandwheel anticline reached the "Mississippi lime" at a depth of 2,178 feet. No detailed record of this well could be obtained, but it was learned that the well passed through a sand about 15 feet thick a few feet above the "Mississippi lime," and it is likely that this sand is the Bartlesville.

It seems probable that oil will be found below the Bandwheel anticline in one of the shallow sands that are productive in sec. 36, T. 24 N., R. 8 E., in the Bartlesville sand, or in the "Mississippi lime." However, it should not be expected that any oil pool will be found to lie uniformly below the entire area covered by this fold; on the contrary, parts of the anticline will probably prove to be barren of commercial quantities of oil and gas. The failure of a single test, even though it may be in a very favorable structural location, should not be considered evidence that will condemn the entire anticline, and a number of dry holes far down on the flank of the anticline are to be expected. Accordingly the failure of the one well which has been drilled on this fold is not particularly discouraging, for it was not favorably located with respect to structure, nor is it known that it was drilled deep enough to constitute an adequate test. Good locations for further testing are the center of the NW. ¼ SE. ¼ sec. 33 and the center of the SW. ¼ sec. 33. In either of these locations the Bartlesville sand should lie between 2,100 and 2,200 feet below the surface and the other possible oil-bearing beds above the "Mississippi lime" should bear approximately the same relation to it as they do in the wells in sec. 36, T. 24 N., R. 8 E.

JACKPOT ANTICLINE.

The Jackpot anticline is a small fold whose curving axis extends from a point a little east of the center of sec. 21, T. 24 N., R. 9 E., to a point a little southeast of the center of sec. 6, T. 23 N., R. 9 E. (See fig. 32.) Only the crest and north end of this anticline were mapped, and it is not possible to state definitely just how large it is or what is its closure. However, it is believed to have a closure of 15 to 20 feet, and the area which is structurally favorable for oil accumulation is probably less than a square mile, covering part of the SW. ¼ sec. 31 and the E. ½ sec. 6.

The crest of this anticline is cut by a fault, which, however, is not large enough to have had any appreciable influence on the oil possibilities of the fold. So far as can be learned similar small faults in producing fields in the Osage Reservation have not affected either favorably or adversely the territory immediately adjacent to them.

The nearest producing field is in sec. 36, T. 24 N., R. 8 E., and the sands which bear oil there may reasonably be expected to be found beneath the Jackpot anticline, although it can not be stated positively either that they are present or that if present they contain oil. The general relations of these sands have been discussed in the description of the Bandwheel anticline (p. 206). So far as has been ascertained no wells have been drilled either on or immediately adjacent to the Jackpot anticline. A well drilled in the NW. ¼ sec. 6, T. 23 N., R. 9 E., would be squarely on the crest of the fold and if drilled deep enough should furnish a very fair test of it. The Fort Scott limestone probably lies about 1,700 feet below the surface, and the Bartlesville sand should be 300 feet lower.

PIPELINE ANTICLINE.

The Pipeline anticline, in the southwestern part of T. 24 N., R. 9 E., is a long, relatively narrow fold with strong dips to the north, west, and south but a very gentle dip to the east. The closure is

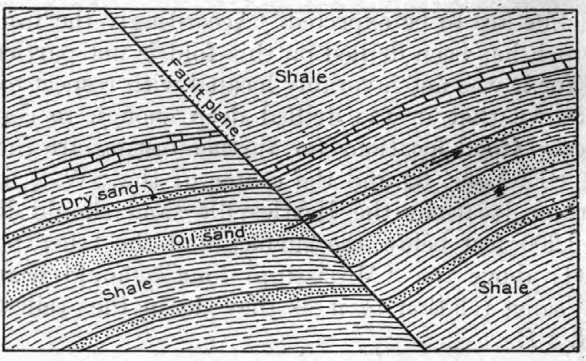


FIGURE 33.—Sketch showing conditions that might permit the escape of oil from a faulted anticline, such as the Pipeline anticline.

about 15 feet, and the area included within the lowest closed contour is considerably less than half a square mile. The axis runs nearly straight from a point a little west of the center of sec. 32 almost to the northeast corner of sec. 29. At its north end it terminates abruptly against a fault which has dropped the beds to the northeast a maximum amount of about 60 feet. Were it not for this fault the Pipeline anticline would probably join the Bulldog anticline, to the east. (See Pl. XXXII and fig. 32.) It is possible that the fault may have affected to some extent the ability of the Pipeline anticline to retain oil. If the beds are faulted in such a manner that a porous sand east of the fault is in contact with an oil-bearing bed west of the fault, a ready avenue of escape for the oil was provided and it may have migrated up the slope to the Bulldog anticline. It is not believed that such a condition exists under the Pipeline anticline, but it must be recognized as a possibility. The possible conditions are shown graphically in figure 33.

It does not appear probable that the Pipeline anticline contains any very great amount of either oil or gas, for this fold does not compare favorably either in size or in shape with the more productive anticlines in the Osage Reservation. However, it does seem probable that wells of moderate productivity will be obtained here. This conclusion is supported by the proximity of this fold to the field in sec. 36, T. 24 N., R. 8 E., and the attendant probability that the oil and gas bearing sands of that field extend under the Pipeline anticline; by the similarity of the Pipeline anticline to folds in other parts of the Osage Reservation under which small accumulations of oil and gas have been discovered; and by the wide stretch of uniformly dipping beds to the west from which the oil may have traveled eastward to lodge on the crown and under the flanks of the fold. If the conditions that exist in the oil field in sec. 36, T. 24 N., R. 8 E., also hold in the Pipeline anticline, such oil as is produced here will probably come principally from the shallow sands above the Bartlesville sand. If there is any very thick sand below this fold at the general horizon of the Bartlesville it will almost certainly contain an abundance of oil, but in the field to the west the Bartlesville is very thin and has not contributed very much to the total oil output of the district. A possibility that should not be overlooked is that the "Mississippi lime" may carry oil and gas in paying quantity, and one or more tests should be drilled into it regardless of the conditions encountered higher in the stratigraphic column.

A good location for a test well on the Pipeline anticline is near the center of the SW. ¼ SE. ¼ sec. 29; an alternative location is the center of the SW. ¼ sec. 29; a third favorable location is the center of the NE. ¼ sec. 29. At the first location the Fort Scott ("Oswego") limestone should be between 1,800 and 1,900 feet below the surface, and the Bartlesville sand is probably 300 to 400 feet lower. At the other two locations these beds will be found approximately 100 feet nearer the surface. Any test drilled near the axis of the fold should be bored to a depth of at least 2,600 feet, unless oil or gas in paying quantities is found at shallower depth.

BULLDOG ANTICLINE.

The Bulldog anticline is a low fold of very irregular outline in the west-central part of T. 24 N., R. 9 E. Its branching axis runs northward from the south line of sec. 21 into the SW. ¼ sec. 16, where it forks, one limb going northward and joining the southern extension of the Cottonmouth anticline, and the other westward into sec. 17, where it in turn divides, one limb continuing westward almost to the west line of sec. 17 and the other southwestward across the NW. ¼ sec. 20 into the east side of sec. 19. (See fig. 32.) Along this axis

there are three small swells or domes, one in the west-central part of sec. 21, one at the southwest corner of sec. 16, and the third in the SE. ¼ sec. 17. None of these minor folds are in the least prominent, and the total closure of the anticline is but 20 feet; moreover, a fault which cuts across the north flank of the fold may possibly reduce the effective closure to 10 feet. The area inclosed by the lowest closed contour is less than a square mile, but the territory over which the beds are so distinctly arched that they may be considered a part of the anticlinal fold is more than 2 square miles.

No wells have been drilled on this anticline, and as it is several miles from any producing field where the underground conditions are known, it is not possible to state definitely what oil and gas bearing beds may be present beneath the fold. In the oil field near the east line of the township, some 3 miles east of the Bulldog anticline, the Bartlesville sand is well developed and carries oil in abundance, but the shallower sands are not known to contain commercial quantities of either oil or gas. (See discussion of the West Birdseye anticline and of the Fourmile dome.) On the other hand, most of the oil and gas in the field in sec. 36, T. 24 N., R. 8 E., about 3 miles southwest of the Bulldog anticline, come from the sands associated with the Big lime and "Oswego lime," whereas the Bartlesville sand in that field is very thin and carries only small quantities of oil and gas. It seems probable that the Bartlesville sand thins from east to west and that although it probably underlies the Bulldog anticline, it is much thinner there than it is near the eastern edge of the township, and the chances of its yielding large volumes of oil are correspondingly less. The shallow sands, however, will very probably prove to contain oil and gas below the Bulldog anticline, as is indicated not only by their productivity in the field to the southwest but also by their oil and gas content in wells drilled far to the west, northwest, north, and northeast.

The structural conditions in the Bulldog anticline do not encourage the belief that many large oil wells will be obtained on it. The closure is much less and the area within the lowest closed contour much smaller than on the more productive of the Osage anticlines. Nevertheless there is a large area to the west in which the rocks dip uniformly westward and from which oil may have migrated to gather under the crest and along the flanks of the anticline. Furthermore, this anticline is in a zone of pronounced deformation marked by irregular folding and extensive faulting, and similar disturbed zones have been found to be oil bearing elsewhere in Osage County, even where the surface structure is not markedly favorable. This is very probably due to deformation which took place in the deep beds before

the deposition of the rocks that now form the surface and which is not reflected save in a general way by the beds that crop out.

Good locations for testing the Bulldog anticline are believed to be the center of the SW. ¼ SW. ¼ sec. 16, the center of the NE. ¼ SW. ¼ sec. 17, just west of the east quarter corner of sec. 19, and the center of the SW. ¼ sec. 21. In the first two and the fourth locations the Fort Scott ("Oswego") limestone should lie between 1,800 and 1,900 feet below the surface, the Bartlesville sand at about 2,150 feet, and the "Mississippi lime" at about 2,300 feet. At the location in sec. 19 the sands should be about 70 feet nearer the surface. Any of these tests must be drilled at least 300 feet into the "Mississippi lime" to be adequate. Elsewhere in the Osage Reservation the expense of drilling wells into the "lime" in areas of good anticlinal structure has almost invariably been rewarded by the production of either oil or gas. The reason for the failure of so many deep tests is that they are poorly located with respect to the structure and are deepened only after they fail to find oil in the shallow beds. The absence of oil in the "Mississippi lime" at these points has no more significance than the dryness of the overlying sands in the same well.

UNFAVORABLE AREAS.

Most of T. 24 N., R. 9 E., is in an area which has been deformed much more than is common in the Osage Reservation. The rocks have been arched in anticlines and domes, bowed down in synclines, and broken by a number of faults. This indicates either that the rocks are incompetent to withstand stresses or that stresses of unusual intensity have been localized in this area. It is probable that deformation was going on long before the deposition of the beds which form the present surface, for geologic history has shown that it is common for stresses to occur in the same general district in successive ages. Accordingly it is not to be expected that the structure of the rocks deep beneath the surface resembles that of the beds which crop out, except in a general way. Although it is reasonable to believe that anticlines in the deep-lying beds underlie anticlines on the surface and that pronounced synclines on the surface overlie synclines in depth, there are probably minor folds in the deep-lying beds which are not reflected at all by similar folds on the surface, and it is quite possible that in such hidden folds there are appreciable pools of oil or of gas. For this reason it is not justifiable to condemn utterly any part of the township, no matter how unfavorable for the accumulation of gas and oil the surface structure may appear. However, there are some parts of the township which should not be drilled unless pools discovered in territory which is structurally more favor-

able are extended into them. Some of this territory has already been proved barren, at least in the beds above the "Mississippi lime," by wildcat tests, and the relation of these dry holes to pronounced synclines suggests that beds underlying similar synclines are barren.

Particularly unfavorable areas are near the axes of the major synclines which cross the area (fig. 32), including the W. ½ sec. 2, the N. ½ sec. 11, the SE. ¼ sec. 10, the NW. ¼ sec. 15, the E. ½ sec. 16, the SE. ¼ sec 28, the S. ½ sec 32, the SE. ¼ sec. 5, the NE. ¼ sec. 8, the NW. ¼ sec. 17, all of sec. 18, the W. ½ sec. 19, all of sec. 30, the N. ½ sec. 31. the SW. ¼ sec. 31, and the N. ½ sec. 12.